ROTHAMSTED RESEARCH

XIII. The Technique of Field Experiments

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T. N. Hoblyn

T. N. Hoblyn (1932) *The Technique of Horticultural Experiments ;* Xiii. The Technique Of Field Experiments, pp 42 - 49 **- DOI: https://doi.org/10.23637/ERADOC-1-214**

the methods devised at Rothamsted, there is still room for further improvement. The complaint is often made that randomised experiments involve a considerable amount of time and trouble, but this is more than compensated by the increase in accuracy and hence in reliability of the results obtained.

The scheme of over fifty experiments which was carried through successfully by Mr. Grieve in Portugal during last season under conditions considerably more difficult than those experienced in this country, gives an indication of what might be accomplished in the British Isles.

Co-ordination of the efforts of the various county agricultural bodies, by conducting a series of multiple schemes over the whole country, would lead to results of great practical value.

THE TECHNIQUE OF HORTICULTURAL EXPERIMENTS

By T. N. HOBLYN

East Malling Research Station

During the last decade the art of horticultural experiment in the field has developed with amazing rapidity. Thirty-five years ago, when Pickering started to make experiments at Woburn, there had been no experience in horticultural research as we understand it to-day.

Since that time many experiments on fruit trees have been carried out, not only in this country and in America on deciduous fruits, such as applies and pears, but also on many tropical and sub-tropical trees cultivated either for their fruit or for some other valuable product, such as rubber, cinchona or tea.

The early experimenters soon found that they were up against problems of lay-out and technique which presented many complications not usually associated with agricultural experiments, and in consequence a system of experimentation has been gradually built up which is in some respects radically different from that used in agriculture.

The first and obvious difference is in the nature and longevity of the plant. Practically all horticultural plants are perennials; and thus an experiment once planned and planted must stay *in situ* often for ten or fifteen years before any results begin to appear.

https://doi.org/10.23637/ERADOC-1-214

Such an experiment involves the recording of the tree's history for perhaps thirty or forty years, a period when all kinds of seasons will be experienced and during which individual trees are liable to damage or accident from any number of sources, all of which must be protected against as far as possible, since such an accident as, say, an aphis attack may alter the performance of a tree for several years.

The second fundamental difference, which is perhaps not so obvious to the layman, is due to the fact that practically none of the plants grown in horticulture will repeat themselves exactly if raised from seed. Methods of vegetative propagation have, it is true, made possible the standardisation of many kinds of fruit tree; thus black currants are produced from cuttings, and apple trees by budding or grafting a scion from the original parent tree on to a rootstock which has been obtained by layering or stooling.

There are, however, many crops, *e.g.* coconuts and other monocotyledonous plants, which cannot be reproduced by other than seminal methods. In other cases, *e.g.* citrus fruits, or cacao, while it may be possible to reproduce a given variety by budding or grafting, the necessary rootstock cannot easily be induced to root by vegetative means and has to be produced from seed.

All this seedling material exhibits immense variability. Thus an apple tree on one rootstock may be ten times the size of an otherwise similar tree on another. Seedling cacao again, as usually grown, is said to "exhibit a range of variability covering all the existing horticultural varieties of apples."

It is therefore essential in nearly all horticultural experiments (and always where trees are concerned) that observations should be taken on individual plants.

For example, in a manurial trial on, say, cacao, if plots of trees were used, the effect of the manure might be different upon each tree and the sum effect upon the whole plot nothing at all.

The most urgent problem in horticulture is thus the production of uniform material. This has to a large extent been accomplished for deciduous fruits, and research work in vegetative propagation and in breeding is in progress already for a great many tropical and sub-tropical crops. However, even when this is accomplished, owing to the manifold accidents which may occur in the long life of a tree, it seems probable that records on individual trees will always be necessary.

Size of the Horticultural Plot

With the small fruits that are grown here, *e.g.* strawberries, currants and raspberries, as long as clonal material is available, in-

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dividual plant records are seldom taken; since not only is the life of the plant shorter, but the difficulties of recording each plant are such that it can only be done for a comparatively small number. The value of uniformity trials, however, in which individual bushes or plants are recorded, cannot be over-estimated when starting trials on a new crop.

With strawberries, 100 plants has been found to be a convenient sized plot; with black-currants four bush plots are about the minimum, and generally speaking eight or ten bushes would seem to be about the best size for variety trials and up to twenty-five bushes for manurial trials.

The individual tree is always regarded as a plot for all tree fruits. This may of course entail difficulties in planning and management, especially since the adoption of modern methods of lay-out, which involve random distribution. In some cases modifications in design have had to be made to enable such operations as spraying, picking, etc., to be carried out more easily, and in others, *e.g.* manurial trials, it has been found necessary to make the plots considerably larger. In this case, however, whether in each differently manured plot the trees are of several different varieties or all the same, individual tree records must still be taken.

The pomologist is thus faced with the necessity of recording minutely the history of a large number of trees for a long period.

The weighing of the crop is undoubtedly the most important record to be considered, but the research worker cannot understand the cropping performance of his trees unless he has a sound knowledge of their vigour, since, even though the most vigorous tree does not necessarily produce the most fruit, the two characteristics are always closely connected. Again, just as the effect of a fertiliser may be shown in the straw of a cereal crop and not in the grain, so the effect of a system of manuring may be shown in the vigour of a fruit tree or bush, although no effect on crop is apparent.

The problem therefore arises as to how to record the vigour of a tree from year to year.

Measurements of Vigour

Few attempts have been made to record the vigour of small fruits until recently, when such measures as the cane length and number of canes to a stool of raspberries, or the spread of strawberry plants have proved exceedingly valuable.

The recording of the life of a tree begins in the nursery, the first notes to be taken being records of the size of each rootstock. Calliper measurements of diameter are a useful measure of size and sometimes notes are taken on the amount of root growth.

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After the tree is budded and has made its first year's growth, it is usually planted in its permanent quarters and at this time records of height, weight and girth of stem are taken.

The girth is usually taken at a fixed height and this marked on the stem with white paint so that it can be measured in exactly the same place in after years.

After planting, several different vigour records may be taken. These include: measurements of annual twig growth, girth of stem, average height, average spread, and in some cases leaf size.

There has been considerable discussion as to which of these records best represents the vigour of the tree. After the examination of the records of very large numbers of trees at East Malling, the writer has come to the somewhat reluctant conclusion that no single record can be considered the best; since, though nearly all these measures of vigour are positively correlated where the trees are treated alike, differences in rootstock, manuring, pruning, etc., are all liable to upset the relationship between the different tree characters.

The cropping of the tree also has an effect upon its vigour. Increase in cross-section is generally low in a year of heavy crop, but the twig growth may not be adversely affected. Again, a heavy crop may weigh down the branches, so as to give a large increase in spread but an actual decrease in height.

The research worker therefore has to consider very carefully the possible results of an experimental treatment before deciding which measures of vigour should be recorded.

Measurements of Productivity

The first measure of productivity of interest to the research worker is the amount of blossom produced by the tree. This record is rather laborious to take, but in many experiments it is essential that some information concerning time of opening, amount of blossom, and proportion of blossoms which set fruit should be obtained. In seasons when weather conditions cause the failure of the crop, blossom records are the only measure of productivity available.

At harvest time weight of fruit is the first obvious record. It is often necessary, however, to supplement this by a count of fruit. Size, colour, quality and cleanliness are other characters of the fruit which must generally be recorded at this time.

Other Records

The above list of records of growth and fruiting may be regarded as more or less of a routine nature. In addition it is necessary to

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take records of other happenings in the life of the tree as often as possible. The incidence of a particular disease or pest, suckering from the roots, and leaf scorch, are some of the occurrences which need to be recorded from time to time.

Finally there are the personal notes of the research worker or his assistants. The small happenings on the plantation, this or that accident to a particular tree, the throwing out of roots from the scion, local variations in fertility or depth of soil, spray injury, etc., should all be carefully noted, for therein lie, not only the inspiration for these routine records, but also the means of interpreting them in after years.

Organisation of Recording

The taking of routine records and management on large scale experiments, wherein the trees or plots are often scattered at random, need very careful organisation, especially when unskilled labour has to be used. The first essential is the careful demarkation of plots.

Where the individual trees are scattered at random, as has been noted before, modifications in design are often necessary to make management possible at all. For example, in a large scale pruning trial on pears recently laid down at East Malling, nine varieties of pear are to be pruned in four different ways. The complete randomisation of these trees would make operations at pruning time very difficult and thus the pruning treatments were arranged more or less systematically, there being two treatments alternately in each row. Apart from this reservation, the thirty-six combinations of variety and treatment were arranged in randomised blocks in the ordinary way.

Although these varieties will be fairly distinctive by the time they are cropping, they will none the less have to be very carefully labelled to avoid errors.

The use of different colours in plot labelling, etc., may be very valuable, especially where illiterate labour has to be used. For example in a manurial trial involving the three constituents nitrogen, potash and phosphates, all the trees which get nitrogen could be given a red band, potash, a blue band, and phosphates white. It is possible to buy different coloured paper bags into which the different fertilisers can be weighed out, and thus the difficulty of application of manures on randomised plots considerably eased. One worker abroad marked his plots in this way and gave his native pickers armlets corresponding to the plot in which they were supposed to be picking, thus making the task of supervision much easier.

The necessity for guard rows in manurial trials, where larger

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plots are used, may also be turned to advantage in this connection, for a distinctive variety, or even another species of tree altogether, materially helps to mark plot boundaries in large orchards.

The use of Labour Saving Devices

Some of the records of vigour and productivity which have been alluded to are, to say the least, difficult to obtain; and often the use of some labour-saving device may make them possible, where otherwise they would have to be abandoned.

Annual twig growth is certainly one of the most valuable vigour records, but also the most difficult to record. On older trees, indeed, it can only be taken for a few trees, since it may take up to an hour to measure a single tree. In most cases, therefore, other records, which give an idea of this character, such as weight of prunings, number of shoots, etc., have to be taken instead. Where growth is actually measured, a considerable saving in time and labour is made by the use of a field telephone connected to the laboratory, where the measurements can be recorded and added up on an adding machine in one operation.

A very good idea of the number of shoots on spur-pruned trees can be obtained from the number of cuts made in pruning. This can be obtained very easily by the use of a pair of secateurs with a counter attached.

At harvest time much labour is saved and many errors avoided, if as many records as possible can be taken in the field immediately the fruit is picked and before it is removed from under the trees.

The number of fruits can be counted automatically by means of a counter attached to a picking bag, so that each fruit is recorded as it enters the bag. The fruit is then weighed upon a portable spring balance adjusted for the weight of the bag.

Grading for size and colour must, of course, be done in the packing shed, and here an ordinary commercial grader can be used.

Sampling

The taking of samples in horticulture probably presents greater difficulties than with agricultural crops, since it is very difficult to take a definite sample from a tree. Thus a single branch will vary tremendously in size; and a definite length of branch measured off and recorded will be a different proportion of the tree according to the size of the whole.

For this reason sampling with the object of measuring the actual crop or size of a tree has not as yet progressed very far.

https://doi.org/10.23637/ERADOC-1-214

On the other hand, qualitative characters have been successfully sampled in recent years. Thus by sampling the prunings from spur-pruned trees the weight of wood per unit length has been obtained and this in combination with the actual weight of prunings from individual trees and the measurement of a small number, has given a good idea of the annual wood growth.

Counts of blossoms and fruits upon measured samples taken at random have been used successfully to determine the percentage set of fruit; and daily counts of flowers open on similar samples have been used to determine the time of blossoming.

Again, random samples have been used to determine size, colour and such disease records as apple scab.

It is most important to remember, however, that such samples must be taken directly from the tree; it is very difficult to pick out a random sample from a box of fruit after it has been picked.

The Management of Fruit Experiments

There is one final point which must be included in any discussion of technique, and that is the proper procedure in such operations as pruning, spraying, manuring and thinning of fruit, where a large number of different kinds of tree are present in the same experiment. The problem arose recently, for example, in a manurial trial wherein nine different kinds of apple tree are included.

Should all these trees be pruned as the grower would prune them, to the best advantage, *e.g.* the large trees tipped more heavily than the small, or should the same proportion of wood be removed from all trees?

At first sight it would seem that the former course would be the better, since any single method adopted would probably be best for none; but if that were done what would happen when all the different effects of the manuring came into play? The larger kinds of tree when unmanured might actually require the same pruning as the smaller kinds when fully manured.

It seems therefore that it is better to treat all kinds of tree as far as possible alike, whether pruning, spraying or thinning; and this is the course generally adopted.

It is not possible to describe in detail all the methods of recording and difficulties with which the pomologist has to contend; but the experiences at East Malling have been described in a paper recently issued.[1] However, the best ways of overcoming the difficulties which

[1] "Field Experiments in Horticulture," by T. N. Hoblyn. Imperial Bureau of Fruit Production: Technical Communication No. 2 (1931).

https://doi.org/10.23637/ERADOC-1-214

arise are those which are evolved by the research worker himself and which suit his own particular conditions.

PRACTICAL DETAILS OF EXPERIMENTATION ON ORDINARY COMMERCIAL FARMS

By H. V. GARNER

Rothamsted Experimental Station

EXPERIMENTAL plots on the commercial farm call for labour of an unusual kind at busy seasons of the year, and there is sometimes a certain amount of difficulty in inducing farmers to co-operate with experimental stations in field work. Our experience has been that having once accepted an experiment the disturbance of farm routine has proved less than might have been expected, and farmers have been willing to retain experiments for a period of years. This co-operation is beneficial to both parties; for the research institute can test its findings under different soil and climatic conditions, while the farmer has the advantage of the only fertiliser experiments which he can interpret with confidence, namely those carried out on his own soil. Accordingly the aim should be to design experiments which have sufficient practical bearing to appeal to the farmer, while also providing information on more general questions.

Hitherto most experiments on commercial farms have been on single or in some cases on duplicate plots, but more elaborate arrangements involving higher replication are required to bring out small differences. Moreover, the finer points, if definitely established, are well worth the farmer's notice. The purpose of this paper is to describe the methods used in carrying out modern replicated experiments under the ordinary conditions of commerical farming.

The work has been done during the last few years by members of the Rothamsted Staff. The experimental centres cover a wide radius up to 150 miles from headquarters. Transport has been by train and hired car and the equipment no more than can be carried as passengers' luggage. Usually two supervisors have been required.

Co-operation with the Farm Staff.—The essential for the success of experiments of the kind under consideration is the close co-opera-

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