SYMPOSIUM ON THE PRESENT STATUS OF AGRICULTURAL EXPERIMENTATION*

INITIATING the Symposium, Dr. G. R. Seth (Indian Council of Agricultural Research, New Delhi) said that in India the development and use of modern statistical techniques in agriculture began in the late twenties after the publication of the book on "Design of Experiments" by Fisher and the development in experimentation followed closely on the lines indicated by Fisher and his followers.

The history of this development was practically that of work done in the first instance at the Indian Statistical Institute and later in the Statistical Wing of the I.C.A.R. Statistical Research in experimentation in agricultural fields in India had at present reached a status comparable to that anywhere else in the world. The work on theoretical lines had outstripped its applications. While there have been satisfactory achievements in the field of agriculture, experimentation on sound statistical lines on the animal husbandry side was still lagging behind due to inherent limitations of the experimental material such as the cost of experimental material and long duration of experiments such as in cattle breeding. The need for proper animal experimentation on sound statistical lines is being increasingly felt. However, the ground has been sufficiently prepared for a systematic use of efficient designs in this part of the field as well.

While the statisticians are doing their best to produce workable designs in agriculture and animal husbandry fields, there is still lack of proper appreciation of their efforts on the part of agricultural scientists. Some of the premier research institutes in agriculture have not yet set up an adequate statistical unit to advise them in their research. The result is, as evidenced by so many reports on certain research schemes of the I.C.A.R., that certain schemes have not obtained the best results either due to faults in planning and in analysis of data and their interpretation. It is indeed gratifying that the Indian Council of Agricultural Research has realized this sad state of affairs and has made it a condition for all the research schemes financed by it that the layout plans of all the experiments should be approved by its Statistical Wing. The politicians have also realized the need of statistics in the

* The Symposium was held on 28th November 1954 during the 8th Annual Meeting of the Indian Society of Agricultural Statistics.

proper planning of experimental research programmes involving experiments or survey. The Estimates Committee of the Parliament has recommended that all the statistical work relating to agricultural research should be co-ordinated by the Statistical Wing of the Council.

With a view to finding out how effectively the developed statistical techniques were being utilized at the various experimental stations in India, the Indian Council of Agricultural Research carried out a survey of the agronomic research programmes in 1952–53. All the experimental stations in the country were sent a questionnaire to give the purpose of each experiment for which a harvest was recorded in 1952–53, details of treatments under study, the design adopted showing the number of replications, net plot size, etc. The data collected revealed very interesting results. Manurial treatments were under study in 80% of the experiments whereas only 10% of them included both cultural and manurial treatments. A very well designed experiment will give the maximum possible information on simple effects consistent with the number of treatments under study. The survey revealed that there was a considerable loss of information in this regard. 12% of experiments gave no information on simple effects while another 13% involved losses upto $\frac{1}{4}$. To mention a few of the other defects in designing noted, 34% of the experiments were such that the experimenter had failed to include additional factors even though there was scope for them or conducted small one-factor or two-factor experiments whereas a complete factorial experiment involving all the factors having a bearing on the problem would give relatively more information with the same number of plots. In 21% of the experiments there was more than the necessary amount of replication showing thereby that the available resources could be better utilized for conducting more research. In about 10% of the experiments either no randomization was done or the same randomization was repeated and 5% of the experiments were not properly replicated. In some experiments technical terms were not understood and thus not applied properly. Non-factorial designs were adopted in certain cases where factorial designs would have given the maximum information. This survey thus revealed that even though the country has made vast progress in the development of statistical techniques, yet their adoption at the experimental stations is not upto the mark. This Dr. Seth believed was mainly due to the fact that the experimental stations lack proper statistical help.

Dr. T. A. Bancroft, Director, Statistical Laboratory, Iowa State College, who presided over the Symposium said that to obtain informa-

tion on the status of experimentation, the Food and Agriculture Organization sent out a questionnaire to different countries requesting a report on the type of experiments being carried out in different fields of agriculture. Information was required on the aim of the experiment, description of treatments, type of design, number of replications, plot size, method of analysing the data, and coefficient of variation. Space was also provided for any remarks which the respondents might care to make. To shorten the report it was suggested that trials on varieties be omitted. It was hoped that an analysis of the data from the returned reports would indicate the status of experimentation in the different countries and hence allow an assessment of their individual needs.

The speaker later undertook an assignment in Egypt, Syria, Iraq and Iran to obtain additional information at first-hand. Approximately six weeks during September to November, 1954, were spent by him with the agricultural research personnel and at agricultural experiment stations in these four countries of the Middle East.

Based on the reports submitted to the Food and Agriculture Organization and personal observations of the Speaker in the four countries visited, the pattern of the state of experimentation could be summarised as follows:—

(1) The basic principles of statistical methods and experimental designs are fairly well understood. Paired comparisons, group comparisons, completely randomized experiments, randomized blocks, latin squares, split-plots, lattice and other incomplete block designs were the commonly used designs. The principles of replication and randomization were in the main being followed although in several instances a single randomization was used for several identical experiments being conducted at different locations. Also in one instance of a complicated factorial experiment the superintendent of the experiment station had assigned the treatments in a systematic fashion in order to simplify his supervision of the fieldwork. Despite the acquaintance with the basic principles of statistical methods and experimental designs considerable progress could be made in obtaining more information for the resources invested in agricultural research programmes.

(2) Efficiency could be gained by co-ordinating regional research programmes. Since many agricultural problems are common to the Middle East, and since research resources are limited, it seems highly desirable to co-ordinate research efforts. F.A.O. has alreday encouraged

such co-operation by establishing regional training centres and promoting the co-operative uniform wheat and barley yield trials in the Middle East and the co-operative uniform wheat and barley rust and bunt resistance investigations. Such co-operative and co-ordinated efforts should be extended to other areas. A regional centre for advanced training in statistics and research methods might be established at some centrally located University. Research publications in the form of reports, bulletins, and journals attacking general and regional problems should be made more readily available to encourage communication among scientists. Efficiency could often be gained in individual experiment by a more judicious choice of treatments or treatment combinations designed to provide information on the particular matter under investigation. Objectives should be clearly stated before treatments or treatment combinations are selected. The aim of the experiment may be unduly narrow, that is, it may have been possible to investigate more factors with little or no additional cost or labour. It may have been possible to include more levels of the same factor in order to more properly obtain an estimate of the response of the plant or animal to differing amounts of this factor.

(3) Efficiency could often be gained in individual experiments by making use of soils and topographical maps of the experimental fields and historical information on previous use. Information from these sources would be of use in locating and orienting the replicates or incomplete blocks so as to reduce the experimental error or avoid including in the experimental area old road beds or other unusable areas.

(4) Efficiency could often be gained in individual experiments by a more judicious choice of size and shape of plots. The experience of many research workers indicated that more information for the resources invested could be gained by a reduction in the size of the plots used in intensive work at agriculture experiment stations. In many cases this would have made possible needed increases in the number of replications. Information from previous uniformity trials on the same crop conducted by others or from previous experiments or new uniformity trials would have been helpful.

(5) Efficiency could often be gained in individual experiments by a more judicious choice of the design. Latin squares were often used where a randomized block would have been a more appropriate design. Several latin squares or randomized blocks experiments were used to accommodate the large number of varieties in plant breeding work where the use of some type of lattice design was clearly indicated. Again complete randomized blocks designs were used for treatment

combinations beyond 25 in factorial experiments instead of the more appropriate split-plot or incomplete blocks designs.

(6) In some of the group comparisons in animal experimentation it was not clear that environmental effects, if existing, had not been confounded with the treatment effects. There was no indication that in such experiments it may be necessary to consider a group as the experimental unit instead of the individual animal or to repeat the trial before drawing firm conclusions. Again in some group comparisons no attention had been given to the possibility of unequal within group variances in performing tests of significance.

In all four countries visited the animal experimentation programme was often handicapped by lack of sufficient number of animals for experimental purposes, limited housing facilities, mixed feeds or facilities for mixing feeds, and sufficient trained personnel to supervise and execute the experiments.

(7) Additional information could sometimes have been obtained by a more complete analysis. For example, in some factorial experiments laid down in complete randomized blocks no further analyses were made after testing the main effects and interaction even though the interaction might have shown significance.

(8) Efficiency could often be gained in individual experiments by the use of covariance analysis to neutralize the effect of an extraneous variable not subject to treatment effects.

(9) Efficiency could often be gained in the individual and overall research programme for a particular country by closer co-ordination of the work at the different experiment stations. While the four countries visited have centralized agricultural research programmes it is sometimes difficult to establish an easy flow of information from one section to another. Costs of reproducing reports and publishing research bulletins has been one deterrent. In service, training in research techniques for directors and staff of sub-experiment stations should prove helpful in increasing efficiency.

In some cases it was observed that coefficients of variation differed considerably and consistently for identical experiments at different sub-experiment stations. Use might be made of this knowledge in selecting designs and/or number of replicates at the different sub-experiment stations.

(10) In only one country visited was provision made for many experiments on cultivators' farms under actual farming conditions.

In this particular country the cultivators' farms used were not a representative sample of such farms but were some of the larger and more progressive farms.

Speaking on the status of experimentation as found by him during a recent visit to some of the countries in South-East Asia and Far East, Dr. V. G. Panse (I.C.A.R., New Delhi) observed that the basic principles of replication and randomization in field experiments are universally known and practised. The principle of local control however is not generally appreciated and plots with a square shape and elongated blocks even with as many as 80 plots in a row are frequently observed. Occasionally a case of spurious replication is met with, as when the effects of shade on tobacco was tried in a single large plot with another large plot in the open as control, but observations under each treatment were recorded plant by plant and these were treated as replicates in the subsequent analysis. What is lacking is the appreciation of the logic underlying the modern experimental design and the analysis of its results.

The experiments are small, usually with a single factor including 2 to 6 treatments and about 4 replications. Out of a list of 80 experiments currently carried out in one country only 16 had more than one factor including 9 to 48 treatments under study. Rest were all experiments with a single factor. The factorial experiments were in simple randomized blocks and occasionally with split-plots and strips, but without any confounding. The analysis was crude, the analysis of variance showing only three components: blocks, treatments and error, even where as many as 84 treatments were under study. This was followed by comparison of individual treatments in pairs on the basis of a significant difference.

In planning fertilizer trials the fundamental problem of plant nutrition is frequently lost sight of and experimental resources wasted in studying *ad hoc* treatments like fixed quantities of commercial fertilizer mixtures or fertilizer combinations which would cost a fixed amount of money. The main objective in such experiments should be to study the crop requirements of principal nutrient elements, such as, nitrogen, phosphate, etc., and their interaction.

Large experiments consisting of treatment combinations representing several factors are now being taken up slowly, but the factorial principle is not appreciated and arbitrary sets of treatments which take away much of the value of such experiments are tried. A typical example is provided by a layout in which a range of doses of differen

fertilizer elements is combined with a fixed dose of a given fertilizer. The analysis is correspondingly defective. The same point is illustrated in another case where an experiment involving age of seedlings and manuring of seed-bed of paddy was conducted separately for each of the three varieties side by side instead of combining them into a single experiment. Mistakes also occur in the analysis because of a lack of proper understanding of the structure of complex experiments.

In regard to experiments on cultivators' fields, the problem is attracting increasing attention, but experimenters are not yet aware of the special techniques that have to be employed by way of an extreme simplification of the design in order to work under prevailing limitations. Urgent attention is required in launching a large-scale programme of simple fertilizer trials in these countries as such a programme would help more than anything else to make the farmer fertilizer minded.

To improve the situation briefly summarized above, the first step is to arrange for the continued education and training of technicians, whether agronomists, breeders or others in the fundamentals of experimentation, its logic, methods, operation and arithmetic. From this point of view, training centres organized by the F.A.O. are of great value and this activity should be strengthened. Secondly, the countries should be helped to have professional agricultural statisticians trained at suitable universities and institutions and placed in positions from where they can help the agricultural experimenters in the adoption of modern statistical techniques. Here also, F.A.O. can render considerable help.

Dr. S. C. Pearce (East Malling Research Station, U.K.) speaking on the status of horticultural experimentation in Western Europe said that the first thing characteristic of Western European fruit research is the great attention that has been given to the standardization of plant material, both for commercial and experimental purposes. Although seedling material does still exist and indeed is still being planted, for apples and pears clonal material, *i.e.*, that raised vegetatively to eliminate genetical variation, is nearly universal for experimental work and is the general rule in commercial plantations. This elimination of the chief source of variation has been of immense benefit to the horticultural statisticians, for, as the major differences brought about by cultural operations have been elucidated, finer differences have been brought under investigation; this would not have been possible with the old, very variable material.

Nevertheless, plant-to-plant variation has not been eliminated. Its magnitude remains one of the chief difficulties in experimentation

with perennial plants and unfortunately no remedy appears to be at hand.

Another feature very noticeable in European horticultural research, though it is found elsewhere, is the care given to the control of pests and diseases, an emphasis that has many repercussions on experimental programmes.

One thing that workers in this field have learnt is the need to co-ordinate their field trials with fundamental investigations in the laboratory. Again this is not a characteristic found only in Europe, though one that is very marked there, and is not confined to investigations concerning control of pests and diseases.

The extent of statistical knowledge varies very much from one part of Western Europe to another. The region contains countries where there are respected leaders of research who are almost entirely unacquainted with statistical methods or their uses; it contains others, such as the United Kingdom, where the statistician has a valued place. The reason for this diversity is to be found in the location of the statisticians. Mostly where they exist at all—they are to be found at the research stations, where they can maintain close contacts with their colleagues, not in offices in the capital city scrutinizing research projects on behalf of those who have the responsibility for allocating funds. Consequently the influence of the statistician is determined by the confidence reposed in him by field workers, and much of the poor experimentation that exists, even where statisticians are available, results from their not being consulted or from their advice being regarded as impracticable. On the other hand, where the statistician has won his way, by acquainting himself with the species under study and the problems that arise from it, his influence can permeate every part of a research programme.

It cannot be too strongly emphasized that in trials with fruit trees the statistician must not be just an expert on Latin squares; he must take an interest in the source of the plant material, the manner of its being planted, the measurement of the trees, and the picking of the fruit. Also he must help to determine when the experiment should be brought to an end. These, his most useful contributions, become impossible unless he is on the spot.

In Western Europe in short-term trials, such as studies of spray substances complicated designs like partial balancing are to be found; but in a long-term trial the statistician's skill is better displayed in

achieving simplicity, at least initially, than in devising complexities, for that is often merely the easy way of reconciling conflicting requirements. The high standard of the best experimentation in this region has been obtained by a striving after initial simplicity together with the evolution of methods that will cope with the accidents that inevitably happen in the course of a long-term trial.

Finally, experiments in this area must impress visitors with their smallness. One-tree plots are common, and in any event it is usual to measure each tree and its crop individually. Such minuteness may seem surprising, but it is no bad thing that horticultural experimentation as opposed to agricultural should reflect the cultivation of a *hortus*, or garden, rather than that of an *ager*, or field.

Dr. P. V. Sukhatme (F.A.O.) said that the subject of the Symposium was of great importance to the F.A.O. and he had therefore listened to previous speakers with considerable interest. F.A.O. had recently conducted a review to assess the precise status of statistical techniques in experimentation in countries of the Near East and the Far East. Dr. Bancroft and Dr. Panse had referred to the findings of this review. These findings were that while the basic principles of experimental designs were widely followed there was considerable scope for improvement in the direction of more effective use of the resources available to the experimenter in planning the experimental programme at research stations and on cultivators' fields. The situation was in a large measure due to the lack of trained personnel in experimental designs and survey techniques of experimentation and also partly due to insufficient appreciation by administrators of the precise role of statistical techniques in experimental designs and in agricultural development programmes. The training centre which was being conducted at Delhi under the joint auspices of the F.A.O. and the Government of India was an effort to remedy in part this situation.

Dr. Sukhatme said that the questionnaire sent out by the F.A.O. was divided in five parts—one dealing with experiments on crops, second with experiments on animals, third with experiments on fodder crops and grasses, fourth with perennial plants and fifth with experiments in cultivators' fields. The information was sought for the most recent available year. The information was supplemented by personal visits wherever possible. When all the information became available it was proposed to publish it in a form which will readily show the weaknesses of experimental methods currently followed in the different countries and the improvements needed in order to put the experimental

programme on a sound basis. He thanked Dr. Bancroft and Dr. Panse for the help which they have given to the F.A.O. in preparing this review.

Dr. Sukhatme then read out a few examples from the replies received to the F.A.O.'s questionnaire and showed how these examples corroborated some of the points brought out earlier by Drs. Bancroft and Panse.

In conclusion he said that F.A.O. had an extensive programme for promoting the use of experimental designs and survey techniques of experimentation and expressed the hope that the countries represented at the meeting would give their whole-hearted co-operation to F.A.O. in this work.

Dr. K. R. Nair (Indian Forest Research Institute) described the developments in application of statistics to experimentation in forestry in India. He said that the publication of the *Silvicultural Research Manual for Use in India*, Vol. 1. *General* (*The Experimental Manual*) by H. G. Champion in 1931 marked the starting point in standardizing methods of experimental research in Indian Forestry. The importance of statistical analysis received recognition at the hands of the author by the inclusion of a chapter on "Statistical Methods" in this Manual.

Whereas most agricultural experiments gave results in the course of a single season, many silvicultural experiments took years and even decades to yield results of scientific value. It was difficult to incorporate the new principles of experimental design in investigations already started. Consequently the adoption of the new technique to experimentation in forestry was a slow process.

At the Sixth Silvicultural Conference held in 1945 it was decided to publish a separate *Statistical Manual* dealing with the statistical principles of design and analysis of forest experiments. This task was undertaken by A. L. Griffith and B. Sant Ram and the new Manual was published in 1947 as Vol. 2 of the revised *Silvicultural Research Code*.

Although this new Manual has been a definite step forward in inducing forest research workers to use statistical methods of experimental design and analysis, it was felt that these methods have been developing at such a rapid pace as to require the full-time service of a specialist at the Forest Research Institute. Accordingly, a new Statistical Branch was created in 1947 at the Institute.

The Silviculture Branch at the Forest Research Institute co-ordinates the research in forestry conducted in the various States throughout India. The Statistical Branch works in close liaison with the Silviculture Branch in the matter of advising the forest research workers of the States on statistical methods of experimental design and analysis of data. A joint silvicultural and statistical training course of six weeks duration is conducted every year at Dehra Dun for the benefit of these Research Workers.

Mr. Chebib (Syria), Mr. Aften Al Rawi (Iraq) and Mr. H. M. Sapra (Pakistan) also took part in the Symposium and described the conditions regarding agricultural experimentation in their countries.