ROTHAMSTED RESEARCH

XIII. The Technique of Field Experiments

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The Technique of Variety Trials

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of conditions. For this purpose I like a strip, say a harrow or two harrow width, carried right through the middle of a field and if possible on and over contiguous fields. Two controls and your treatment—up hill down dale, over every sort of soil. We have quite a number of these, our largest being nearly a mile long, in connection with our work on the open hills. What, for example, would not a basic slag strip right across England have taught us, and I would like to join up Rothamsted and Aberystwyth with a single mixture strip.

THE TECHNIQUE OF VARIETY TRIALS

By S. F. ARMSTRONG

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Introduction

This is rapidly becoming an extensive subject, and as our programme to-day is lengthy I shall confine myself to such points as I feel are especially worthy of emphasis. These points are largely the outcome of experience gained by the staff of the National Institute of Agricultural Botany while engaged in actual field trials.

The first essential for those engaged in this work is that they should realise something of the difficulties and complexities of their task. We are dealing with living organisms. We are setting out to get a measure of their output—*yield*—itself the result of a large variety of causes. We are attempting to measure that even more elusive and undefinable thing—*quality*; and besides this we have still to take into account many other "crop behaviour points" which often to a large degree modify the "crop value" in farming practice. Moreover, we are dealing with "variety trials," that is to say, with the comparison of closely related plants. Therefore the differences we are attempting to measure are not usually of a large or obvious kind. For these and other reasons a well-defined and scientific technique is essential to success.

In variety trials it is necessary that we have a suitable standard of measurement by which we may judge the comparative performance of any variety as regards yield, quality or value of produce. The best known means available to us is to place a similar organism (or mass of organisms) under similar conditions. We employ a closely related variety as a standard or control and in this way obtain a

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relative measure of the performance of the test variety. From beginning to end of a variety trial it is therefore essential that the treatment of the control and the test variety shall be identical.

It will be obvious that a given variety cannot be used as a suitable standard of comparison against any and every variety of the same crop. To be suitable a control should mature at nearly the same time as the varieties tested alongside it. Also it should be a fairly widely grown variety of good standing either in general or local agricultural practice.

I would emphasise a further point. If the information we derive from variety trials is to be of real value in agricultural practice such trials must be carried out in the normal manner of cultivation and under ordinary farming conditions.

Choice of Land

This requires due care. Some unevenness is sure to exist, but land should be avoided for variety trials where gross irregularities occur either in depth, slope, water supply, etc. The more level and uniform the soil the more likely it is that any differences obtained between two varieties are real varietal differences and not due to soil variation, *i.e.* the results will possess a higher statistical significance.

It is worth while enquiring into the performance of previous crops to get an approximate measure of the uniformity and fertility of the land. Such knowledge will serve as a guide to the rational treatment of the experimental crops. Indeed, all possible available information about the soil, its previous cropping, manuring, etc., should be gathered before laying down trials. It should be ascertained beforehand that game or vermin do not exist in such numbers as to be a real danger to crops. The land should be ample in area so that plots may be at least 20 yards clear of hedges, shade of trees, etc.

Lay-out of Trials

On the respective merits of different lay-outs I do not feel qualified to speak. I shall therefore confine myself to such points as arise in the proper management of the lay-outs which are at present adopted by the National Institute of Agricultural Botany. It is probable that the perfect plot arrangement for variety trials is unworkable in ordinary practice, and therefore some form of compromise between the two aspects of the matter must be adopted.

In the Institute's cereal trials ten pairs of comparative strips are laid down for each separate trial. This number is found to be

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ample, whilst it does not involve any serious practical difficulty. The strips are sown at right angles to the direction of previously formed furrows and ridges. Dr. Beaven's half-drill-strip method is employed for all cereals, a wide 16 coulter steerage drill being used. The control and variety strips are thus sown side by side in a balanced manner which makes direct comparison simple. As "interference" is likely to occur between different varieties of cereals a so-called "interference strip" is interpolated between each variety and control strip. Also as irregular spacing would frequently occur at the wheel track due to overlap or underlap another "interference strip" is arranged for at this point. These "interference strips" are discarded at harvest.

A complete trial occupies half an acre of land, plus margins. Each comparative strip for weighing is normally $^1/_{80}$ of an acre. There are ten $^1/_{80}$ acre strips of the test variety for comparison with the same number of control strips. The rest are discard strips.

It is most important that the spacing of the coulters shall be accurate and equal on both sides of the drill. Each comparative strip must be of equal width, otherwise a serious constant error is introduced. A flat wooden rod (1 inch by 4 inches), with notches cut to indicate the correct coulter positions, is much better for spacing purposes than a tape measure. This should be used at the beginning and end of every trial. If any serious "shift" does occur it may be necessary to measure across the rows at brairding time, or across the stubbles after harvest, to discover what the average spacing actually is.

In the case of root crops, a single row is considered as a strip. With such crops it is possible to place the ten rows in a "scattered" lay-out over the entire trial area. The rows are all first correctly marked out with an empty drill; each row is then numbered and the strains sown in their respective rows by means of a one-row hand drill. One variety is selected as control. The mean of all the yields is used for the calculation of the Probable Error and each strain can be directly compared with another. Normally no interference strips are used where only strains of a similar type are grown in one set of trials. If, however, it is desired to test a large topped strain against a small topped one interference rows are introduced, *e.g.* in some sugar beet trials.

Grasses and clovers are sown on a scattered lay-out with intervening interference strips. For these a seed barrow is used, half the seed being sown in one direction and half in the opposite direction to ensure greater uniformity.

Each drill strip (or row) receives a distinctive number by which it can be referred to if special observations are necessary. We dis-

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pense with the ordinary wooden label as far as possible until all cultivations have been completed. After this the varieties and controls are indicated by suitable labels. In all cases, however, carefully drawn plans are placed in the field notebook and we depend on these plans rather than on labels to show the position of the strips.

When plots are sown by hand (*e.g.* small checker board plots) it is possible to define the exact limits of each plot. In laying down field variety trials it is not practicable to do this, or even desirable. The ends of strips are always more or less uneven and ragged owing to irregular starting of the drill, to inspections, etc. All strips are therefore drilled several yards longer than they are actually required to be. These extra lengths at the ends are useful for inspection, etc., and also serve to protect the trial area proper. At harvest these surplus lengths are removed, leaving the actual trial area isolated ready for cutting.

Plans for crop protection form a very important part of the work in variety trials. Indecisive results and even complete failures are frequently due to pests of various kinds. No pest is more serious in cereal trails than the common sparrow. It is not an easy matter to keep these birds entirely off the crop, even though a man is constantly on the spot. Clock guns are helpful. This year we are attempting to meet the difficulty by an additional precaution. We are surrounding each block of trials with a strip of an earlier ripening variety in the hope that this may attract the attention of the birds from the actual trial.

Rate of Seeding

A full and regular plant should be aimed at. With root crops extra heavy seedings are used, *e.g.* 12 to 14 lb. of mangold seed. The plants can be thinned and spaced to any desired distance.

With cereals the problem of seeding is different, as there cannot be excess seeding and thinning out afterwards. The question then arises—Is it more correct to sow the control and test variety seed in equal numbers or in equal weights per unit area ? The Institute normally follows the method of sowing equal weights for the reason that in agricultural practice it is the general custom to sow a given volume or weight of seed per acre. Different varieties of cereal grains vary considerably in size and shape—expecially in oats. Therefore to even out the seed rate of two varieties (either by number or weight of seed sown) necessitates a special form of drill if the two varieties are to be sown by the same implement at the same time. No English make of drill will do this. The Institute uses a Czecho-Slovakian type known as " The Melichar " in which the cups are

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expansible. The two halves of the drill are specially made to work independently of each other. The cups on either side may be increased or reduced in size, so that seeds of widely different sizes may be sown in equal weights or numbers at the same time.

It is of course necessary to make preliminary tests to discover the correct setting of the cups. In making such tests it is important to be sure not only that equal weights of seed are delivered on either side, but also that all the sprouts are fed uniformly throughout.

Seed Supply

As is well known the size, weight, moisture content, purity and germination of grain are all influenced by the soil and climatic conditions of the year of growth, and these points are still further modified by the condition of harvesting, threshing, cleaning and storage which they undergo. For obtaining accurate comparisons it is therefore essential that the seed of variety and control shall have been grown under similar conditions. Both stocks should be grown in the same year in the same locality, and if possible side by side. This is the invariable aim of the National Institute of Agricultural Botany and it also takes steps to see that the conditions of handling and storage are identical from the time the crops are harvested until the grain reaches its destination for sowing.

Cultivations

In order that our results may apply to actual farm practice we follow what are considered to be the most approved practices of the district in which the trial is situated. This applies to the preparation of the soil and seed bed, the time of sowing, the seed rate, distance apart of rows, etc. The same is true of manuring and all subsequent cultivations.

The essential point insisted upon is that throughout, the variety under test shall receive precisely the same treatment as its control, and also at the same time. Thus, such operations as rolling, application of fertilisers, etc., are carried out at right angles to the drill strips. In setting out or singling roots the work is done in definite strips across all the varieties. In this way any difference in type of work is spread over all strains alike, and also each receives attention alike in point of time. This is a very important matter in variety trials.

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Harvesting

For any crop we first decide upon a base line. This is fixed quite clear from the ragged ends of strips. From the base line the length of strip to be cut and weighed is measured off.

In the case of cereals the strips are cut one at a time, all in the same direction. Either a reaping machine or a binder is used for this purpose. If the crop is lodged it may be necessary for men to lift up the crop on each strip previous to cutting. It is essential that the whole of each strip be cut evenly, and that no portion of a neighbouring strip be taken in. If odd straws are missed by the reaper these are cut off by hand and placed in the strip to which they belong. As each strip is cut the sheaves are tied with string of a distinctive colour to indicate variety, while the strip itself is labelled with its proper number.

As soon as possible after cutting, each strip is weighed, and all the control produce placed in one stack and the variety in another. If storms or other circumstances put a stop to operations when either cutting, stooking or weighing is in progress the work is always left off at a point where an equal number of comparative strips is completed.

Strip Weighing, Threshing

Spring balances are convenient for taking weights of the strip produce. As they are subject to variation they should be tested frequently. Weighing cannot be done in a satisfactory manner when wind is strong, or in wet weather. The half-drill strip lay-out has, however, the great advantage that even if weather conditions are rather adverse the method of weighing the strips in comparative pairs gives comparable results. In all cases, as a precaution, the canvas weighing slings are weighed every half hour, or even more frequently, to find if any change in weight is taking place.

Roots are conveniently weighed in baskets holding about 100 lb. Wire baskets are far superior to wicker baskets. The latter soon collect mud and absorb much water. Roots like sugar beet, to which soil adheres, must be thoroughly washed if yield differences are to be correctly estimated.

In obtaining weights of cereal grains the thresher employed should be of a simple type which may quickly be cleaned out. The Institute uses a small thresher manufactured by Messrs. Garvie & Sons of Aberdeen. It has a 2-feet drum, and is without screen or elevator. Separation of the grain from chaff and debris is effected by the use of a fan in conjunction with two sieves. The object is

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to secure *all* the grain from the straw with the minimum of breakage. If the grain is much cut or broken estimations of quality are rendered difficult or impossible.

Sampling of Produce

To compare *yields* accurately the moisture content of the produce must be known. Samples for "moisture content" are taken at the same time as the grain weights and placed in sealed bottles.

Quality is taken into account as well as yield. In the case of wheat and barley sufficiently large samples are drawn for milling, baking or malting tests. These tests are conducted by experts under controlled conditions. In the case of oats the percentage of husk is determined. Samples are also drawn for local market valuations to be made by competent millers or grain merchants.

In the case of roots the percentages of dry matter and sugar are determined. When sampling sugar beet whole roots are taken; other roots are cored. Two duplicate samples, each of fifty roots (or cores) are drawn of each strain. Each of the ten rows contributes ten roots to the samples. End roots are excluded, and every *n*th root is taken in such a manner that the fifty roots of sample A are drawn from every portion of the trial area, and so also for sample B. Cores are wrapped in water-proof paper and packed in tins, and all samples are despatched by passenger train the same day to the laboratory.

Recording Observations

It is most important that accurate records of crop behaviour be kept at all stages of growth. Such records may indeed afford the clue to exceptionally good or bad results. Where two varieties are apparently equal in yield and quality the possession by one of them of an excellent additional feature may turn the scale entirely in its favour. In making such records we judge constantly by comparison with the control. All statements are relative to this standard. It is therefore essential that all observations be committed to writing *on the spot*. Mental impressions are fleeting things and can only be accurately conveyed by writing them down whilst they are clear and vivid in the mind.

One has constantly to guard against the use of loose or vague expressions. For example, the statement that "a certain amount of disease is present" gives no definite or comparative information at all. The following suggestions are made: where counts or measurements are possible these should be taken, *e.g.* number of plants

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missing in a row; number of "bolters" per row; length of straw in inches.

When word description is difficult, or lengthy, a simple sketch may serve far better, *e.g.* to indicate the shape of a mangold or beet-root or its relative position in the ground.

When counts or measurements are out of the question a scale of points may be usefully employed, *e.g.* to denote severity of rust attack, amount of lodging, etc.

Care is necessary if weights are to be recorded accurately. The produce of a strip may require two or several separate weighings. Each of these weighings is recorded so that the totals may be independently checked. Each weight is given in lb. and includes the basket or weighing sling. The tare weights are deducted afterwards, and not at the time of weighing.

Sheaves of cereals and grain are weighed to the nearest half lb.; straw and roots to the nearest lb. In recording fractional weights in decimals less than ·5 is expressed as the nearest whole number below it, and ·5 or any decimal greater than this is expressed as the next whole number above it.

Statement of Results

For the purpose of direct comparison the yield of a variety is most conveniently given as a percentage of the control. These percentages are based on dry weight yields. The size of the calculated probable error then indicates whether any difference may be considered as significant or not.

From the farmers' standpoint it is also desirable that results of variety trials should be stated on a comparative financial basis. In any such statement not only yield and quality have to be considered, but also any factors that appreciably affect the cost of growing, or marketing, *e.g.* in sugar beet the size of top, bolting, fangs, ease of lifting, etc.

Conclusion

Finally there must be *continuity of work* at any given centre. Variety trials are greatly influenced by soil, climate and season. Single year's results are of little value by themselves. It is only after the accumulation of at least three years' results (and often longer periods) that information can be published with any real confidence.

Also in variety trials adequate supervision is essential if all the necessary details of technique are to be properly attended to. Thoroughness in a few trials is far more likely to produce helpful

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information than numerous trials conducted under rush conditions. Statistical methods may serve to interpret results, but they are no remedy for agricultural errors. And great patience, perseverance and constant vigilance are prime requisites of workers in this particular branch of investigation.

MULTIPLE SCHEMES OF FIELD EXPERIMENTS

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Introduction

Just as repetition of plots of the same treatment in a single experiment adds to our information in that it enables more precise comparisons to be made between the treatments tested, so repetition of experiments is of value in substantiating conclusions reached for a single experiment and in testing the treatment over a variety of soil and climatic conditions and over more than one season. It is often found, for example, that the seasonal differences may be of a quite different order of magnitude from the differences between treatments which are often relatively small, while, what is more important, it may be found that the response to the treatments under test cannot be easily predicted. In some seasons a treatment may show a response; in others it may be ineffective or may even depress the yield. Similarly, variation in response may be found with variation in kind of soil or climate.

By multiple schemes of experiments is meant merely a series of experiments of the same type conducted at a number of different centres. The individual experiments should all be alike in that they should contain the same number of treatments at the same rate of application. They should also be of the same form of experimental design, *i.e.* they should all be randomized blocks or Latin squares with the same number of replicates. Although of the same form of experimental design, the random lay-out should not be standardised. It is essential that the lay-out at each centre should be selected at random from all the possible lay-outs of the same form of design. When a scheme of experiments satisfies the above conditions the data obtained can be analysed as a composite whole. The average effects

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