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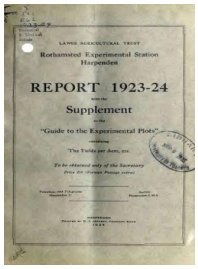
Report for 1923-1924 With the Supplement to the Guide to the Experimental Plots Containing the Yields per Acre Etc.



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Statistical Control of Field and Laboratory Work

Rothamsted Research

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In addition to this qualitative work, Dr. Bristol Roach has introduced exact methods. She has studied quantitatively the growth of a single species in nutrient solutions differing only in the nature of the carbohydrate present, the substances tested being the sugars (pentoses, hexoses, disaccharoses), also mannite and glycerol. The rate of growth of the algae in culture, as measured by the increase in bulk, is constant under uniform favourable conditions for about the first ten days after inoculation, and parallel cultures have equal growth rates within the limits of experimental error. It has therefore been possible to devise a method for growing the alga under constant conditions of temperature, light and aeration, and by taking daily measurements of its bulk to ascertain the rate of growth in the presence of the various compounds under investigation. In this way figures have been obtained for a number of the sugars which can be regarded as representing their relative values as energy sources for the organism concerned. Without this physiological work it is impossible to ascertain with certainty the part played by the algae in the important changes going on in the soil.

STATISTICAL CONTROL OF THE FIELD AND LABORATORY OBSERVATIONS.

It is one of the distinguishing characteristics of the recent Rothamsted work that the field and laboratory observations are, wherever possible, subjected to close scrutiny in the Statistical Department, with the view of estimating the degree of probability attaching to the results, and of indicating modifications in the plan of the experiments that may increase their accuracy. The field data are examined in order to trace correlations between weather, crop growth and other of the quantities measured, the mass of the data being so great that no other procedure gives equally useful results.

As a preliminary, Mr. Fisher found it necessary to develop adequate statistical methods for the study of field data. This work has now progressed considerably.

The methods of experimentation have been closely examined and improvements introduced which allow of a far higher degree of accuracy than could previously be attained.

The difficulties of the older methods of field experimentation arose from uncontrollable variations in the weather and the soil. Experiments repeated on the same soil in different years give discrepant results owing to the variation of the weather; while experiments repeated on different land in the same season give equally discrepant results owing to the variation of the soil. In consequence, even well conducted field experiments suffered from errors of the order of 5 or 10 per cent., a range of inaccuracy too large to meet the requirements of the practical farmer, to whom a difference of 5 per cent. in his average gross yield may make the whole difference between profitable and unprofitable farming. In order to eliminate these errors, three types of procedure have been adopted by experimenters :—

1. To repeat an experiment for a long sequence of years, so that the average yield may be taken to indicate the

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result not of a single year's weather, but of the prevailing climate of the district.

2. To repeat the same experiment on a large number of farms, so that the average yield may indicate not the result of a single soil, but the average result of the soils of the region explored.
3. To repeat the same experiments on small plots on an apparently uniform piece of land, and so to obtain some estimate of the experimental errors of field experimentation.

The difficulties encountered by the first method are great expense, delay in arriving at definite conclusions, cumulative effect of soil heterogeneity and uncertainty to what extent the discrepancies between different years are ascribable to weather differences and to what extent to experimental errors.

The difficulties of the second method are expense in the absence of widespread and intelligent support from the farmers, unrepresentative character of the weather of a single season and uncertainty to what extent discrepancies between different farms are ascribable to soil differences, to experimental errors or to weather differences.

The third method possesses the advantage of attempting not merely to "average out," but to evaluate the causes of variation; by itself it makes no attempt to study the variations due to soil and weather, but deliberately aims at evaluating the experimental errors and so of obtaining a result of known accuracy. The principal difficulty encountered has been the marked heterogeneity often found on apparently uniform pieces of land. The soil heterogeneity has often not merely detracted from the accuracy of the results, but has vitiated the estimates of error in such a way that the degree of accuracy of the results is in reality unknown.

These difficulties of the method of experimentation may be overcome by the replication of small plots. A valid estimate of accuracy may be achieved by arranging the plots in the field so that they conform to the requirements of the statistical theory used in the reduction of the data. To this end, definite rules may now be laid down. The lowering of the experimental error may be achieved to a greater extent than has hitherto been attempted by the systematic adoption of the principle of local control, by which plots to be compared are set out on land of comparatively similar quality, without vitiating the estimate of the experimental error calculated from the totality of the results.

Testing these new principles of procedure upon the results of uniformity trials, such as that of Mercer and Hall (1910), it appears that when small plots (1/200th acre) are practicable, the comparative values of, say, five different treatments or varieties may be obtained from an acre of land with errors within 1 per cent., and moreover with known accuracy. The actual arrangement may be varied to meet other requirements, but for small plot work with four, five or six treatments to be

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compared, the Latin Square, replicated and randomised, apparently always gives highly accurate results.

The bearing of this advance on plot experimentation in all its branches is obvious. If plot experiments of known accuracy are repeated either upon different soils or under different weather conditions it becomes possible to distinguish discrepancies due to experimental errors from those due to changed conditions. Where the latter are of importance, it is possible to evaluate them analytically, and the results afford valuable guidance in showing in what soils and in what regions a proposed change in variety, in manurial treatment or in tillage procedure is likely to be beneficial or the reverse. In all cases the need for the very numerous results in order to average out uncontrolled causes of error can be obviated by the use of fewer observations of known accuracy under known conditions.

APICULTURAL INVESTIGATIONS.

Work has been directed towards the solution of two practical problems of importance to beekeepers and is being carried out by Mr. D. M. T. Morland.

(*a*) The suitability of metal " semicomb " in place of wax foundation as a basis for comb building.

The results so far obtained appear to indicate that the metal combs are not suitable for brood rearing in the climate of this country. The Queens did not lay well in them, the brood was scattered and the population consequently not kept up. Moreover, the larvæ tend to leave the metallic cell base and to work upwards towards the wax extension at the mouth of the cell.

Temperature appears to be maintained only at the expense of the consumption of an undue quantity of stores. It is probable that more adequate protection than that afforded by the simple air space of the W.B.C. type of hive is needed when using these combs. It is intended to test this point in the future.

It was also noted that the bees were quick to detect small inaccuracies in manufacture of the artificial cells, and where the cells were on the small side the bees endeavoured to correct matters by missing out a row every now and then and faulty combs were the result.

It was found that a strong stock would store honey in metal combs in the supers. The season of 1924 was, however, such a poor one in this locality that the test cannot be considered as fair.

(*b*) The situation of the frames in relation to the hive front.

The data respecting the situation of the frames in relation to the hive front need to be analysed more fully than at present before reliable conclusions can be drawn. The work has, however, brought to light useful indications for future enquiry.

The chief method in both these investigations has been a consideration of temperature conditions within the hive. It is intended to continue work on these lines and also to make a preliminary study of moisture and carbon dioxide in the hives.

In the summer of 1924 a number of beekeepers representing various county beekeepers' associations met and had a discussion

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