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OBSERVATIONS ON THE MAJOR CLASSIFICATIONS OF FIELD TRIALS USED IN FARMING SYSTEMS RESEARCH

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1. Introduction

No single set of guidelines can apply to all trials used in farming systems research, for the simple reason that within farming systems research the use of field trials may have many different kinds of objectives.

One distinction that should be clear in the researchers' mind is that that the objective of a trial can be to quantify an input or output or that the objective of the trial can be to observe the variation in an input or output and identify its source. Designed or structured trials exists principally to do the quantifying inputs and outputs, but in farming systems research, the study of uncontrolled variation may be exceedingly important.

The farming systems researcher should be careful to detect conflict between the goal of quantification of responses of treatments within the experiment, and the goal of observation of variation resulting from factors which are not included as treatments. The designs which are suitable for one objective are not always suitable for the other. For the goal of quantification, the standard rules of experimental design apply. Designing experiments in order to clearify sources of variation is more an art than a science. Though there are formal tools for this job, such as regression analysis and analysis of covariance, the evidence provided by these tools always lacks the power of proof of the results of a designed trial where the factor in question is been deliberately controlled.

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program (Perrin. et al., 1976) for the basic division of field trials into 3 classes, and for pointing out the correspondence between these classes of trials and the economic methodologies used to evaluate them.

The objectives of this report are limited to the presentation of observations about trials in farming systems research. No attempts will be made to synthesis the principles of experimental design.

2. Trials Used to Choose Among Production Techniques

2.1 - The Objectives of Trials for Technique Choice

When one describes the physical world, one tends to use two different modes of description. The two modes are classification and quantification. Classification is associated with qualitative differences among the objects or operations being described, while quantification is associated with differences which can be expressed on a scale.

The nature of some factors of production are such that they cannot be easily divided. On such example is the choice of the crop. One species is qualitatively different from another species. There is no gradual transition from one crop species to another in most cases. Such qualitative choices must be analysed using factor choice trials. Choice of chemicals, varieties, etc. are commonly of this nature.

Many production choices concern quantiable decisions : how much fertilizer, how much seed, how much insecticide, etc. These decisions can be made using application rate experiments. Cases exist where the distinction between the two kinds of variable become unclear. Most such cases concern variable inputs or outputs which come in indivisible units. Take the number of weedings a crop receives. As a rule one says that a crop can be weeded once, twice, etc. but that it can not be weeded 1.763 times. Fractions are not permited. If the size of units is small compared to the total range of variation one would probably treat the variable as a quantitative variable. If the units are large compared to the range, one would treat the variable as a qualitative variable and make the decision on the basis of the results of a factor choice experiment.

Trials used to choose amoung Techniques or Factors of production are "generally factorial designs intended to assess major effects and interactions of critical limiting factors. Two levels of inputs are generally used : the current farmer-practice level and a significantly higher level" (CIMMYT, 1979). This assumes that the factor is quantifiable. If the factor is not quantifiable it is by definition either present or absent. In this case, the factor choice trial is not a preparatory step for designing a factor level trial. It is the only type of researcher managed trial possible. Cases where inputs are not quantifiable are either less importan or more infrequent than cases of quantifiable inputs.

2.2 Design of Trials for Factor Choice

There are three aspects of trials design. One concerns the placement of the replicates, that is site selection ; the second concerns the choice of the treatments to be included in each replicate, and the third concerns the plot sizes, number of replicates, etc.

2.2.1 - Site Selection for Factor Choice Trials - Inference Space

The physical problem of site selection is much the same for all three kinds of on farmer's field trials. For all three kinds of trials one must be conscious of the environmental specificity of the treatments to be included when making decisions on the distribution of replications in space.

The division of a geographic area into zones for grouping field trials can be carried out in similar to the division of a geographic area for reconnaissance of extensive surveys, but with more importance placed on physical and soil characteristics. Stratification within the zone is done on the basis of soil characteristics.

The criteria for choice of the farmers with which to place trials designed for the choice of techniques does differ somewhat from the criteria for choice of farmers for verification trials.

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Site selection and site grouping is more important for technique or factor choice trials and factor level trials, because one wishes to be able to identify clearly the inference space to which the quantitative results apply. For verification trials in the case where the objective is to identify sources of variation, site selection and site grouping may be less important. In this case, the grouping of sites comes as an output of the analysis rather than an assumption on inference at the time the experiment is installed.

Technique or Factor choice trials frequently have several treatments, and therefore, they must be managed by the researcher. Thus a succesful trial requires a farmer with whom the researcher can cooperate. This may mean that the sociological or economic characteristics of these farmers would not be representative, but this is not a great obstacle because the factor choice trial is oriented more toward accurately representing the physical environment than toward representing the sociological environment within which the technique must preform.

2.2.2 - Choice of Factors to be Included in ON-Farm Factor Choice Trials

The choice of technique is made through a synthesis of knowledge about the practical problems of production, with knowledge about the potential techniques for solving those problems. Particular attention must be paid to Factors or Techniques which can be expected to have major interactions with each other. It is the desire to detect and measure factor interactions and the limitation on the number of treatments which one can put in a field, which frequently lead to the use of two-level factorial designs for these experiments. The low level corresponds to the farmers' practice and the high level corresponds to something considerably better.

2.2.3 - The Structure of the Factor Selection Trial

As a rule, the most valuable replication is over different fields, different years, and different locations. Replication within a field usually does not represent a good allocation of resources for farming systems field trials.

Even with researcher management there is a limit to the number of different treatments which can be handled in a farmers field. For variety trials the number of possible treatments is greater because the cultural management of the trial is uniform. The experience of the FSU indicates that 12 agronomic techniques or 20 varieties per trial are the maximum practical limits and that less than 64 agronomic techniques or less than 6 varieties per trial are much to prefered.

Without knowing the nature of the data to be collected, there is nothing general that one can say about plot size. Measurement of labor requirements for different operations generally requires larger plots, but the optimum size depends on the operation. For light tasks such fertilizer application or spraying, the right plot size may be 2000 square meters. For heavy work the FSU has found that 300-500 square meters plots work well. The researcher should be aware that the optimum plot size for different kinds of data will not be the same, and thus, he may be well advised to use different designs for different measurements. As an example, if one were trying to estimate the return to an additional weeding it might be desirable to measure the labor input in a trial with large plots but measure the yield increment in a different trial with small plots so as to make the yield comparisons more precise.

2.2 - Evaluation and Recommendations

Partial budget analysis is the methode economic analysis normally associated with two-level factorials and with factor choice trials. The most likely difficulties with this analysis are first, the likelyhood that the factor is not being applied at the optimum economic level, and second, that the trial may not have been replicated enough to be truely representative. In addition, because there may be several factors, one may have to be satisfied with secondary information and rough estimates of the costs of the factors. With many factors the amount of time available to the researcher for acquisition of information on costs decreases. In this case the researcher may have to be satisfied with rough cost/benefit ratios as criteria for comparisons of the techniques rather than partial budget analysis.

At this stage subjective evaluation of factors and techniques by the farmers is often a great help. Having seen and participated in the experiments, farmers will have opinions. Some of their impressions may be irrelevant by-products of plot sizes and designs which seem odd to the farmer, but some of their observations will help to point out the practical problems of integrating the new technology into the previous system, and help to point out conceptual problems that the farmers may have in understanding why a technique works. It is at this stage, that the extension person should start thinking about the terms he will use to describe to farmers how a new technique works.

3. Trials to Determine Optimum Factor Application Rates

3.1 The Objectives of Application Rate Experiments

Experiments designed to determine application rates or levels of input usage, only determine the physical yield responses to application of inputs. To determine rates for recommendation one needs rather precise information about the cost of the inputs and the value of crop. For this reason rate experiments are valuable, not only for new products, but for old ones as well. Man's production environment is always changing. Important changes occure when farmers who produced principally for their own subsistance in past, begin to become part of a modern commercial economy. The quantities of traditional resources which these farmers have may not change substantially, but their relative value in production may change rapidly when the farmer gets access to new inputs and new product markets. The value of rate experiments for recommendations on the reallocation of old resources should be appreciated.

The objective of application rate experiment is to determine optimum levels, but this is very much a function of both the farmers economic environment and his own resources. The design of rate experiments must take particular care in specifying the inference space for the recommendations and the underlying assumptions of the evaluation.

3.2 The Design of Trials to Determine Optimum Application Rates

3.2.1 The Problem of Interactions and Deciding whether or not to Include Multiple Factors

Interactions the yield responses to factors of production with the yield responses of other variables, both controllable factors and variables that arise from the external

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environment, frequently reduce the utility of rate experiment data. Including extra factors makes the experiments unmanageable in the field, particularly in the farmer's field, while failure to include them makes the results very environmentally specific.

The design of multifactor rate experiments goes beyond the scope of this paper. The comparative advantages of the different possible layouts : split plots, etc. are best discussed for concret cases. One does well to consult a statistician before planning such experiments, but one should not encourage him to expend the list of factors. Restricting the inference space by specifying the level of external factors for which the results are valid is usually the best alternative, particularly when the trials are to be carried out on farmers' fields.

3.2.2 Site Selection

As one is concerned with the quantification of yield responses and possibly, with the quantification of labor or time inputs, it is particularly important that these experiments be well dispersed over their inference space. Descriptionsof the individual sites are particularly important. One may wish to group the trial data by different kinds of sites or environments. The criteria for site selection for complex rate experiments, is much the same as for the experiments aimed at identification of promising technologies.

The criteria for site selection of simple farmer-managed rate experiments may be much different. Here, one usually has to pay close attention to the characteristics of the farmer. The need for precision is frequently in conflict with the need for representativeness. Richer and more educated farmers may be able to follow instructions more precisely because of the additional resources which they command. Frequently, they take the investigation more seriously because they have the means to act if the technique appears profitable. Their work habits and even their soils, however, may not be at all representative. Such biases should be recorded even though the researcher may not be able to avoid them.

Farmer-managed rate experiments can be handled in a manner similar to verification trials. The researcher may not be able to tell the farmer what rate should be best at this stage, as he should be able to do with a true verification trial. Since the researcher would usually be supplying the input, this uncertainly shouldn't annoy the farmer. Trials involving different rates of labor input, ie. frequent weedings, may meet with real resistance if the levels are high enough or low enough to seem absurd to the farmer.

Trials in which timing is critical may be difficult or impossible to carry out under farmer control. In a village, they may even be difficult to carry out in researcher managed trials because of the problems of getting from one field to another of getting information about the state of the fields and need for various operations. Trials where timing is critical should be situated at a central location even at the risk of being somewhat unrepresentative.

3.2.3 Choice of Factor Levels and Specifying the Model for Analysis

If one can justify the use of specific models for quantification of yield responses, it may be possible to greatly simplify rate experiments. For instance, one may be able to assume a linear response and plateau. If yield response to a particular plant nutrient can be assumed to

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rise in a linear fashion until it reaches a maximum, then one only would need only three treatments to specify the curve. One would need a check and a low treatment, under the maximum, to establish the linear portion of the curve, and one would need a high treatment well above the maximum to establish the level of the yield plateau. All points on the linear sloping portion of the graph would have the same per unit return for the input applied. Assuming that the optimum application rate is not zero, a farmer would probably choose to operate at the point where the two lines cross unless some external factor restricted his access to the variable input.

Linearity is frequently a helpful assumption, particularly where the range of choice for a factor is limited, but this assumption leads abandonning the rate experiment. In the inland sahelian countries for instance, fertilizer supply is often limited by external factors which preclude farmers from getting more than a few kilograms of fertilizer for each hectare of crop land. In this case, a rate experiment is not appropriate. The farmer is choosing between not applying fertilizer and applying all that he can get. Thus, when one assumes linearily the experiment becomes a factor choice experiment rather than a rate experiment.

The most meaningful simplification of rate experiments occures when one knows from previous work that a known curved function of one or two prameters will describe the response. In this case, one needs only the check and one or two points to define the parameters. Knowledge of the shape of the curve allows one to maximize returns to the input in a more meaningful fashion than for the case of the linear increase and plateau model.

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3.2.4 Layout of Rate Trials

It has already been asserted that the design of rate experiments can be difficult. In reality, the processes of choosing the factors to included in the experiment, choosing the sites for the experiment, and choosing the internal structure of the trial cannot be separated. If one excludes factors from the list of treatments, the real inference space may be reduced at the same time that one reduces the complexity of the trial layout. One should always take a close look to make sure that first, the trial tests what one wishes to test, and second that the inference is large enough to make the trial worth the expenses incurred in doing it.

One is always tempted to use non-random plot orders in rate experiments. It is always pleasing to the human sense of symmetry to see yields gradually and uniformly increasing from plot to plot, right to left, etc. The temptation should be resisted. Rate trials are particularly sensitive to boarder effects, and only good randomization can keep the rate and boarder effects from being mixed. It is impossible to separate out boarder effects from non-random layouts.

Rate experiments offer the greatest opportunity for specific farmer recommendations, but are difficult to design, execute, and analyse in such a fashion that the recommendations have a broad applicability.

4. Verification Trials

Verification trials are widely replicated trials of well tested techniques or packages of techniques, carried out with the purpose of, not only measuring input and output

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parameters, but also with the purpose of observing how the farmers other activities interact or complete with the technique or packages. They are farmer controlled. The plots or fields must be large enough so that the farmer can appreciate the difficulty or ease of operations and the relative expense of inputs, in comparison to his previous methods.

Verification trials do not differ significantly from demonstration plots in their design or execution. Calling them verification trials merely emphasizes that there are still some doubts as to how the techniques will fit into the farmers's systems. At this stage, the farming systems researcher should be reasonably sure that his technique will be successful, but he may not know all the criteria which will determine the degree of success, and he may not know the factors which describe the environment within which success will ocure.

By using large numbers of observations, the researcher will be able to classify the responses and profits in terms of the physical characteristics of the fields, management factors exterior to the treatments, and past history of the fields. He will be able to do this in a much more comprehensive fashion than he would be able to do in trials to choose factors or in trials to determine optimum factor level.

The first goal of a verification trial is to describe the nature of variation in net benefits from the use of a particular technique. This is the most precise means of determining both the average net benefit and the distribution of the magnitudes of those benefits about the mean. One can collect data on net benefits from surveys about farmers practices. Survey data on net benefits are always biased by the farmers choice of the fields to which he applies

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a particular technique. Farmers will apply the techniques to fields where they will have the highest returns. Baseline yields on these fields may be higher or lower than those of the rest of the fields and will not usually be equal. Paired or grouped observations of techniques placed at random eliminates this bias, and provides one of the most important reasons for doing verification trials.

By virtue of the large plot size used in verification trials, the plot to plot variation represents field to field variation. The variation in the net benefits from these plots therefore comes much closer to the variation the farmers would observe on their fields. Calculations of the variations in net benefits from the results of small-plot trials will usually overestimate the variation of net benefits.

4.1 Objectives of Verification Trials

Field to field variation in verification trials plays a much different role than it does in the two other kinds of trials. In the factor choice and factor level trials, every effort is made to limit variation ; by stratifying environments, by using researcher management, and by blocking of treatments. In the verification trial the main goal is to explain variation. In the former trials, the goal is to be able to compare differences between treatments. In the latter there is an effort to explain interaction of treatments with environmental and/or management factors which have not been controlled in the experiment, and to quantify variation in yields and benefits.

4.2 Design of Verification Trials

The internal design of the verification trial which one is to place in a particular farmer's field, is of less importance than the internal design of factor choice and factor level trials, because the emphasis in the verification trial is on uncontrolled external factors.

4.2.1 Site Selection for Verification Trials

Site and farmer selection should be based primarily on representativeness within the confines of the ecological or economic nitch for which the one believes the technology to be adapted. However, the bounderies of these nitches, be they physical or economic, are unclear by definition, since one of the goals of the verification trials is to show where the technique is adapted. Logically then, it is impossible to define the inference space and therefore impossible to draw a random sample from it. The farming systems researcher should not be over concerned about this dilemma. Establishing where and when technology is profitable is an iterative process. The results of the analysis of or verification trial can be fed back into the process of site selection, grouping, and the internal design of other verification trials. On the farmers side, his observations about the trial on his field will start his own iterative process of learning how the technique fits into his production system, as that system changes. One hopes that either the researchers' learning curve will be faster, or that he will be able to learn from the farmer or group of farmers and pass the information on to others.

4.2.2 The Choice of Techniques for Verification Trials

It has been suggested that the factor choice and factor level trials are preparatory steps for verification trials. The researcher should not get the impression that the process of selecting treatments for verification trials should be rigid and formal. The world abounds with ideas, and the processes by which one can go about choosing the

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good ones from the bad, are many and varied. The ability to make good choices separates good farmers from bad ones, and separates good applied researchers from bad ones as well. The formal step-by-step process starting from factor choice trials and going through factor level trials probably should only be a last resort in a case of a radically new technique. In the case of a technique in which one can have resonably confidence without the other trials by all means go ahead with verification trials, but be aware that irregularities, in the form of unforseen interactions, may arise, and that these irregularities may send one back to researcher-managed trials.

4.2.3 The Internal Structure of Verification Trials

Even for verification trials treatments should always be blocked together to avoid heterogenious soil conditions. If the technique involves changes in labor use patterns for cereal production, plots of over 1 000 m^2 are necessary. If an operation on a plot does not constitute a major portion of a work day then one may miss conflicts with other farm operations.

The need for large plots makes blocking and placement difficult. Plots may include trees, termite hills, rock outcroppings, etc. Plots can be separated by short distances to avoid irregularities. But inevitably the irregularities will exist. If they cannot be avoid, then one is obliged to either accept them as background variation or analyse them as external factors determining yield. Plots need not to be of exactly the same shape or size, if it is practical to measure inputs and outputs on a per hectare basis.

4.2.4 Evaluation and Recommendations from Verification Trials

Frequency distributions of the magnitudes of net

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benefits from the use of a technique are the primary goal of verification trials. They are a final judgement of the worth of the technique to the farmers.

The regression analysis, analysis of covariance, and informal observation are the methods most frequently used to attempt to explain the various sources of variation. The results of these analyses can point the way to factors to be investigated in another round of experimentation for the next step in production increase. They are of more immediatly interest to the researcher than to the farmer.

5. Conclusion

Factor choice trials and factor level trials can be designed using the conventional techniques of experimental design, although some of the variables to be measured may be different from those usually measured in more conventional agronomic trials. Labor inputs for various operations are the most frequent example of an variable which would be measured in farming systems trials. The internal structure of trials designed to measure labor inputs will be different, but the procedure for designing them is conventional.

Designing and interpreting verification trials is an art. Frequently, one will modify the analysis after the trial has been done. Identification of external sources of variation is one of the principle goals. The researcher will make hypothesis about the causes of variation in yields and profits, but he cannot control these hypothetical sources of variation, after the fact and he will therefore not be able to prove his assertions.

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