**Indian Agricultural Statistics Research Institute**
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| Workshop Series | 0 |
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| DESIGN AND ANALYSIS OF ON-STATION AND ON-FARM AGRICULTURAL RESEARCH EXPERIMENTS: A REVISIT | |
| Organized at Lucknow on December 04, 2003 | |

**Introduction**
Proper blocking of experimental units is an important point that has to be taken care of during the experimentation. In field experimentation, the experimental units are the plots and a group of plots having similar fertility level forms a block. To ensure that the plots within a block are homogeneous, the traditional way is to form the blocks across the direction of the fertility gradient with the presumption that the fertility gradient is in one direction. This is seldom the case, unless the land has high slope like in the hills. In most situations particularly in the plains, the fertility contour maps show that the variations in fertility are in patches rather than in a single direction. Hence, the very concept of forming blocks in rectangular shapes with one or more than one strip as is being done at present may be faulty and may lead to erroneous conclusions. This may be the reason why in most situations the block mean square is small as compared to error mean square. Therefore, there is a need to develop a methodology of deciding shape and size of plots and blocks, so that in the new blocking structure, the block mean square is large as compared to error mean square.

The above discussion relates to the blocking of experimental units in field experiments conducted on research stations. The technology generated at the research stations has to be adopted by the farmers to increase the productivity and maintaining the soil fertility. The technology has, therefore, to be tested by taking into account the realistic environment and with farmers' participation in specific recommendation domain. As a consequence, more and more emphasis is being laid by different organizations on 'On-Farm Research'. The experiments conducted on Farmers' fields have been classified into three categories viz. (a) trials designed and managed by the researcher, (b) trials designed by the researcher and managed by the farmer and (c) trials designed and managed by the farmer. The statistical designing of experiments for categories I and II suffers primarily from lack of control on variability due to (a) variation in farmers' managerial skills and resources, (b) plot to plot variation due to different fertility levels, weed incidence in the last season, undulated land, etc. Such problems were highlighted during a discussion between Dr. A.K. Nigam, Director, Institute of Applied Statistics and Development Studies, Lucknow and Dr. R.K.Singh, International Rice Research Institute (IRRI) representative, on the problems of variability between the plots of the same farmer encountered under the Rice-Eco-System project of IRRI conducted in Eastern Uttar Pradesh. Development/ identification of designs that can take care of the variations and problems of On-Farm research will be quite helpful in improving the precision of treatment comparisons. The data generated from an experiment is analyzed to draw statistically valid conclusions. In most of the On-farm trials, the farmers are selected using a multistage random sampling design. As a consequence, some of the effects considered in the model are random whereas the analysis is generally carried out using a fixed effects model. Therefore, an analytical procedure based on linear mixed effects model will be quite helpful in drawing statistically valid conclusions.

In view of the importance of proper blocking techniques for on-station experiments; efficient designs for on-farm trials and sophisticated analytical techniques for analysis of such experimental data, Institute of Applied Statistics and Development Studies (IASDS), Lucknow and Indian Agricultural Statistics Research Institute (IASRI), New Delhi took up a collaborative project entitled **Design and Analysis of On-Station and On-Farm Agricultural Research Experiments: A Revisit** financed by AP-CESS fund of ICAR with the following objectives:

i) To develop suitable methodology by using data of uniformity trials and past experiments in deciding the shape and size of irregular plots and blocks for future experimentation.
ii) To develop efficient designs and appropriate methods of analysis of data by exploiting the principle of resolvability, fractional factorials and nested models for On-Farm Research experiments.

**Aims and Objective of the Workshop**
Dissemination of the research findings to the stakeholders is the most important component of any research endeavour. To achieve this objective a workshop was organized with the following objectives:

- To familiarize the participants with the importance of proper blocking in field experiments.

- To familiarize the participants with the efficient designing of on-farm trials.
- To sensitize the participants about the collection of auxiliary information like soil test values at different locations for use in proper blocking or use them as covariates for reduction of mean square error.
- To disseminate the findings of the research project to the stake holders.

**Programme of the Workshop**

The participants of the Workshop included many eminent research workers actually engaged in on-station and on-farm agricultural research experiments and the statisticians from various reputed institutions. Dr. J. P. Mishra, Assistant Director General (ESM), Dr. A. K. Singh, Principal Scientist and Incharge, On Farm Research, Project Directorate of Cropping Systems Research, Modipuram along with Chief Agronomist from Lucknow participated in the workshop along with other delegates. Dr. M. N. Das, Former Director, IASRI New Delhi and Dr. Aloke Dey, Head, ISI Delhi Centre Chaired the technical sessions organized during the workshop. Initiating the discussion, Dr. A.K. Nigam, the Principal Investigator of the project gave a brief genesis of the project. He also described the potential applications of the research output emerging from the project.

This was followed by remarks from Dr. M.N. Das, Chairman of the session, who emphasized the importance of the subject and also highlighted the need and importance of such studies in other areas of research like response surface methodology and incomplete block designs, to name a few. Dr. V.K. Gupta, Co-Principal Investigator discussed and brought out achievements and importance of the role played by IASRI.

A very detailed presentation of the findings of the project according to the objectives was made by Dr. Rajender Parsad, Co-Principal Investigator.

In brief, following **salient findings** of the project were presented:

- Based on the analysis of several uniformity trial data obtained from CCS HAU Hissar and from the published literature, it has been observed that the fertility patches are not in rectangular shapes. Therefore, an attempt was made to answer the question “how to form blocks so that the experimental units within a group are homogeneous?”. Different blocking structures viz. by taking the plots with row (column) numbers or the fertility contour numbers as blocks. The classification according to row (column) numbers, is the blocking across the direction of fertility gradient. Row (column) one at a time represents the block as a long strip whereas row (column) numbers two at a time represent the blocks in rectangular strips containing two rows (columns). The classification according to fertility contour numbers represents the blocking techniques suggested on the bass of taking plots of similar fertility status in one block. The data were then analyzed using one way classified Analysis of Variance (ANOVA). It was observed that the coefficient of variation (CV%) and Root mean square error (RMSE) are least when the blocking is done on the basis of similar contours. From implementation point of view, it was felt that the block formation on the basis of similar contour numbers may give rise to practical difficulties. Therefore, the possibility of nested blocking structure was also explored. For this, rows (columns) are taken as blocks and the contour numbers within them as sub-blocks. It was observed that the nested block structures with smaller block sizes are beneficial in comparison to usual procedure of blocking in the sense that it reduces the CV% and hence, the precision of the treatment comparisons.
- In on-Farm Research, it has been shown that the problem of variability due to the (a) plot to plot variation and (b) variation in farmers’ managerial skills and resources in the farmers’ fields can effectively be addressed using resolvable block designs. A resolvable block design is one in which the blocks can be grouped in such a fashion that each of the treatments occurs in each of the groups exactly once. In these designs, the partitioning of degrees of freedom according to resolvable block designs will be quite useful in studying the variations in managerial skills and resources of the farmers or plot to plot variations. A catalogue of resolvable block designs for $v \leq 10$ has also been prepared. This catalogue will serve as a ready reckoner for planning the on-farm research experiments.
- In 'On Farm Research Trials', one of the treatments is generally taken as farmers' practice (most common practice adopted by the farmers in a given farming situation understood through a diagnostic survey). The rationale behind the inclusion of farmers' practice as one of the treatments is to compare new treatments with farmer’s practice with, as high a precision as possible and comparisons among new treatments may be of lesser importance. The application of efficient block designs for comparing new (test) treatments with a control (farmers' practice) has been illustrated. In many experimental situations, the identification of one common farmers' practice for a given farming situation is a problem. In such cases, for a given farming situation, it has been shown that instead of identifying one common farmers’

practice to be used as control, one can group the farmers on the basis of practices used and as many controls should be used as the number of groups. In such situations, reinforced blocks/nested block designs could be helpful. A reinforced resolvable design is a resolvable design in test treatments and the control treatments are added once to every block of the resolvable group (or bigger block). Each resolvable group would have different sets of controls (farmers' practice).

- In the trials designed and managed by farmers, the farmers are encouraged to run the experiments on their own and select their own treatments. In these trials, it may happen that the treatments selected are allocated to the blocks in such a way that over all design becomes disconnected and it is not possible to estimate all possible pairwise treatment comparisons from the design. To take care of such problems, an analogy has been drawn between germplasm evaluation trials and the trials designed and managed by farmers. It is suggested that the treatments may be divided into two groups (i) core treatments and (ii) farmer decided treatments. The core treatments should be used by every farmer. Augmented designs have been recommended for such experimental situations.
- In "On Farm" experiments where the treatment structure is factorial in nature fractional factorial plans can usefully be employed. These designs include only a subset of the complete set of factorial treatment combinations. These designs have to be suitably chosen so as to ensure that the objectives of the experiment are met. To be clearer, consider an experimental situation where the treatment structure is factorial in nature. The total number of treatment combinations in the factorial is $n$. Out of these $n$ treatment combinations only $n_1$ treatments are practically feasible. In other words, $n-n_1$ treatments are not feasible. For example, according to agronomists, the doses of phosphorus and potassium cannot be used in the absence of nitrogen in many of agronomic experiments. Further, based on the resource availability with the experimenter, not more than $m < n_1$ treatment combinations be accommodated in the experiment. Out of these $m$ treatment combinations, $m_0$ treatment combinations have to be included to achieve some objective like response of average effect of the factors at optimum levels. There is a flexibility of choosing $m-m_0$ treatment combinations from $n_1-m_0$ treatment combinations. These treatment combinations have to be selected to maximize the efficiency of the design. For this, one can make $\binom{n_1-m_0}{m-m_0}$ all possible distinct combinations of the number of treatments to be chosen. Test each of these combinations for well known optimality criteria. The set with highest efficiency may be included for experimentation.
- In some experimental situations, the fractional factorial plan can directly be chosen by deleting the non-feasible treatment combinations and the treatment combinations that are required to meet the objectives of the experiment. In these experiments, $n-n_1$ treatments involve the non-feasible and undesired treatment combinations and $m=n_1$. The usefulness of the fractional factorial plans in the selection of farmers has been illustrated with the help of UP Sodic Reclamation Project.
- The analytical procedure based on a linear mixed effect model has been developed for the analysis of data from On-Farm trials conducted under the aegis of Project Directorate of Cropping Systems Research, Modipuram. The method is capable of identifying the specific blocks that seemed to favour one treatment over the other. This will also help in identification of the recommendation zones that is not possible through comparing the treatment effects averaged over all the development blocks alone. The method has been illustrated with the help of data obtained from the on-farm trials conducted under the aegis of Project Directorate of Cropping Systems Research, Modipuram.

The findings of the project were well received by the statisticians as well as the experimenters. Dr. A.K. Singh, Principal Scientist, PDCSR, Modipuram was very appreciative of the findings of the project and was of the opinion that the designs recommended could be used in the experiments "On farm" and "On station". In particular he appreciated the analytical approach based on nested linear mixed effects model where it is possible to identify promising treatments at development block level.

During the discussions, it was felt that the fertility pattern of the field may change every year and it is not practically feasible to conduct uniformity trials every year. To circumvent such problems, one can initiate the experiment based on the fertility contour map and modify the contour map through the study of residuals obtained by fitting only the treatment effects in the model using the data from experiments conducted in the recent past. The fertility maps may further be modified by taking the soil test values and other important characteristics every 3 to 4 years. If it is not possible to conduct the uniformity trials, then soil test values at different places and different locations of the experimental sites should be obtained regularly. These soil parameters may then be used for building soil fertility contour maps and for improving the precision of the experiment by using the soil characteristics for blocking of the experimental units or as covariates. Generation of fertility contour maps and application of inputs according to the fertility status of the soil is of paramount importance in this era of precision farming.

After the discussions Dr. Aloke Dey, gave his remarks and was appreciative of the efforts made in this project. He also emphasized the need of replicating this workshop over time and over locations. Dr. J.P.Mishra, ADG (ESM) expressed his happiness at the way the workshop was organized and the scientific discussions that took place. He felt that these findings must be discussed in the Director's Conference and the recommendations may be implemented in the National Agricultural Research System. He also echoed the feelings of replicating this and similar workshops at different places and presenting the research output of this project in different fora in view of the policy implications emerging from the project.

Following recommendations emerged from the workshop.

**Recommendations of the Workshop:**

- A status paper may be prepared and sent to J.P. Mishra (ADG) for presentation in Director's conference and the meetings of the Vice Chancellors of Agricultural Universities.
- Instead of using the usual block designs where blocks are generally rectangular or square strips, nested block designs with smaller sub-block sizes should be used as far as possible. A nested block design is a block design where another source of variation is controlled by forming sub-blocks within each block of design.
- Soil test values at different places of different locations of the experimental sites should be obtained regularly and the soil parameters should be used for building soil fertility contour maps and for improving the precision of the experiment by using the soil characteristics for blocking of the experimental units or as covariates.
- In on-farm trials, selection of farmers should be made in such a way that small, medium and large farmers are represented in the study.
- In 'On-Farm Research', resolvable block designs should be used to take care of the (a) plot to plot variation and (b) variation in farmers' managerial skills. Resolvable block designs are those designs in which there are two types of blocks, one nested within the other. The bigger blocks are complete replicates and every treatment appears exactly once in the bigger blocks. The small or sub-blocks are formed within the bigger blocks. These sub-blocks are incomplete in the sense that all the treatments do not appear in these blocks. These designs are similar to nested block designs
- For the trials designed and managed by farmers, with some intervention of the researcher, the treatments can be partitioned into two groups, viz., treatments decided by the farmers and core treatments (decided by the researcher). Core treatments will act as check treatments and will be applied on each selected farmer's field. The farmers decided treatments will be specific to a given farmer and will act as test treatments for these experimental situations augmented designs can be quite helpful.
- The appropriate models (linear, nested mixed effect model) should be used for analysis of on-farm trial data currently being generated by PDCSR, Modipuram. This will be helpful in identifying specific developmental blocks that favour one treatment over the other. This will also help in identification of the recommendation zones that is not possible through comparing the treatment effects averaged over all the development blocks alone.
- The analytical procedure developed here is at farming situation level only. The analytical procedure for the combined analysis of data over different farming situations within a NARP zone should be developed using the concept of linear nested mixed effects models.
- For given farming situation, instead of identifying one common farmer's practice to be used as control, one can group the farmers on the basis of practices used and as many controls should be used as the number of groups. In such situations, reinforced blocks/nested block designs could be helpful. Here a reinforced resolvable design is a resolvable design in test treatments and the control treatments are added once to every block of the resolvable group (or bigger block). Each resolvable group would have different sets of controls (farmers' practice).
- In "On Farm" experiments where the treatment structure is factorial in nature fractional factorial plans can usefully be employed. These designs include only a subset of the complete set of factorial treatment combinations. These designs have to be suitably chosen so as to ensure that the objectives of the experiment are met.

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