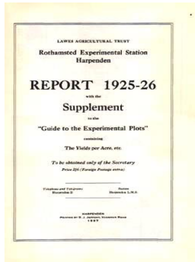
Report 1925-26 With the Supplement to the Guide to the Experimental Plots


Rothamsted Experimental Station
Harpenden
REPORT 1925-26
Supplement

Full Table of Content

Methods of Field Experimentation

Rothamsted Research

Rothamsted Research (1926) *Methods of Field Experimentation ;* Report 1925-26 With The Supplement To The Guide To The Experimental Plots, pp 26 - 29 **- DOI: https://doi.org/10.23637/ERADOC-1-84**

cost of winning the crop. This is undoubtedly true, but it is also true that many farmers are not near the point of diminishing returns and would obtain better results, both in output and financially, by putting more into the land.

Data are accumulating (see 1923-24 Report, p. 16) to show that in many instances the return from fertilisers and other improvements increases with increasing quantities before it begins to decrease. This is shown in the potato experiment of 1926, where the successive increases in yield given by successive doses of sulphate of ammonia are, in cwts. per acre :—

Quantity of Sulphate of Potash per acre.	Successive Increases in yield for Sulphate of Ammonia. 1st cwt.	2nd cwt.	3rd and 4th cwt.
1 cwt.	23.6	31.6	6
2 cwt.	23.2	22.6	13.2
4 cwt.	24.4	28.6	19.0
Mean	23.7	27.6	—

The second cwt. of sulphate of ammonia is not only profitable, but more profitable than the first.

This increasing return has so far been observed only with nitrogenous manures, and it is marked only in certain seasons. It may, however, always occur but be missed: in a field experiment only few quantities can be tested, and usually for potatoes the steps have been greater than 1 cwt. per acre.

The effect of the fertiliser is influenced by the time at which it is applied. In the experiments on oats in 1925 the late dressing gave the better result for 1 cwt. sulphate of ammonia, while in 1923 the earlier dressing had proved the better. In both years 2 cwts. per acre gave better returns when applied late. The increased yields for the early applications of the sulphate of ammonia are curiously similar : there is more difference for the late application :—

Time of Application.	1923. 1 cwt. bush.	1923. 2 cwt. bush.	1925. 1 cwt. bush.	1925. 2 cwt. bush.
Early (*a*)	8.1	17.3	9.8	16.8
Late (*b*)	5.4	24.5	14.7	19.7

(*a*) March 28th in 1923, March 5th in 1925.
(*b*) May 22nd in 1923, May 5th in 1925.

The effectiveness of the late dressing is probably in some way bound up with the relation between grain formation and growth.

METHODS OF FIELD EXPERIMENTATION.

The foregoing pages show how completely the modern fertiliser problems differ from those of the earlier days. Formerly the interest lay in showing that good crops could be obtained by the use of artificial manures, or in comparing artificials with farmyard manure. The results have now become embodied in general farming experience and no longer form the theme for experiments. Modern problems are concerned much more with matters of detail : such as the comparison of fertilisers which are nearly alike, or the tracing out of the effects on the growing crop and seeing how these can be used for increasing the output from the farm. Greater accuracy is now necessary than formerly, because a five or ten per cent. margin may make all the difference between profit and loss to the farmer : the results must also be obtained quickly, before changes in the economic situation have destroyed the interest in the work.

This change in the problems has necessitated a change in the method of making field experiments. The older methods had the great merits of directness and simplicity, but they are not very accurate; however carefully carried out, they are liable to errors which in any year may amount to at least ten per cent. Improvements in technique have reduced this liability, and repetition of the experiments for a number of years, as at Rothamsted, tends to cancel out some of the errors. But quite apart from the fact that agriculturists now want information speedily, there is the serious disadvantage that the amount of the error is unknown. For any valid estimate of error it is essential that the arrangement or the "sample" should be at random and not the result of selection, which forms the basis of all the older methods.

The statistical and field departments have worked out new methods which are not only more accurate in their working details than the old ones, but satisfy this statistical requirement of random sampling as against selection, and thus admit of the calculation of the error, so that the experimenter knows what degree of significance attaches to the results. Further, the experimenter can adjust the degree of accuracy to the requirements of the problem; if he needs an accuracy of two per cent. he can get it; if, on the other hand, he needs only to be within 10 per cent., he can change the design accordingly. The higher the accuracy aimed at, the greater the elaboration and the cost, and although it is possible to interweave various experiments into one large whole, nevertheless, the cost necessarily remains high.

These new methods are now used for all the new experiments (though not for the classical ones, which are still continued in the old way without change) and the standard error is calculated and recorded in the tables. This is the first time our field experiments have been treated in this way. (See p. 122.)

The new methods are the outcome of long previous investigations in which several workers, including the agriculturist, the ecologist, the plant physiologist and the statistician took part.

It was recognised that in the past more useful information had often been obtained from field observations during the growth of the crops than from the final weighings at the end. A field laboratory was therefore built on the experimental fields and equipped with appliances for making measurements on the growing plant, and an ecologist (T. Eden) and a plant physiologist (E. J. Maskell) devoted their whole time to measuring and observing such things as rate of growth; for cereals the number of tillers, dates of emergence of heads, length of straw and of ear, number of grains per ear; for roots and potatoes height and spread of the plant, nature of foliage, etc. These observations

https://doi.org/10.23637/ERADOC-1-84

promise to be of great value in explaining the effect of soil and season on plant growth and on fertiliser action.

The figures for final yield, however, must always be the chief, and have often been the only, test of any agricultural treatment. In order to increase their value a statistical investigation was undertaken to discover the basis on which improvement could be effected, and field experiments were used to test which of the various theoretically sound methods were also practically sound.

The work began in 1919, when Dr. Fisher applied to the study of variation an arithmetical analysis known as the analysis of variance, which had the advantage over the ordinary calculus of correlations of avoiding both the calculation of a large number of irrelevant values and also the numerous corrections to which correlations are liable, especially with small samples. He applied the method to the Broadbalk wheat yields and showed its value for measuring the effect of distinct groups of causes. This investigation, however, showed the need for more exact methods than those previously used for treating the small number of cases, or samples, generally available in agricultural investigations. The first example of an analysis of variance in its modern form was the examination of the results of T. Eden's experiment in 1922 on the response of different potato varieties to manures (Fisher & Mackenzie, Journ. Agric. Sci., 1923). Somewhat later, "Student" gave alternative proofs by himself and by Fisher of formulæ appropriate to cereal variety experiments. Thus rigorous methods of statistical examination were elaborated.

The next step was to develop a correspondingly rigorous field technique, and this was done by Dr. Fisher in co-operation with T. Eden and E. J. Maskell. The chief difficulty was to overcome the effects of the irregularities in the soil which had long been a serious stumbling block to field experimenters.

Part of the irregularity or heterogeneity could be eliminated by suitable arrangements of the plots, but there was always an unknown remainder of residual errors. It was shown that the statistical analysis previously developed could eliminate the former and at the same time afford a valid estimate of the remaining errors, provided that the plots were sufficiently replicated and deliberately randomised.

Dr. Fisher then devised various types of experiments to meet the requirements of the statistical analysis and tested these on the results of uniformity trials so as to discover which were the most accurate and convenient in actual working. Two types stood out as satisfactory; randomised blocks and Latin squares. The randomised block is the simpler and the more easily adjusted to suit the peculiarities of the field and the crop. The experimental area is divided into several strips or blocks, each of which contains one plot of each treatment, the arrangement being deliberately at random and determined not by selection, but by writing the possible arrangements on separate cards, shuffling them, and drawing one out. Since one block is not directly compared with another, the differences in soil fertility between them are eliminated; and since the arrangement within the blocks has been entirely at random, the significance of the results can be estimated. An example of this method is given on p. 146.

https://doi.org/10.23637/ERADOC-1-84

The Latin square is the more accurate but less widely applicable in fertiliser experiments. The plots are arranged with as many rows and columns as there are treatments. Each treatment appears once, and only once, in each row and each column. A surprisingly large number of arrangements are possible, but the selection is again deliberately at random and, as before, is effected by the shuffling and drawing of cards. The potassic fertiliser experiments on potatoes are an example (p. 138).

Two years' experience of these methods has satisfied us that they are practicable, though they are costly because they necessitate large numbers of plots : a single experiment may require some 50 to 80 plots. The additional accuracy, as compared with the older methods, is a great boon to the agricultural expert because it gives him much better material on which to base his advice to farmers. And it has the supreme advantage that the actual figures of crop yield have for the first time become definite scientific data, so that they can be related to other values such, for example, as meteorological data. Strict comparison can be made where previously only vague and general comparisons were possible.

THE INFLUENCE OF WEATHER ON CROP YIELDS AND FERTILISER ACTION.

The new methods outlined above for making field experiments, and studying the results, make it possible to discover with considerable precision the influence on crop yields of rain, temperature, sunshine, or any other meteorological factor that can be measured and expressed in figures. Dr. Fisher has already traced the connection between rainfall in the different months of the year and wheat yields under different fertiliser treatments : a similar investigation into barley yields has now been made. The effect of hours of sunshine on wheat yields has also been examined : the most striking effect is of autumn sunshine just before or just after the sowing of the crop : whether the benefit arises from the warming or the drying of the soil is not yet found. For the rest of the year, even in July, actual sunshine seems unimportant : the great weather factors seem to be the temperature and the rainfall.

Observation in the field has brought out several interesting facts : that nitrogenous fertilisers are affected less than any others by season (p. 17), that phosphates act better on swedes and turnips in a cold, wet year than in a good growing season (p. 18), that potassic fertilisers act better on potatoes in a dry spring than a wet one (p. 23). With fuller knowledge of these actions it would be possible to draw up schemes of manuring suitable to any specified kind of season. To some extent this has been done for potatoes. There are each year at Rothamsted a number of plots of potatoes receiving various manures. The highest yield shows little variation from year to year, being about 12 tons per acre whatever the season (excepting in 1921, the summer of exceptional drought). But the manurial treatment required to get it does vary : in some seasons potassic manures were the most important, and in others nitrogenous.