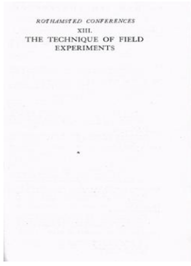
XIII. The Technique of Field Experiments


ROTHAMSTED CONFERENCES
XIII.
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Multiple Schemes of Field Experiments

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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

By A. H. LEWIS, A. D. MANSON and J. PROCTER

Imperial Chemical Industries

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 of the treatments, the difference between centres and the interaction of treatment and centre and season can be estimated.

It is quite feasible to conduct a number of experiments of a fairly simple character at a number of centres, and at the base or research station, where facilities are better, to test the same treatments on a more precise basis, *e.g.* four treatments might be tested in duplicate or triplicate blocks at the outside centres but at the base a more elaborate experiment could be conducted.

1930 *Experiments*

During the 1930 season Imperial Chemical Industries Ltd. carried out a number of multiple schemes, both in the British Isles and in several foreign countries, including Portugal, Egypt and China.

The schemes started from a small beginning. Experience gained during 1927-29 showed that absolute control by the experimenter at every important stage of the experiment was necessary. It was also found that randomised experiments involving a number of replicates of *small* plots of about $^1/_{40}$ acre in area were more valuable for demonstration purposes than large plots of $^1/_2$ to 1 acre, the Latin square form of layout being particularly suitable for this purpose.

Thus the use of small plots increased the accuracy of the experiments and lowered their cost whilst increasing their demonstrational value. Another great advantage in using small plots is that co-operation with the farmer is facilitated. Large plots mean inconvenience and loss of time to the farmer as his machinery and help are required to a considerable extent, whilst, with small plots, these difficulties are reduced to a minimum.

The success of multiple schemes, carried out over a large area, depended upon centralised control, detailed organisation and meticulous care on the part of the experimenter, and last, but not least, the goodwill of the farmer. Co-operation of farmers was easily secured when the nature of the experiments was explained, and when it was made clear that they would be absolved, where necessary, from all work in the conduct of the experiments, and that we were always prepared to hire casual labour.

It is essential that the experiments be carried out by men with a thorough training in the practical side of field experimental work.

Experiments in British Isles

The experiments carried out on a number of crops in the British Isles in 1930 involved two fertiliser treatments and a control, so that the 3 × 3 Latin square form of lay-out was adopted. Although a single 3×3 Latin square is of relatively little value, since no great reliability can be placed in the standard error obtained and, in any case, differences have to be very large for significance, the results of a number of 3×3 Latin squares can be grouped together and treated statistically as already explained.

Labour

When the experimenter was assisted by one casual labourer, the two operations of laying down the experiment and application of fertilisers could be completed on a cereal, hay or root crop in about three hours. A cereal or hay trial was easily harvested in one day by two casual labourers. Four casual labourers could lift a trial on roots in one day. Grading and weighing of potatoes was carried out on the second day.

Cost

The cost of all casual labour on any root crop never exceeded £3 to £4, whilst hay and cereal trials could be done for at least half that amount. It frequently occurred, especially with the hay and cereal trials, that the farmer offered the casual labour and would not consider any compensation.

Threshing Cereals

It was necessary to undertake the threshing of cereal trials ourselves, as it was not considered satisfactory to thresh each small plot separately with the ordinary farm thresher. A portable thresher with an 18-inch drum mounted on a commercial motor, the thresher being driven by a 4 h.p. engine, was used for this purpose. The total cost was about £400. Using this machine, the threshing and weighing of the produce from nine plots was easily completed in four hours. That the outfit gave complete satisfaction will be realised from the fact that twenty-four trials distributed throughout England, Scotland and Ireland were threshed in a month. During the threshing itinerary in England and the Irish Free State one trial per day was averaged as the weather was good.

Degree of Accuracy

The figures given in Table I give an idea of the standard of accuracy obtained. It will be seen that all the standard errors are satisfactory :—

TABLE I

Country	*Crop*	*No. of Centres*	*Layout. Treatment × Replicates*	*Standard Error. Percentage of Mean*	
				Average Results for all Centres	*Average Results for Individual Centres*
BRITISH ISLES	Hay	16	3 × 3	0·52	1·93
		7	3 × 3	3·09	2·18
		3	3 × 3	3·12	3·29
	Oats Grain	13	3 × 3	1·84	3·7
	Oats Straw	13	3 × 3	1·69	5·03
	Potatoes	14	3 × 3	2·57	4·62
	Sugar beet Washed beet	13	3 × 3	2·26	3·59
	Sugar beet Tops	13	3 × 3	2·54	5·10
PORTUGAL	Maize Grain	5	4 × 4	1·51	—
	Maize Straw	5	4 × 4	2·25	—
	Maize Grain	4	4 × 4	2·26	—
	Maize Grain	4	4 × 4	3·68	—
	Potatoes	7	4 × 4	2·63	—
CANADA	Potatoes	31	2 × 1	1·7	—
		21	2 × 1	2·1	—
		10	3 × 1	2·8	—

Value of Multiple Experiments

To show the value of multiple schemes we may take an example. The example demonstrates the effect of rainfall on the response of maize to fertilisers and is taken from the results of an experiment conducted in Portugal in 1930. In Fig. 1 the distribution of the centres is shown and in Fig. 2 the results of fertilization are represented diagrammatically. It will be seen that a response to nitrogen, as reflected in the yields of grain and straw, was obtained in the wet areas whilst nitrogen had a depressing effect on yield in the dry areas.

Conclusion

In conclusion a plea should be made for an improvement in the general standard of field experiments. Although a considerable improvement has been effected in recent years due to the adoption of

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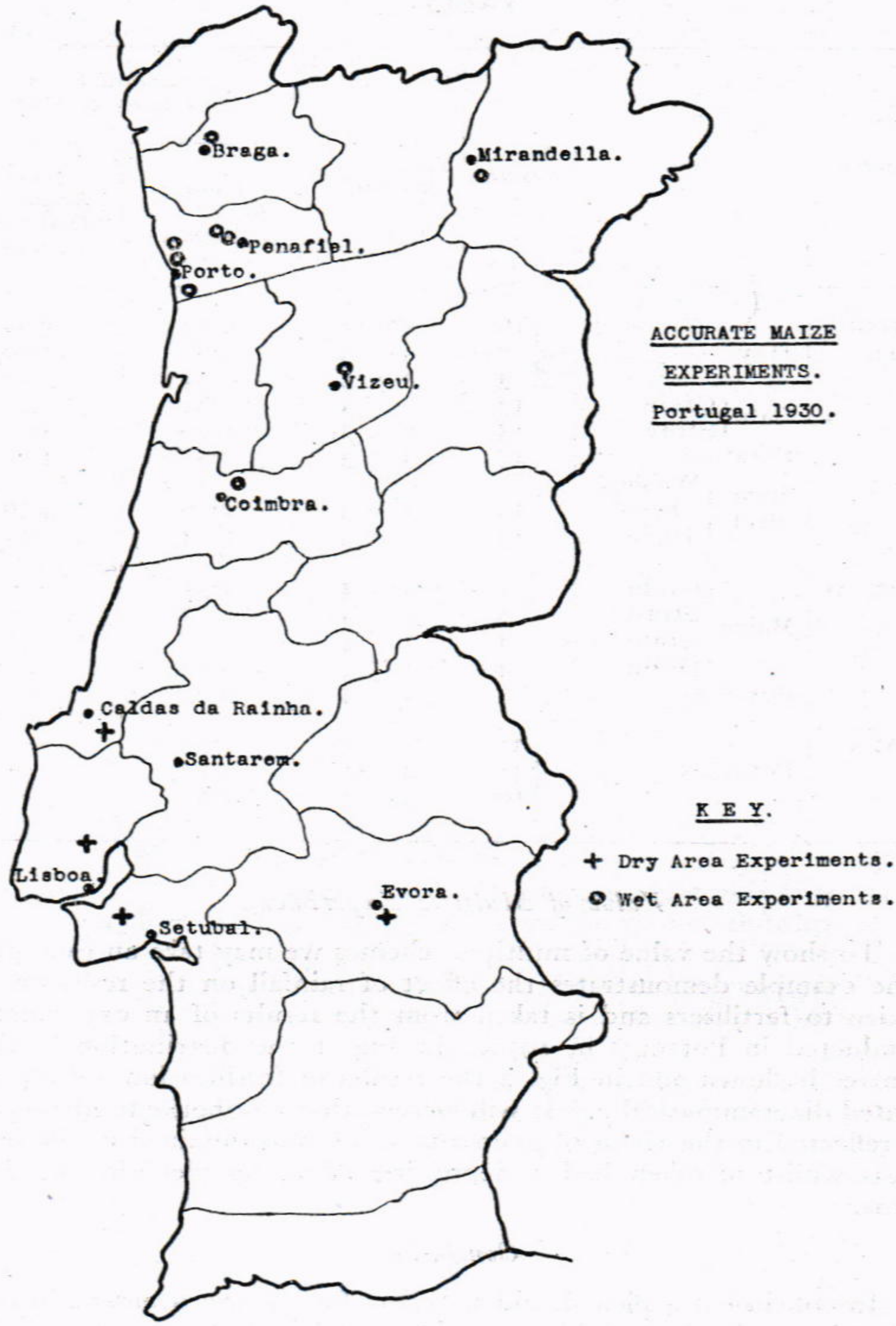
Braga.
Mirandella.
Penafiel.
Porto.
ACCURATE MAIZE
EXPERIMENTS.
Portugal 1930.
Vizeu.
Coimbra.
Caldas da Rainha.
Santarem.
KEY.
+ Dry Area Experiments.
Wet Area Experiments.
Lisboa.
Evora.
Setubal.

FIG. 1.

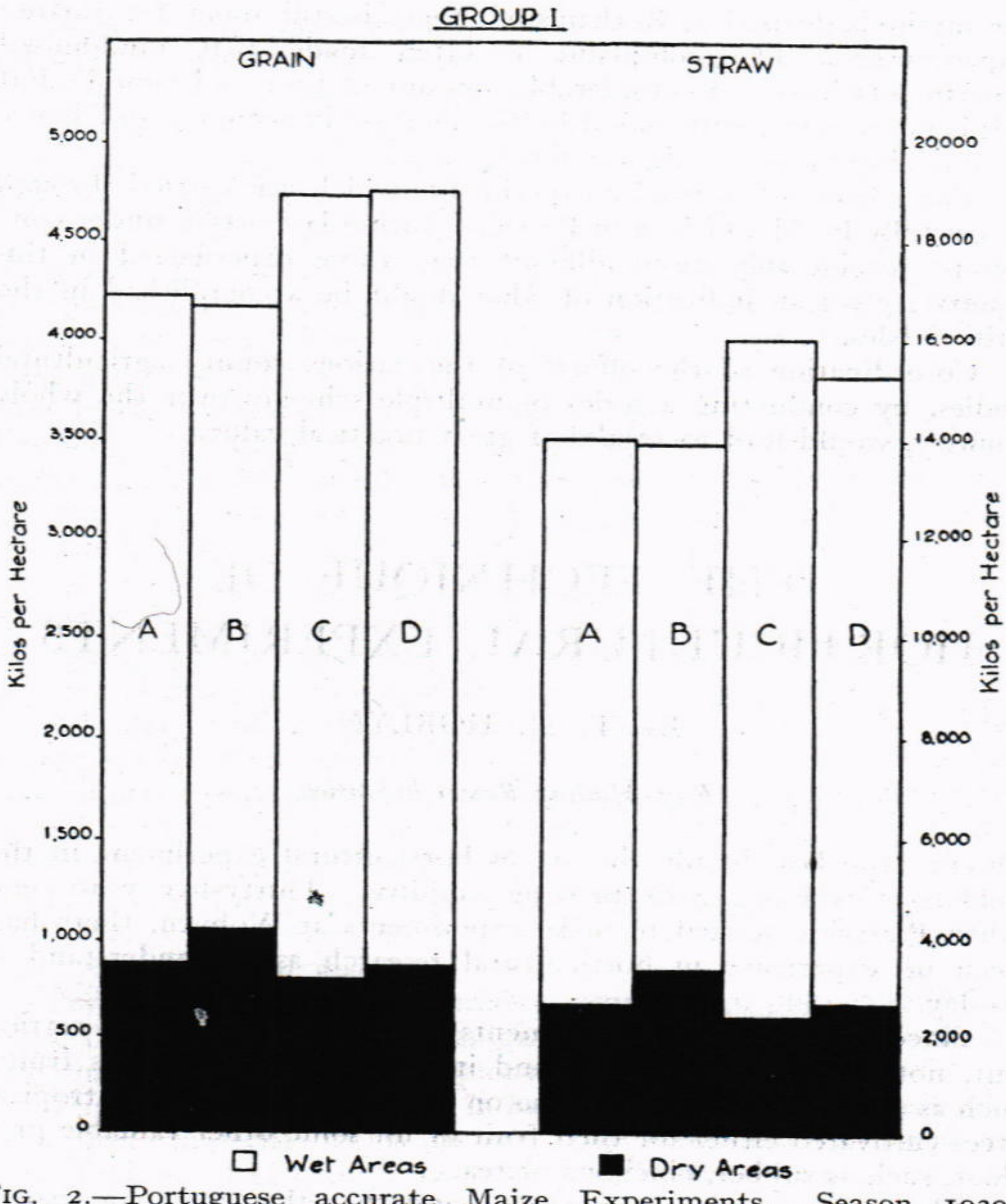

FIG. 2.—Portuguese accurate Maize Experiments. Season 1930. Graphs showing effect of Treatments on Yield in Wet and Dry Areas.

TREATMENTS

A	No Fertilisers			
B	700 kilos	12 per cent. Superphosphate		Per Hectare
	100 ,,	Sulphate of Potash		
C	200 ,,	Sulphate of Ammonia		
	100 ,,	Sulphate of Potash		
D	200 ,,	Sulphate of Ammonia		
	700 ,,	12 per cent. Superphosphate		
	100 ,,	Sulphate of Potash		

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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

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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.