SYMPOSIUM ON EXPERIMENTS IN CULTIVATORS' FIELDS*

DR. P. V. SUKHATME (F.A.O., Rome) opening the Symposium stressed the need for conducting experiments in cultivators' fields in order to verify the results obtained at research stations. The number of experimental stations in a country is usually small. Besides, fertility of the soil and the level of management at the experimental stations are superior to those in the surrounding cultivators' fields. Experimentation at research stations cannot, therefore, provide a reliable guide for generalising the results under actual farming conditions and it becomes important to determine the responses to different improvement measures under actual farming conditions by experimenting on a representative sample of cultivators' fields. Since the method combines the use of survey and experimental techniques, the method is known as the survey method of experimentation. Dr. Sukhatme then dealt with the various aspects of this type of experimentation.

PRACTICAL DIFFICULTIES

There are several practical difficulties in experimenting on cultivators' fields. The cost involved in organizing the experimental programme of this type is also large. The chief difficulty arises from the limited experimental facilities in the countryside, indifferent attitude towards experimentation on the part of the cultivator and relative inaccessibility of many of the fields selected for the experiments. The average cultivator is a poor man working on a small, usually unfenced land and is preoccupied with his daily routine. He cannot therefore be expected to divert his limited resources to experimental work which might disturb the operations on his field or in which there is a risk of incurring loss. The correct psychological approach to win his confidence is thus the first step in initiating a successful experimental programme of this type.

For this purpose it is necessary to ensure that (1) the design of experiment is simple enough to be conducted within the available resources on cultivators' field; (2) it can easily be fitted into the normal routine of his work; (3) the treatments for experimentation are so

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chosen that the cultivator may not incur loss through the granting of facilities for experimentation; and (4) the treatments are such that the experiment will have a demonstrative value to the cultivator.

Design of Experiment

The simplest of experimental design, *viz.*, the randomised block design involving replication with numerous small plots lying side by side cannot enable the cultivator to carry out his normal field operation undisturbed. The design which might appeal to the cultivator would be to divide his field into as many portions as there are treatments, apply the treatments over the whole of each of these portions and harvest plots of standard dimensions located in the portions in presence of the experimenter. Thus with an experiment having five treatments, the field would be divided into five equal portions. In one portion the crop would be grown according to the cultivators' normal practice and this would be the control treatment for the purpose of experiment. In the other portions of the field the experimental dressings would be superimposed on the cultivator's normal practice. In this way the cultivator would hardly feel that there is any experiment at all on his field. He can go about just as if he was cultivating his field the normal way, and yet at harvest time he would see for himself the relative value of the different treatments applied in his field.

An experimental design of this type has some obvious objections on statistical grounds. In the first place there is no replication within a field. This objection is however unreal since fields rather than compact blocks within the fields constitute the replication for the experiment. The second objection is that the procedure does not allow effective use being made of the principle of local control in eliminating fertility variation from treatment comparisons. This, however, is an unimportant factor in experimental programme intended to estimate the average response of the various treatments in a tract as a whole. Even so, the fact that the different treatments would be tried out in the same field provides some degree of local control. The third requirement of an experimental design is random allocation of treatments to the different portions. This can be easily ensured by the supervisor at the time of application of the treatments. Looked at from this angle it can be seen that the procedure of spreading out the experiment over several fields, dividing each into as many portions as there are treatments to be tried, allocating the treatments to these portions in random order and harvesting and weighing the produce from plots of the requisite dimensions in each portion at harvest time would enable the cultivator to proceed with his normal operations undisturbed and at the same time satisfy the basic principles of randomization, replication and local control of experimental design.

CHOICE OF TREATMENTS

The choice of treatments is governed by three considerations: (1) they should show promising results, (2) they should be small in number so as to avoid laying out more than four or five plots per field and (3) they should form a self-contained set in the sense that easily intelligible comparisons of practical value can be made from the set.

As an illustrative example Dr. Sukhatme referred to the experiments for determining the response curve to nitrogen and phosphate. The experiment clearly requires a minimum of three levels of nitrogen and three levels of phosphate, making altogether nine combinations. Nine plots is however a large number to be tried out on cultivators' fields. The treatments have therefore to be divided into sets, so that no set would contain more than four or five plots per field. A suitable design for the purpose had recently been recommended but he would leave it to later speakers to deal with.

Keeping down the number of treatments to be tried in an experiment to three or four is of particular importance when the fieldwork has to be managed by relatively unskilled staff and the co-operation of the cultivator has to be enlisted for the first time. When however trained and skilled staff is available and there is adequate supervision and the cultivator is appreciative of the value of such experiment more ambitious experimental programme can be undertaken. Even then it is desirable not to exceed five or six treatments per field.

NEED FOR USING THE PRINCIPLE OF RANDOM SAMPLING IN LOCATING SITES FOR EXPERIMENTS

It is necessary to use the principle of random sampling in locating fields for experiments in a programme of this type, since it is only from experiments on such fields that results of general applicability and of measurable precision can be derived. There is a temptation to use personal judgment in choosing sites. But as is well known non-random methods cannot be relied upon to give a sample representative of the population, and consequently estimates of response are liable to be seriously biased. It is of course true that such methods are convenient to use in practice and their cost is also low but they lack the means for judging the precision of the response obtained.

It is contended that selection of experimental fields should not be made from all the fields in the tract but from say a given soil type or an agriculturally homogeneous zone. If a sufficiently detailed soil map is available and if the experimental treatments warrant their trial only on a specified soil type, there is nothing to prevent the use of the method of random sampling in selecting fields out of a given soil type. Where however, such a soil map is not available it is convenient to select the sample from the totality of the fields and then classify the fields selected for experimentation by the desired types.

Another possible objection to the use of the method of random sampling is that a particular experiment may be located in a site where the manurial treatment may be ineffective because of the operation of some limiting factor. There is however nothing to prevent the experimenter from defining the population of fields in advance in a way considered most suitable for trying out given experimental treatments. Thus in experiments with manurial treatments one can confine the selection to fields receiving irrigation or again in experiments with a new promising variety one might well have to limit the experiments to those areas where the growing season is long if the variety to be tried is a late maturing one.

Another objection of any substance to the use of the method of random sampling arises from the limitations of communication. If the experiments have to possess demonstrative value, the experimenter would like experimental sites to be near the roads and not too far in the interior. If a good road map is available, using the stratified method of random sampling to ensure that a certain proportion of the experiments lie near the roadside can be considered.

Again fields may be inaccessible during rainy season making transport of manures, fertilizers, seed, etc., difficult. Deviations from the principle of random sampling may in such cases be inevitable. Even here the principle of random sampling can be approximated by subsampling randomly a small pre-determined number of fields out of the initially selected fields in the sample whose omission appears unavoidable and making a determined effort to experiment thereon.

The Number of Experimental Fields and Its Distribution Between and Within Villages

Fields for experiments would ordinarily be selected in two stages of sampling, places (usually villages) in the first stage and fields within the selected villages in the second stage. The cost of repeating an experiment in one more field in the same village will obviously be smaller than repeating it in a field in another randomly selected village. Likewise the variation of the treatment responses within the village will ordinarily be smaller than that between villages. The aim of the experimenter should be to so determine the number of experimental fields and its distribution between and within villages that the treatment response over the tract is estimated with the maximum precision for a given budget.

It is easy to see that the error variance per plot will consist of two parts: (1) the error variance per plot at a village σ_e^2 and (2) the variance due to interaction of response with villages σ_m^2. The variance of average treatment response estimated from nm experiments spread over n villages with m replications in each is given by

$$V = \frac{2}{n}\left(\sigma_m^2 + \frac{\sigma_e^2}{m}\right) \qquad (1)$$

This expression determines the relationship between the precision of the estimated response and the number of villages and replication per village. Likewise the total cost of experimentation can also be considered as made up of two components: (1) the cost of setting up an experimental centre and (2) the cost of operations in conducting the experiment. The former includes the cost of salary of the experimenter for the days of his visit to the village and the cost of his journey including transport of equipment. The total cost of experimentation can therefore be expressed as

$$C = c_1 n + c_2 nm \qquad (2)$$

The problem of determining the number of experimental centres and the number of replications per centre is thus the problem of minimising the total cost for a prescribed value of the variance V_0 with which the response to given treatments is sought to be estimated. It can be shown that these values are given by

$$\hat{m} = \sqrt{\frac{c_1}{c_2}} \cdot \frac{\sigma_e}{\sigma_m}; \quad \hat{n} = \frac{2\left(\sigma_m^2 + \frac{\sigma_e^2}{m}\right)}{V_0}. \qquad (3)$$

Experimental surveys on a pilot scale should provide the data to evaluate n and m. If the treatment effects vary considerably from village to village σ_e/σ_m would be less than 1. Formula (3) would therefore show that $\sqrt{c_1/c_2}$ must be as high as σ_m/σ_e to give $m = 1$. c_1 will of course be larger than c_2 but the exact value of the ratio would depend on the local conditions, the rate of pay, the cost of labour and the number of treatments.

It is desirable that the tract should first be divided into homogeneous agricultural zones. Even within the agricultural zones the experiments may have to be confined to given soil and climatic types so that the cropping system is more or less uniform over the zone. Again it is not sufficient to study the interaction of response with regions. It is equally important to study the interaction of response with seasons. This does not imply that the same fields and plots would continue to be experimented with year after year. On the contrary the fields for experiments should be chosen afresh each year. If it is desired to estimate the residual effect, this can be done by taking observations on a pre-selected fraction of the total number of fields of the previous year.

Analysis of Data

The analysis and interpretation of data from simple experiments is often intricate. However no new principles are involved. Dr. Sukhatme did not propose to deal with the topic which would be discussed by the subsequent speakers.

Dr. V. G. Panse (I.C.A.R., New Delhi) confined his remarks to the layout of experiments in cultivators' fields. In carrying out such experiments no elaborate layout with its numerous small plots and replications of treatments is possible. The layout should not contain more than three to six plots per field representing different treatments in a single replication. Alternatively the experiment may be regarded as spread out over the entire tract and fields rather than blocks in a field should serve as replications. In marking the plots the whole field or a suitable portion of it depending upon its size may be divided into the requisite number of equal portions; or a compact block of plots of standard size, say 1/10th of an acre, may be marked in the midst of the chosen field. The latter would be more economical in that the experiment would need less fertilizer, seed, etc., but might come more in the way of the cultivator doing his normal operations undisturbed. Where the whole field was divided into plots, a plot of a standard size would require to be randomly located within each, at the time of harvest. Where fields are small, as in the case of those growing paddy, the whole field may be taken as a plot, which would then save the necessity of putting up bunds between plots. It is desirable to randomise the treatments among the plots in order to avoid unforeseen biases. The treatments themselves should be promising, *i.e.*, not likely to result in a loss, and the whole set should form a self-contained demonstration and should therefore include the farmers' normal practice as a control. This may be illustrated by the trial of nitrogen and phosphate in a standard form at three levels each. There would be nine treatments and these could be broken up into the following groups to make it possible to compare them under the above conditions:—

Group I	Group II
$O, N_1, N_2.$	$O, P_1, P_2.$
$O, P_1, N_1P_1, N_2P_1.$	$O, N_1, P_1N_1, P_2N_1.$
$O, P_2, N_1P_2, N_2P_2.$	$O, N_2, P_1N_2, P_2N_2.$

In the first group the effect of P is confounded between sets and in the second group the effect of N is similarly confounded. Where the soil is not responsive to phosphate the first group may be tried, one-third of the experiments being devoted to each set. Where response to phosphate is expected, it would be advisable to try both groups. Another illustration could be given for comparing different quantities and forms of nitrogen. If nitrogen was to be tried at three levels (0, 1, 2) and three forms of nitrogen N, N' and N'' were to be tried the treatments could grouped into the following sets:—

$$O, N_1, N_2, N_1', N_2'$$
$$O, N_1, N_2, N_1'', N_2''$$
$$O, N_1', N_2', N_1'' N_2''.$$

If the responses were to be studied in conjunction with phosphate, an additional treatment P could be included in each set and the nitrogen treatments combined with P. For example the first set would then become

$$O, P, N_1P, N_2P, N_1'P, N_2'P.$$

The choice of most suitable sets of treatments among different possible alternatives is an interesting subject which needs much further attention from statisticians.

Dr. S. P. Raychaudhuri (I.A.R.I., New Delhi) said that one of the main objects of manurial experiments in cultivators' fields is to advise the farmers on the nature of plant nutrient deficiencies in soils and recommend suitable doses of manures for obtaining maximum yields of crops. Soil analysis in conjunction with experimentation on cultivators' fields will thus give indication of the correlation of the available nutrient deficiency of soil and yields of crops and thus enable the soil scientist and the agronomist to fix the limits of available nutrients as poor, medium, fair and high. Soil analysis in experimentation on cultivators' fields is also important for finding out whether certain manurial treatments which apparently give increased yields would continue to improve soil fertility in the long run or deplete it over a number of years.

In order that the results may be fruitfully used, the broad soil types of the experimental areas should be known. A beginning has been made in this direction under the T.C.M. project on the determination of soil fertility and fertilizer use and experiments on cultivators' fields have been in progress at 22 community project areas, selected on the basis of the soil types such as alluvial black, desert red and laterite, etc.

The number of experiments which may be carried out on cultivators' fields is rather limited and though the average results of the experiments done in a particular area give a fair idea of the manurial requirements of the area, yet this cannot possibly indicate the true manurial requirements of the individual cultivators' plots. For example, if the average recommendation for an area is 40 lb. N and 40 lb. P_2O_5 per acre it may well be found out by rapid chemical tests of an individual plot that it contains a large amount of phosphorus and the use of any phosphatic fertilizers in such cases would be a wastage. Some work in this direction has been made in India but not on a systematic scale for which a beginning has been made under the T.C.M. project.

The proper organisation for conducting these experiments is an important aspect which requires serious consideration in order to obtain dependable results commensurate with the cost. To ensure that absolutely reliable results are obtained, not more than 30 experiments should allotted to each person so that all the experiments can receive his ersonal attention. Further, the randomisation of plots should be so arranged that at least 50% of the experiments lie on the roadside for effective supervision.

Dr. P. C. Raheja (I.A.R.I., New Delhi) expressed the view that demonstration of improved agricultural practices is one of the functions of all departments of agriculture. In doing so, progressive cultivators are usually selected and approachable villages are made centres of demonstration which do not provide a true sample of cultivators. The principles of randomisation, replication and a standard basis for comparison, *i.e.*, use of a control are not followed. To follow these principles the experiments have to cover all villages in a block irrespective of the nature of field, standard of cultivation and type of cultivator.

One of the working difficulties is that facilities of transport are lacking to approach inaccessible villages particularly in the rainy season. The programme of work is sometimes not acceptable to the cultivator. The plans of experiments are sent out very late and the agronomical assistant is left with no choice but to lay down experiments in specially selected fields. Quite often the co-operation of village level workers is not available as they can hardly spare time for this work. Sometimes the headquarters of the staff are located far away from the centre of work. Occasionally there are budgetary difficulties. Dr. Raheja then offered some suggestions for a more efficient organisation of the work by overcoming these difficulties.

Dr. James M. Blume (T.C.M., New Delhi) said that experimentation on cultivators' fields plays an essential part in the development and spread of improved farming practices. The older agricultural programmes generally operated through two well recognised organisations: experiment stations to develop new practices and an extension service to carry these improved practices to the cultivators. This type of organisation leaves a serious gap, since before new practices developed at experiment stations are ready for recommendation to farmers, extensive testing under more representative conditions is needed.

Intensive research at experiment stations and extensive testing on cultivators' fields serve distinctly separate purposes. At the risk of over-simplification, we may say that the experiment station research *discovers good practices* and the extensive research determines their *applicability to local conditions.* Intensive research may give the first clues to what is a better practice but usually it alone does not furnish a sound basis for recommendations to cultivators.

There is no substitute for the extensive testing of an agricult practice within the region concerned. However, there is no reas why intensive research should be repeated in each state or even in eac country. Often the data from experiment stations of one state or country may be utilized as the basis of an extensive testing programme in a second state or country.

To make clear the distinction between questions best answered by experiment station research (intensive) and questions best answered by cultivator field trials (extensive) we might point out broad problems that typically involve applicability and therefore are best solved by extensive testing on farms.

(1) *To determine condition in an area.*—Some tests are undertaken to determine the existing conditions within an area. An example is a test to determine the average response to a particular fertilizer, say superphosphate. Problems of this kind might be looked upon as a survey conducted by means of tests. The answer cannot be obtained through research at one or two experiment stations. The validity of the answer depends on getting results from an adequate number of tests spread over the area.

(2) *To find responses for different regions.*—Another group of problems concerns different responses to a practice in the different regions of the state or country. A region may be a soil series, a geographical complex, or even a particular class of farmers. You may have a lead on a practice from an experimental station but you may still need to delineate the regions where the practice applies or where variations must be made in the practice. Such a problem cannot be solved at one location; the tests will have to be made at many.

(3) *To assess a practice when there is no single check.*—The present practices of farmers, even within small geographical areas, may vary widely. Intensive research at experiment stations would ordinarily involve only one of these practices as a check. Extensive research over a large number of farms may well use the farmers' method as a check and thus incorporate measurements of the improved practice against a variety of present practices.

The foregoing has dwelt with the benefits to be derived from testing on cultivators' fields in so far as the individual cultivators are concerned. It should be pointed out that many of the questions best answered by this type of testing are also of intense interest to governmental agencies. The results from extensive field trials, when properly compiled and interpreted, furnish data essential to the intelligent formulation of Government policy on agricultural problems.

A series of extensive experiments often offers the opportunity to gain much additional information through a small amount of extra work. The fertilizer field trials on cultivators' fields now being carried on under the TCM scheme was a case in point. Soil samples properly taken from each of these hundreds of trials furnish invaluable raw material for the soil testing service now under development. These samples are useful to determine which laboratory methods are best adapted to Indian soils, how consistently each of the methods reflect the yield responses found in the field, and whether different areas of India will require different methods or whether a common method can satisfactorily be used over the entire country. They also provide the basis for one kind of fertility survey.

Dr. Uttam Chand (I.C.A.R., New Delhi) pointed out that the scope of experiments on cultivators' fields has recently assumed a great national importance for several reasons. Since not much is known about fertilizer responses under conditions of cultivators' fields, a wide range of experiments is needed to give information on optimal dressings [illegible]different soil types for making recommendations to the cultivators.

Such type of experimental investigations is also expected to play a very important role in aiding the Government in evolving a suitable fertilizer policy with regard to manufacture, prices and import. He went on to emphasise that the choice of treatments and their levels in any given scheme of experiments should be based upon knowledge of soil types and on the results of past local experience. He gave some illustrative examples of five and six plot arrangements. He further pointed out that in the study of results of fertilizer experiments investigating different levels of applications, standard response curves should be used to estimate the response to a standard dressing for purposes of comparison and to find out economic optimal dressings for different nutrient-produce price ratios. Regarding the problem of prediction of fertilizer responses through soil characters he pointed out that it may not be necessary to carry out soil analysis for all the experimental sites and that it could be restricted to a selected fraction of experiments.

Shri T. P. Abraham (I.C.A.R., New Delhi) explained the procedure of statistical analysis and summarisation of data relating to simple fertilizer trials on cultivators' fields with special reference to the All-India simple manurial trials scheme currently being carried out with the assistance of the American Technical Co-operation Mission. Under this scheme simple five or six plot trials were conducted in selected community project centres distributed over the major soil climatic regions in the country. The selection of experimental sites was done by adopting a two stage random sampling procedure. The required number of villages were first selected at random and subsequently two fields growing the crop were selected at random from each of the selected villages. An unreplicated trial was carried out on each such field. The statistical analysis of the data was carried out based on the following model. If y_{ijk} denote the yield of the kth treatment in the jth field of the ith village

$$y_{ijk} = m + v_i + f_{ij} + t_k + c_{ik} + d_{ijk},$$

where m denotes the general mean, v_i the effect of the ith village, f_{ij} the effect of the jth field in the ith village, t_k the average effect of the kth treatment, c_{ik} the interaction of the kth treatment effect with the ith village and d_{ijk} the interaction of the kth treatment effect with the jth field of the ith village. This last term also includes experimental errors at a given site. The variation associated with the estimated responses are contributed by the components c's and d's. If V_c and V_d are the variances of these components, then the variance of the estimated response R, based on m villages and n_i experiments in the ith village, is given by

$$V(R) = 2\left[\frac{\sum_{i=1}^{m} n_i^2}{\left(\sum_{i=1}^{m} n_i\right)^2} \cdot V_c + \frac{V_d}{\left(\sum_{i=1}^{m} n_i\right)}\right]$$

Estimates of the components of variance V_c and V_d are easily obtained from the analysis of variance table.

Estimates of responses and their standard errors were obtained in this manner for each centre.

Subsequently these estimates were averaged by weighting them inversely to the variance for all the centres having a given soil type and finally the simple mean of these soil type averages was taken to obtain the All-India average. Based on the estimated average responses to two or more non-zero levels of fertilizer, estimates of the responses to other intermediary levels can be obtained by fitting a suitable response curve such as the well-known Mitserlich or the quadratic curves and optimum levels of fertilizer for given cost-price ratios can be worked out to draw up manurial schedules for different crops and regions.

The question of correlating crop responses with the soil nutrient status was also considered. The simplest approach will be to work out multiple regression equations of crop responses on soil nutrients such as *N*, *P*, *K*, *Ca*, etc., present in the soil, for each major soil type, so that it might be possible to predict with reasonable accuracy the expected crop responses to a given fertilizer dose from the results of quick soil tests. It is quite possible that no simple linear relationship will be adequate and the question of suitable transformation of variables for rectifying the regression function would need careful investigation.

Dr. H. N. Mukerjee (Agricultural Chemist, Bihar) said that as an Agricultural Chemist, he was called upon by the cultivators of Bihar to advise them, as to the manures and fertilizers that they should use for profitably increasing their crop yields. Following old practice, he started giving advice on the basis of manurial experiments done at the nearest Government farm, combined with a chemical analysis of the cultivators' soil. After an extensive analysis of soils, he realised that the soils of Bihar were too heterogeneous to be correctly represented by the few Government Farms and usually the results obtained in these farms, did not apply to the cultivators' fields, even across the fence. Secondly, the methods of chemical analysis in their very nature, were only indicative and useless for economic manurial recommendations, unless backed by crop response data on similar soils. He therefore felt that it was absolutely unsound to advise cultivators on the basis of existing farm data and chemical analysis.

A more reliable method for advisory work was therefore called for, and it was proposed that simple manurial experiments should be done on cultivators' fields on an extensive scale, and the soil type and its chemical analysis would be recorded for each experiment. This would give a sound basis, on the strength of which correct advice could be given to the cultivators in different parts of Bihar for the profitable manuring of different crops. The proposals drawn up by Dr. Mukherjee in 1943, could only be tested in actual practice from April 1948, due to financial considerations. The speaker then gave a summary of the highlights of the work carried out so far.

From 1948 about 4,000 experiments are being carried out every year on important crops like paddy, maize, wheat, gram, barley, etc. The manurial treatments in these experiments are being modified as experience is gained year by year. Different treatments like compost, oilcake, bonemeal, lime, ammonium sulphate, superphosphate and muriate of potash have all been tried singly and in combinations and in different doses during different years. Experiments with six or seven plots in balanced designs are being conducted, the plot size varying from 1/10th acre to 1/20th acre in hilly regions. Each field assistant carries out about 80 experiments per year. Soil profiles from experimental plots are examined and chemical analysis of surface soil carried out for correlating with the yields. Results of these experiments have shown that the responses to fertilizers on cultivators' fields are different from those on Government farms. The doses which are adequate on farm soils are generally too high on cultivators' fields. Areas which showed no response to phosphates or potash in farm experiments freely show response in the cultivators' plots. As a result of the work done, the project with a staff of about 180 field assistants has been placed on a permanent footing in Bihar State.