Paper 5

TECHNIQUES FOR THE DESIGN OF POTATO CULTIVAR TRIALS

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INTRODUCTION

Experiments comparing cultivars may have a number of aims, but measurement of relative yields is always high among them. Of course, such things as maturity, disease resistance, size and shape of tuber, cooking quality and storage behaviour are all of concern and many may be observed or measured, but yield of saleable tubers is always important.

In comparing the yielding ability of different cultivars there are a number of matters to consider in both experimental strategy and technique. For example, if the performance of a new cultivar in New Zealand is being examined, then questions of experimental strategy include:

- where in the country should experiments be sited?
- how many experiments are needed?
- how many seasons should be covered?
- should experiments be irrigated?
- what levels of fertility should they be at?

Questions of experimental technique include:

- size and shape of plots;
- use of guard rows;
- number of replications and nature of blocking;
- nature of equipment to be used;
- choice of treatments.

There is some measure of overlap between the two lists in that, for example, it may be decided rather than to irrigate the whole experiment, to introduce irrigation as a treatment and compare cultivars both in the absence and in the presence of irrigation. However, the distinction that I am making between strategy and technique could be expressed in this way:

> The **strategy** used determines the extent of generalisation that is appropriate from experiments, e.g. whether the results apply only to a particular geographical area or a particular soil type, or whether they apply to a number of areas and soil types.
>
> The **techniques** used determine the precision with which results are measured, e.g. if a yield difference between two cultivars is estimated as 5 t/ha, whether this means the true difference lies between 4 and 6 t/ha or between, say, −2 and +12 t/ha.

This paper reviews techniques, but will also venture into the overlappling area, where factors used as treatments affect the generality of conclusions that can be drawn.

PLOT SIZE AND SHAPE AND GUARD ROWS

The 'best' plot size is that which gives the precision required for the minimum cost. The usual way of investigating the effect of different plot size is by the 'uniformity' trial, an experiment in which a large block of the crop is harvested in small units, and the effects of amalgamating those units into plots of different sizes is observed. Uniformity trials on potatoes have been reported on by Justesen (1932), Kalambar (1932), Mountier (1964), Nonnecke and Smillie (1964), Sardana *et al.* (1967) and Bist *et al.* (1975).

There is a fair measure of agreement between the conclusions of these different writers, even though their work was carried out in different conditions and in different countries, as can be seen in Table 1. Only Justesen's recommendation stands apart. The basic unit for his study was 6.7 m^2 and his recommendation is difficult to reconcile with his data, which show the efficiency of the 26 m^2 plot as being only 53% of the 6.7 m^2 one. There is general agreement that long narrow plots are better than short wide ones.

Table 1: Recommended plot areas from uniformity trials

Reported by:	Approx. area m^2
Justesen	26 or more
Kalambar	6.1
Mountier	2.3 – 4.6
Nonnecke and Smillie	2.2 – 5.0
Sardana *et al*	3.4 – 8.4
Bist *et al*	4.4 – 5.6

However, these are the conclusions for trials without guards either at the sides or the ends of plots. It is common to use guard plants of a variety with red-coloured tubers at the ends of each plot (Mountier, 1964; Dyke, 1974), as this aids plot separation at harvest, as well as eliminating effects on the end plants of one plot by the next plot along. Satisfaction of both these aims has been achieved by using 2 coloured-tuber plants at each end of each plot row, so that there are four coloured-tuber plants between each pair of yield rows.

An effect of this practice is that only a proportion of a plot is used for estimating yield. Since the length of this buffer guard area is constant, the proportion of the plot taken up by guard plants is larger for a short plot than a long plot. This then tends in favour of a longer plot and therefore when this is taken into account, a plot length of around 5 m emerges as most satisfactory. At 300 mm spacing within the row, this results in about 75% of the plot length planted being used for yield measurement.

The question of guard rows at the sides of yield plots presents more difficulties, because a three-row plot of which the outside two rows are guards and only the centre row used for measurement is an inefficient user of space. Obviously guard rows are to be avoided if possible. In the published evidence, Brown (1922) was unable to detect any effect from the adjacent rows in cultivar trials, and Terman *et al.* (1957) found a similarly negative result from the effect of phosphate fertiliser on the adjacent row. However, Jacob (1940) did find an effect with fertiliser which included nitrogen, phosphate and potash, and Mountier (1964) detected an effect as large as 20% on the yield of table size potatoes from the cultivars planted in the adjacent rows and also detected effects in leaf composition of both phosphate and potassium fertilisers on the adjacent row. The cultivars in this study were the high-yielding Glen Ilam and the lighter yielding Katahdin, and the yield of each was higher when the cultivar in adjacent rows was Katahdin than when it was Glen Ilam.

It seems clear that these positive results should not be disregarded, and that it is therefore desirable to use guard rows to plots in both cultivar and fertiliser experiments. The penalty for failing to do this is not just a loss of precision, which might be compensated by greater replication, but also the more serious possibility of a biased result. Where guard-rows are used, the evidence shows (Kalambar, 1932; Mountier, 1964) that 4-row plots are more efficient than either 3-row or 5-row plots.

The conclusion is that a plot size of 4-rows by about 5 m is most efficient. A series of experiments using such a plot size (Mountier and Lucas, 1981) reported coefficients of variation on total yield ranging from 6.3% to 15.7%.

One qualification should be made to these assessments: the cost of planting and harvesting an experiment has been taken to be proportional to the total area of the trial, and this assumption might not be valid where operations of planting and harvesting can be highly mechanised. Optimum plot size and shape can be influenced substantially by the equipment being used.

BLOCK DESIGN

The object of blocking is to reduce unexplained or residual variation by grouping relatively similar plots together in one block. Questions of blocking have been discussed in some of the papers already referred to. Sardana *et al.* (1967) considered a number of different block sizes and shapes and found no consistent effect from shape of block, but reached the not surprising conclusion that small blocks were more efficient than large ones. There is general agreement that blocking is useful in increasing the efficiency of an experiment, but most effective block shape will depend on such things as soil fertility pattern, topography, and shape of plot. There is a rough general rule for field trials that blocks should be square rather than elongated, and this rule comes from experience of the usual pattern of soil variability. However, the best block shape may also be affected by the equipment used to plant and mould the rows. If there is variability in depth of planting, for instance, it may affect a whole row length in the same way, and therefore make it desirable that a block includes the whole row. Similar remarks apply to operations of moulding and spraying which are also carried out along the row. These considerations tend to make a relatively long narrow block shape the most effective in reducing residual variation with this crop.

The facility of arranging plots in blocks of a particular size is dependent on the number and nature of the treatments used, and the block size used in a particular case will be largely influenced by the treatments structure. Factorial designs using confounding or designs of the lattice type may be used to allow an acceptable block size when the total number of treatments is large.

The Latin square type of design extends the blocking principle into a second dimension, so that variation both down and across plots may be measured and removed from the 'unexplained' or 'residual' category. Gains from this type of design have not been very marked in many cases, but it may be worth using when the main direction of variability is unknown.

CHOICE OF TREATMENTS

The decision on what treatments to use in an experiment falls partly in the area of technique and partly in strategy. If cultivars are to be compared then they must be compared over a range of fertility and other conditions. The generality of the conclusion is dependent on the range of the conditions.

This range can be achieved, in part, by carrying out a number of experiments at different places and in different seasons. But some of that range can be obtained in a single experiment by including treatment factors that affect for example, fertility and water availability. Moreover, the relationship between these factors and relative yield of cultivars is more precisely measured in an experiment in which the factor levels are controlled. The experiments reported by Mountier and Lucas (1981) illustrate this. The cultivar Wha was compared with Ilam Hardy in four experiments conducted over three seasons. The most striking result from this study was that while at lower levels of fertiliser and water availability the cultivars tended to yield similar amounts, Ilam Hardy was much more responsive to higher levels of these inputs. In other words, the comparison between the two cultivars changes at different fertility levels.

The factorial type of experimental design makes possible efficient cultivar comparisons over a range of other treatments, and the use of confounding allows moderate block sizes to be used. The inclusion of factors of fertiliser and irrigation application leads to a wider generality of the conclusions about cultivars, whether or not there is an interaction with these factors.

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