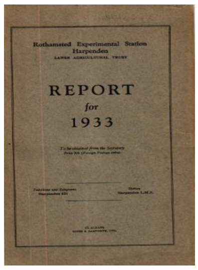
ROTHAMSTED RESEARCH

Report for 1933

Full Table of Content



Notes on the Summary Tables

Rothamsted Research

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Notes on the Construction and Use of the Summary Tables.

The presentation of the results of simple experiments is an easy matter, it being usually sufficient to give the mean yields of the individual treatments with an associated standard error by which differences may be compared ; a difference of three times the standard error of a treatment mean may be regarded as significant. In the case of complex experiments, however, where there are all combinations of several groups of treatments, the mere presentation of the mean yields of the sets of plots receiving all the different combinations of treatments does not give an adequate or easily comprehended survey of the results.

In order to illustrate the points involved we will first consider the simple type of complex experiment in which there are all combinations of two standard fertilisers, nitrogen and phosphate, each at one level in addition to no application. This is called a 2×2 arrangement, and involves the four treatments

$$\text{O, N, P, NP.}$$

Each treatment will be replicated several times, using a randomised block or Latin square layout. In what follows the symbols are taken to represent the mean yields of each particular combination of treatments.

There are two responses to N, one in the absence of P, namely (N—O), and one in the presence of P, namely (NP—P). These two responses may differ, but frequently the difference is small—too small to be distinguished from experimental error—and in such cases it is often sufficient in considering the results of the experiment to take the average response to N when P is both present and absent. The average response is clearly

$$\tfrac{1}{2}[(N-O)+(NP-P),]$$

or

$$\tfrac{1}{2}(NP+N-P-O).$$

The differential response to N in the presence and absence of P, usually called the *interaction* between N and P, is the difference between the response to N when P is present, and the response when P is absent. It is given by

$$[(NP-P)-(N-O),]$$

or

$$NP-N-P+O.$$

Note that with this convention there is no factor $\tfrac{1}{2}$ as there was in the average response, also that the differential response to N in the presence and absence of P is the same as the differential response to P in the presence and absence of N, i.e., there is only one interaction between N and P.

If potash is also included in the experiment we have a $2 \times 2 \times 2$ arrangement with the eight treatments

$$\text{O, N, P, K, NP, NK, PK, NPK.}$$

The average response to N is the average of four responses and is therefore

$$\tfrac{1}{4}[(N-O)+(NP-P)+(NK-K)+(NPK-PK)],$$

or

$$\tfrac{1}{4}(NPK+NP+NK-PK+N-P-K-O).$$

The interaction between N and P is the average of the interaction when K is present and the interaction when K is absent, i.e.,

$$\tfrac{1}{2}[(NPK-NK-PK+K)-(NP-N-P+O),]$$

or

$$\tfrac{1}{2}(NPK+NP-NK-PK-N-P+K+O).$$

The difference between the interactions between N and P when K is present and absent is called the *second order* interaction between N, P and K, and is given by

$$[(NPK-NK-PK+K)-(NP-N-P+O)],$$

or

$$NPK-NP-NK-PK+N+P+K-O.$$

Just as there is only one interaction between two treatments, so there are three first order interactions between three treatments, one between each of the pairs of the treatments, but only one second order interaction between the three treatments.

The summaries of this report are so arranged that as far as possible the main effects and first order interactions are available without the necessity of taking out any means. The first order interactions are often given in the form of response to one treatment in the presence of, and in the absence of the other, under the heading of "differential responses." The standard errors (prefaced by the sign $\pm$) applicable to all comparisons which are likely to be of interest are also shown. They are deduced from the standard errors per plot, which are given in the details of the experiment.

The rough rule for use with standard errors is that a quantity is significant if it is greater than twice its standard error, and the difference between two quantities having the same standard error is significant if it is three times that standard error. Thus the mean response to sulphate of ammonia in the 1934 Brussels Sprouts experiment at Woburn is given as 9.01 cwt. $\pm$1.89 cwt., which is therefore significant, since the response is almost 5 times its standard error. The responses in the absence and presence of poultry manure are 12.38 cwt. and 5.64 cwt., each with a standard error of ± 2.67, and the differential response (or interaction) which is the difference of these, though suggestive, is not significant, being only about two and a half times the standard error of each of them. The response to sulphate of ammonia in the presence of poultry manure, 5.64 ,is significant, being more than twice its standard error. The same interaction can be looked at from the point of view of response to poultry manure in the absence and presence of sulphate of ammonia. These responses are 8.18 and 1.44 cwt., again with a standard error of ± 2.67, giving a mean response of 4.81 cwt. with a standard error of ± 1.89. The mean response and the response in the absence of sulphate of ammonia are therefore significant, but the response in the presence of sulphate of ammonia is small and not significant. We have here a case of common occurrence where one of two quantities is significant and the other is not, but where the two quantities do not differ significantly from one another.

Standard errors, besides their use for testing the significance of comparisons from one particular experiment, are of importance when the results of a number of experiments are combined, since they serve as a measure of the reliability of each experiment, and also give the information necessary for telling whether the variation from experiment to experiment in the effect under survey is a real one or whether it can be attributed to experimental errors.

The second and higher order interactions are likely to be of even less importance than the first order interactions, and this fact is made use of in *confounding*, which is a modification of the randomised block method, introduced in order to keep the number of plots per block small while allowing a large number of different treatments. In confounded experiments certain comparisons representing high order interactions are confounded (i.e. mixed up) with differences between blocks. Thus in the $2\times2\times2$ arrangement given above, the plots receiving the treatments NPK, N, P and K might be put in one set of sub-blocks of 4 plots, and the plots receiving treatments NP, NK, PK and O in another set of sub-blocks of 4 plots. The second order interaction would then be completely confounded. On irregular land a considerable increase in precision may result from keeping the blocks small. There are many examples of confounding of varying complexity in the experiments of this report. There is not space to discuss all the implications of confounding here, but it will be seen that in general the results of interest, namely the main effects and first order interactions, are unaffected by confounding, and tables involving these interactions only can be used without regard to the confounding. In certain cases, e.g., $3\times2\times2$ and $3\times3\times2$ experiments, where some of the first order interactions are unavoidably slightly confounded,these interactions have slightly higher standard errors than the others ; this is indicated in the tables themselves, the correct standard errors being given.

The high order interactions are not only unimportant, but it can often be confidently predicted that they are likely to be very small in magnitude compared with the experimental errors. They can therefore be used to provide an estimate of experimental error instead of the usual estimate provided by replication. This makes possible complex experiments in which each combination of treatments occurs once only, thus enabling greater complexity to be attained with a reasonable number of plots. The 1933 potato experiment at Wisbech is an example of this type of layout.

CONVERSION TABLE.

1 acre	0.405 Hectare	0.963 Feddan.
1 bushel (Imperial)	0.364 Hectolitre (36.364 litres)	0.184 Ardeb.
1 lb. (pound avoirdupois)	0.453 Kilogramme	1.009 Rotls.
1 cwt. (hundredweight, 112 lb.)	50.8 Kilogrammes	113.0 Rotls. 1.366 Maunds.
1 ton (20 cwt. or 2,240 lb.)	1016 Kilogrammes.	
1 metric quintal or Doppel Zentner (Dz.)	100.0 Kilogrammes. 220.46 lb.	
1 metric ton (tonne)	1000 Kilogrammes.	
1 bushel per acre	0.9 Hectolitre per Hectare	0.191 Ardeb per Feddan
1 lb. per acre	1.12 Kilogramme per Hectare	1.049 Rotls. per Feddan
1 cwt. per acre	1.256 dz. per Hectare	117.4 Rotls. per Feddan
1 ton per acre	25.12 dz. per Hectare.	
1 dz. per Hectare	0.796 cwt. per acre.	
1 kg. per Hectare	0.892 lb. per acre.	

In America the Winchester bushel is used = 35.236 litres. 1 English bushel = 1.032 American bushels.

The yields of grain in the replicated experiments are given in cwt. per acre. One bushel of wheat weighs 60 lb., of barley weighs 52 lb., of oats weighs 42 lb., approximately.