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A GUIDE TO FIELD CROPS EXPERIMENTS

Field experiment is the oldest and the most common form of agricultural experiment. The idea of testing the value of different manures, or of different weedicides, or of diverse varieties of crops by means of comparative trials on adjacent plots of ground, would have led to agricultural field experiments. In its beginning it must have been crude, and yet the fundamental idea was essentially scientific, viz., to place the things to be compared under the same conditions, and let each bring forth its results; and while the details of such experiments have been gradually refined, and errors of method eliminated, they are still the same in purpose and essence.

The scientific method of experiment requires two things: i) All the conditions of the experiment must be identical, with the exception of the one whose action is to be tested, and that must vary to a known extent and ii) The limits of error of the methods of weighing, measuring, etc., used, must be known, to the end that we may know whether any difference which may be observed is accidental or significant.

Terminology

Experiment: Planned inquiry to obtain new knowledge or to confirm or deny previous results.

Experimental design: The study of strategies for efficient plans for the collection of data, which lead to proper estimates of parameters relevant to the researcher's objective, is known as experimental design. A properly designed experiment, for a particular research objective, is the basis of all successful experiments.

Experimental unit: The smallest entity to which the treatment is applied and which is capable of being assigned a different treatment independently of other experimental units if the randomization was repeated.

Factor: Procedure or condition whose effect is to be measured.

Experimental error: Measure of the variation which exists among experimental units treated alike.

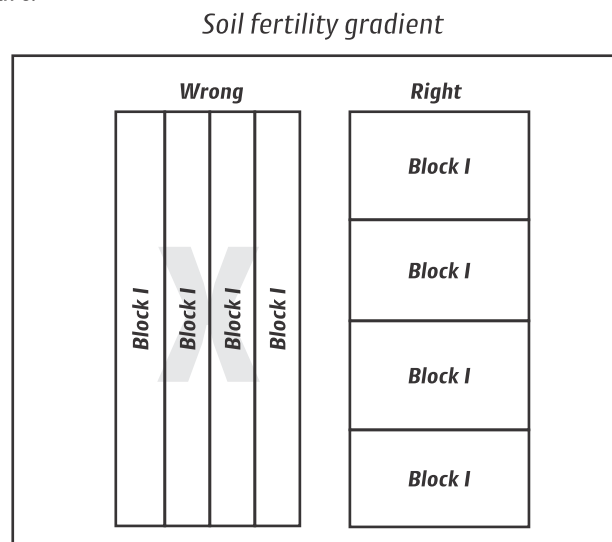
Randomization: Randomly allocating the experimental units across the treatment groups. Thus, if the experiment compares new maize varieties against a check variety, which is used as a control, then new varieties are allocated to the plots, or experimental units, randomly. Randomization is thus the process by which experimental units (the basic objects upon which the study or experiment is carried out) are allocated to treatments by a random process and not by any subjective and hence possibly biased approach.

Replication: The repetition of an experiment on a large group of treatments. Replication reduces variability in experimental results, increasing their significance and the confidence level with which a researcher can draw conclusions about an experimental factor.

Blocking: In the design of experiments, blocking is the arrangement of experimental units into groups (blocks) that are similar to one another. For example, if an experiment is designed to test 20 new rice varieties, the field in which the varieties are to be tested may not be uniform, having two fertility gradients – low and high soil fertility. The level

of fertility may introduce variability within the experiment; therefore, blocking is required to remove the effect of fertility. This reduces sources of variability and thus leads to greater precision.

When the fertility pattern of the experimental field is known, orient the blocks so that soil differences between blocks are maximized and those within blocks are minimized. For example, for a field with a unidirectional fertility gradient along the length of the field, blocking should be made across the width of the field, that is, cutting across or perpendicular to the gradient. When fertility pattern is not known, avoid using long and narrow blocks. Instead, use blocks that are as compact, or as nearly square, as possible since plots that are closer can be expected to be more alike than those that are farther apart.



Experimental Designs for Field Crops Research

Experimental design refers to the rules regulating the assignment of treatments to the experimental plots. Properly done it allows valid comparisons among treatments and it controls the principal source of variation in field experiments – soil heterogeneity. A proper experimental design must include replication, randomization, and error control.

Choosing a design: The best type of design for an experiment depends primarily on the magnitude of soil heterogeneity in the test area, the type and number of treatments to be tested, and the degree of precision desired. When you start a new experiment, consult a competent statistician, when possible, for a proper design to ensure that the objectives of the experiment will be met. Do not choose a design lacking any of the three principles: replication, randomization, and error control. Three groups of designs are commonly used in field experiments: complete block designs, incomplete block designs, and split-plot designs.

Complete block designs are generally used for simple experiments involving a small number of treatments. Some characteristics of these designs are that all treatments appear in a block, analysis of data is simple, missing data are easy to handle, and these designs can be used for either single-factor or factorial experiments.

Incomplete block designs are generally used for experiments that have such a large number of treatments that all treatments cannot fit into homogeneous blocks. An example is varietal tests which usually involve many varieties or selections. Some properties of such designs are that not all treatments appear in the same block and data analysis is more complicated than for complete block designs—especially with missing data. These designs can be used for either single factor or factorial experiments.

Split-plot designs are used only for factorial experiments, either when a large number of treatment combinations is involved or when certain treatments require a larger plot size than others. When statistical assistance is not available, the rules of thumb given below for choosing an experimental design for a single-factor or for a factorial experiment may be helpful.

SINGLE-FACTOR EXPERIMENTS: Complete Block Designs

Randomized complete block (RCB)

- Less than 10 treatments
- Any number of replications is possible
- Uni-directional fertility gradient in the area

Latin square (LS)

- Four to eight treatments
- Number of replications same as number of treatments
- Bi-directional fertility gradient in the area

FACTORIAL EXPERIMENTS: Complete Block Designs

Randomized complete block (RCB)

- Less than 10 treatment combinations
- Any number of replications is possible
- Uni-directional fertility gradient in the area
- Main effects and interactions equally important

Latin square (LS)

- Treatment combinations between four and eight
- Number of replications same as number of treatment combinations
- Bi-directional fertility gradient in the area
- Main effects and interactions equally important

Split-plot

- At least two factors involved
- The factors are not equally important
- The main effect of one (or more) of the factors is less important than the other; this factor will be assigned to the main plots
- One factor (say, fertilizer or water management) may require larger area than that of the subplot used; this factor will be assigned to the main plots

Border Effect

A border effect is the difference in performance between plants along the sides or ends of a plot and those in the center. It occurs when an unplanted space is left between adjacent plots or at the end of plots, when adjacent plots are planted with different varieties, or when adjacent plots have different fertilizer treatments. It influences many agronomic characters including yield. When plots are adjacent to unplanted borders, plants in the outermost row (that is, the first row bordering unplanted space) give higher yields than those in the center. On the other hand, yields of the second row may be decreased. The effect on yield and other components is due to availability of more nutrient, light, moisture or other growth factors by the border plants.

Missing Hills

In transplanted rice, a missing hill refers to the spot where a hill of transplanted seedlings died before maturity. The presence of a missing hill means that not all hills in the plot have been subjected to the same plant spacing and plant competition. In experimental plots, rice plants immediately adjacent to a missing hill perform differently than normal hills (hills surrounded by living hills). These hills generally grow more vigorously and yield more than normal hills. Thus, the occurrence of missing hills poses two major problems: how to determine yield of plots with one or more missing hills, and whether to treat plants adjacent to a missing hill as normal hills in sampling for agronomic characters.

Coping with missing hills: If a missing hill occurs, do not measure grain yield, yield components, or any agronomic character from the four hills immediately adjacent to the missing hill. That is, harvest only hills surrounded by living hills and adjust grain weights to allow for the difference in the number of harvested hills. For example, if 95 hills were harvested instead of 100 hills, the grain weight of these 95 hills is multiplied by 100/95 (or 1.0576) to obtain the plot yield. If the reduction in the number of hills due to the presence of missing hills in any plot is more than 20% of the total number of hills to be harvested in a normal plot, do not determine plot yield and regard it as "missing data" in the statistical analysis.

Plot Sampling

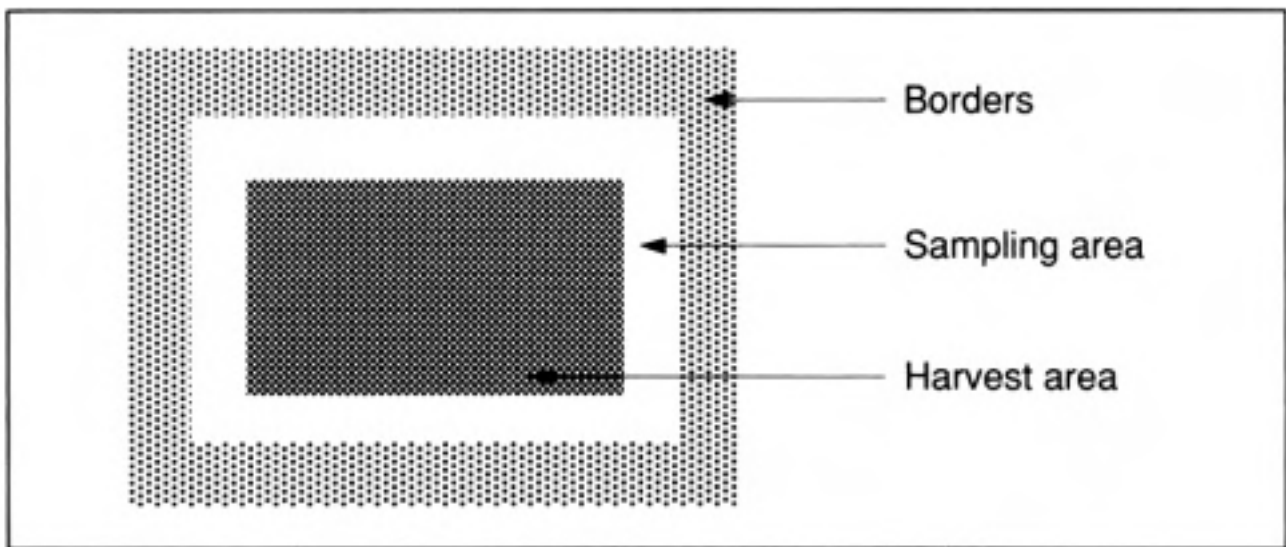
A sampling method is a procedure for selecting a fraction of a total population to represent that population accurately. When the total population to be sampled is an experimental plot as in replicated field trials, the sampling procedure is referred to as plot sampling. A plot sampling technique is considered good if the values of the characters measured from the sample are very close to those that would have been obtained if measurements were made on all plants in the plot. Plot sampling is used when total measurement is too laborious and expensive. A sampling method

specifies i) the sampling unit—the unit upon which measurements are to be made ii) the method of selecting the sampling units from a plot and iii) the sample size—the number of sampling units to be taken from each plot. Although it may be convenient to use only one sampling procedure for measuring several characters, a sampling procedure that is appropriate for one character is not necessarily appropriate for others. Whenever possible, select sampling units at random.

Measuring Grain Yield

Grain yield refers to the weight of cleaned and dried grains harvested from a unit area. For rice, grain yield is usually expressed either in kilograms per hectare (kg/ha) or in metric tons per hectare (t/ha) at 14% moisture.

How to measure grain yield: After discarding border areas on all four sides of a plot, harvest from the middle of the plot. For reliable results in rice, the harvested area must not be less than 5 sq m per plot. Thresh, clean, dry, and weigh all grains harvested from each plot separately. Immediately after the grain from a plot is weighed, determine its moisture content. Adjust grain weight to 14% moisture using the formula:



$$\text{Adjusted grain weight} = A \times W$$

where A is the adjustment coefficient and W the weight of the harvested grains. Calculate A as follows:

$$A = \frac{100 - M}{86}$$

where M is the moisture content (percent) of the grains.

Handling missing hills and off-types: When one or more hills are missing, exclude from harvest all hills immediately adjacent to the missing hills. When off-types are present, remove all of them from the harvest and treat as missing hill. If the reduction in the number of hills harvested due to the presence of either missing hills or off-types is not more than 20%, adjust grain yield in the following way:

$$\text{Grain yield per plot} = \frac{W}{n} \times N$$

where W is the weight of grains from harvested hills, n the number of harvested hills, and N the total number of hills in normal plots.

Calculate the final grain yield per unit area (ha or acre) as follows:

$$\text{Grain yield (t/ha)} = \frac{\text{Adjusted grain yield (kg)}}{1000} \times \frac{10,000 \text{ m}^2}{\text{Harvest area (m}^2\text{)}}$$

Note: Be mindful of the units. The adjusted yield is divided by 1000 to convert into tons. If you prefer to present the yield in kg per ha, there is no need to divide by 1000. Adjusted yield refers to the grain yield which is standardized at 14% moisture content and where adjustment is made for missing hills. If you wish to present the yield in t/acre, use 4000 m² instead of 10,000 m², or simply divide the final answer by 2.5