Experiences with designing and managing organic rotation trials

Dick Taylor, David Younie, Michael Coutts, Stella Matheson
SAC, Ferguson Building, Craibstone, Aberdeen AB21 9YA, UK

Claus Mayer
BIOSS, Rowett Research Institute, Bucksburn, Aberdeen AB21 9SB, UK

ABSTRACT

Practical problems encountered in two long-term organic rotation trials at Aberdeen and Elgin are discussed. Compromises have had to be made in designing and managing the trials: how to include livestock and measure output, plot size, marking and fencing, discards and paths, replication, rotation length, randomisation of crop sequence, site uniformity, manoeuvrability of machines, soil compaction and exposure to pest damage.

Keywords: organic farming, rotations

INTRODUCTION

The aim of organic crop rotations is to achieve a balance between crops which deplete soil fertility (plant nutrients and soil organic matter), and crops which restore fertility (Watson *et al.*, 1999). Rotations should also give opportunities for the control of weeds, should break pest and disease life cycles, and should be profitable.

It is normally recommended that at least half the rotation should consist of fertility-building crops such as grass/clover leys. However, leys and livestock enterprises are less profitable than arable crops and there is a need to develop rotations which are less reliant on leys. The objective of the trials discussed here was to compare, at two sites, crop rotations which included different proportions of grass/clover. This paper discusses some of the practical, scientific and statistical issues related to the design and management of these trials.

THE SAC ROTATIONS TRIALS

The trials established started in 1991 on the SAC farms at Tulloch, Craibstone, Aberdeen (map ref. NJ843094; 160m above sea level; sandy loam soil; average rainfall 820mm), and Woodside, Aldroughty, Elgin (map ref. NJ167625; 25m above sea level; loamy sand/sandy loam soil; average rainfall 730mm) one year before the farms were fully converted to organic status. The objectives of the trials are described by Younie *et al.* (1996).

Two rotations are compared in each trial. The six-year rotations at Tulloch have 50% (T1) and 67% (T2) fertility-building grass/clover leys. At Woodside, the eight-year rotation (W1) has 38% in fertility-building crops and the six-year rotation (W2), 50%. There are two replicates of each rotation at each site. The field layout and first year cropping are shown in Figures 1 and 2 for Tulloch and Woodside respectively.

Figure 1. Layout and first year cropping at Tulloch (not to scale)

Rep 2	C2	S	C1	G3	G2	G1
	C2	C1	G4	G3	G2	G1

Rep 1	G3	G2	G1	C2	S	C1
	G4	G3	G2	G1	C2	C1

T1 T2 G- grass/clover: C- oats; S swedes; -1 first year etc; u/s undersown

Plot sizes are 26m x 32m at Tulloch and 23 x 40m at Woodside. All plots are fenced with permanent post and wire fences capable of retaining sheep. The central, or spine, fences at Tulloch are removable.

Figure 2. Layout and first year cropping at Woodside (not to scale)

Rep 2	G2	C3 u/s	C2 u/s	GR	C2 u/s	G2	C1
	C1	S	G1	P	P	G1	G3

Rep 1	G3	G2	C2 u/s	G1	G2	C2 u/s	P
	P	G1	C1	C1	S	C3 u/s	GR

W1 G- grass/white clover: C- oats; S swedes; P potatoes;
W2 GR grass/red clover; -1 first year etc; u/s undersown

TRIAL MANAGEMENT

Site selection

Sheep were used as grazing animals on the grass/clover phases of the rotations in preference to simulated grazing, since it is important to take account of the effect of grazing on the nutrient dynamics. Plot sizes were chosen to be large enough to hold a group of animals in order to minimise differences between animals and to allow normal behaviour. Access is required to all plots for machines and animals, and this necessitates a deep (minimum 8m) surrounding buffer which is securely fenced and gated to retain escaped animals. The resulting trial areas are large (2.7ha at Tulloch and 3.4ha at Woodside), restricting replication and initial choice of suitable sites. Finding a uniform site has, therefore, been a compromise and some plots have been consistently lower yielding than others although this did not become apparent immediately. Variations in drainage appear to have more influence on growth than variations in soil type.

Although plot sizes are large enough to attract pests (especially birds) they are not sufficiently large to withstand prolonged attack, and are too large to protect easily. In addition, some trial crops are not grown in nearby fields and damage from birds and rabbits can be disproportionate. Swedes at Woodside have suffered severe seedling damage by pigeons in 7 years out of 10. Future trials might use a less pest susceptible crop, for example a leafy fodder crop, or fodder beet.

Fertility

For simplicity, organic manure used in the trials is cattle manure from the host farm rather than being produced from straw taken from the trials. Manure application rates assume self-sufficiency for each of the rotations; thus, the total quantity of manure available for each rotation is based on the area of grass/clover ley in the rotation, a standard stocking rate of 1.7 livestock units (LU) per forage hectare, and an assumed 7.2 tonnes manure available per LU. No attempt is made to adjust manure applications for nutrient content which vary with different animals, housing conditions and storage methods. More control of nutrient applications might have been possible if more homogenous materials such as slurry were used (Askegaard *et al.*, 1999).

Nitrogen fertility, measured in nitrogen offtake in cereal grain, has increased gradually (Watson *et al.*, 1999). Soil P and K levels are maintained through organic manures with rock phosphate and sulphate of potash applied once to raise soil levels at Woodside. Soil P and K levels appear stable at Tulloch but there is an indication of a decline in K levels at Woodside. Micro-nutrient deficiencies have occurred in individual plots and have been treated, with approved materials. There have been no instances of deficiencies in all plots of one crop at one time and it is likely that subclinical deficiencies in other plots may have affected growth and yield.

Field operations

In long term rotation trials, management methods evolve as problems arise (Philipps *et al.*, 1999; Olesen *et al.*, 1999). Although the crops and sequences have remained unchanged during the trial, seed rates have been changed to be consistent with best practice and varieties with availability. Weed control is carried out according to requirements, normally only in the row crops (swedes and potatoes), and relies on dry conditions. Perennial weeds have not become a problem.

Although the trial simulates a 'farmlet', most available machinery is 'field' size. Because all plots were permanently fenced at the outset, edge and end discards have to be allowed where machines turn or cannot reach. However, at Tulloch the spine fences are removable and this facilitates machinery operation and minimises soil compaction. Longer and narrower plots with turning outside the plots would avoid soil compaction and be more suitable for machines, but would have been likely to have affected the grazing behaviour of animals.

Soil movement is a risk in long-term trials (Olesen *et al.*, 1999). Ploughing is carried out in one direction only, away from the spine fence, each time turning the soil in a different direction to the last. However, seed bed cultivations which are also carried out moving away from the spine fence have resulted in soil movement towards the buffer area at Woodside. Uni-directional cultivation and the presence of permanent fencing has also resulted in soil compaction from traffic at the edges of plots. Some machinery is difficult to operate within the confines of the plot, for example, grass harvesting machinery. However, rear delivery manure spreaders which are required because of the amounts involved (20t/ha = 2t/plot) have been no problem.

Animals restricted to relatively small plots are liable to escape and (mesh) fence maintenance is expensive and continuous where sheep are the grazing animal. Barren ewes are easier to manage than ewes and lambs. It is important to match livestock numbers to available herbage and to have a buffer area to hold the spare animals needed at peak growing periods. Poaching by stock can be avoided by removing them to the surrounding buffer area. Stock should be of a uniform type and size and need daily checking. Water is required in each plot and mineral supplementation is necessary on these soil types at certain times of the year. The aim has been to avoid unnecessary movement of stock, grazing each plot thoroughly before moving.

Recordings

Crop yield is estimated by sampling in order to avoid compacted edges and reduce the work involved. For cereals, two strips are cut from each plot with a 2m plot combine; for potatoes and swedes ten samples totalling 20m of row are lifted and weighed. Harvested areas are generally selected as those representative of the plot, although this may result in bias in plots with high levels of variation. Botanical analyses are determined along fixed transects in each plot. Samples to analyse weed seed banks are taken at fixed points along a diagonal between plot corner posts.

Grazing is recorded as sheep grazing days and converted to livestock unit grazing days (LUGD). Livestock are introduced for as long as herbage is available. Standard values are used for livestock units (e.g. heavy ewe = 0.11 LU, store lamb = 0.04 LU). Errors occur when animals escape and are not detected immediately.

Statistical analysis

Rotation trials are challenging as two of the main objectives of a design are hard to satisfy: replication and balance. For practical reasons it has not been possible to have more than two replicates of each rotation per site. Although temporal instead of spatial replication is used it is time demanding. Olesen *et al.* (1999) suggest that rotation trials need to run for at least three cycles in order to evaluate the effects of different systems on soil fertility. Time also puts serious constraints on the balance of the design. It is desirable to observe full rotations within the experiment, but for Woodside that would require a trial of at least 24 years. More violations of balance are a direct consequence of the difference between the rotations and cannot be avoided.

These inevitable shortcomings in the design are especially serious in the presence of several sources of variability, which might hide the rotation effects. The most significant variation in these trials is from year to year. For certain variables year to year matching could be achieved by choosing different starting years of the rotation. If for example W1 had started one year after W2 it would have been possible to compare data for first year spring oats, potatoes and undersown spring oats in W1 and W2 in the same years. However, these comparisons would not have been possible for the second cycle of the rotation.

Plot effects are also important. Although the assumption of homogeneity across plots is a desirable it is not always realistic. For Tulloch the split-plot-type design shown in Figure 1 helps account for some of this variability. Due to the different length of the rotations this approach was not suitable for Woodside. Here a complete randomisation of plots instead of the present within-rotation randomisation would have been more effective.

CONCLUSIONS

Organic rotation trials which simulate mixed systems and include animals are complex and costly. Choice of a uniform site is important and plot size and shape are a compromise between what is best for animals and machines. Management changes and compromises will have to be made as the trial progresses. A fully randomised block layout is preferred but may be more prone to mistakes and less valuable for demonstration. Year to year variation is likely to exceed treatment variation.

ACKNOWLEDGEMENTS

SAC receives funding from the Scottish Executive Environment and Rural Affairs Department. This work was carried out under SEERAD ROAME No. 606020.

REFERENCES

Askegaard M; Rasmussen I A; Olesen J E (1999). Agronomic considerations and dilemmas in the Danish crop rotation experiment. In *Designing and Testing Crop Rotations for Organic Farming* (eds J E Olesen, R Eltun, M J Gooding, E S Jensen & U. Kopke), DARCOF Report No. 1, 63-69.

Olesen J E; Rasmussen I A; Askegaard M; Kristensen K (1999). Design of the Danish crop rotation experiment. In *Designing and Testing Crop Rotations for Organic Farming* (eds J E Olesen, R Eltun, M J Gooding, E S Jensen & U Kopke), DARCOF Report No.1, 49-62.

Philips L; Welsh J P; Wolfe M (1999). Ten years experience of all-arable rotations. . In *Designing and Testing Crop Rotations for Organic Farming* (eds J E Olesen, R Eltun, M J Gooding, E S Jensen & U Kopke), DARCOF Report No.1, 71-77.

Watson C A; Younie D; Armstrong G (1999). Designing crop rotations for organic farming: the importance of the ley/arable balance. In *Designing and Testing Crop Rotations for Organic Farming* (eds J E Olesen, R Eltun, M J Gooding, E S Jensen & U Kopke), DARCOF Report No.1, 91-98.

Younie D; Watson C A; Squire G R (1996). A comparison of crop rotations in organic farming: agronomic performance. *Aspects of Applied Biology* **47**, *Rotations and Cropping Systems*, 379-382.

From: Powell et al. (eds), *UK Organic Research 2002: Proceedings of the COR Conference, 26-28th March 2002, Aberystwyth*, pp. 37-41.