# Techniques for field experiments with rice

Kwanchai A. Gomez

INTERNATIONAL
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International Rice Research Institute
Los Baños, Laguna, Philippines

# Contents

# Foreword

This manual is primarily intended for field researchers conducting experiments on rice. It attempts to define and provide tested solutions to all major problems of experimentation technique. Most problems discussed are common to many field experiments dealing with rice.

In an effort to be brief, direct, and clear, emphasis is placed on recommended solutions rather than on the data substantiating the recommendations. Whenever possible, both preventive and remedial measures are presented. Only substantiated procedures are recommended: untried alternatives are not included.

The manual has two parts. The first covers field plot techniques, experimental design, and sources of experimental error. The second part deals with sampling and measurement techniques for determining plot yield and other characters.

I am grateful to Mr. Steven A. Breth for editing the manuscript and for his stimulating influence; to Dr. S.K. De Datta for his invaluable assistance in the conduct of actual field experiments from which data presented here were gathered; to Mr. Federico Gatmaitan. Jr. and Mr. Arnulfo del Rosario for preparing the illustrations; and to the staff of the department of statistics for the collection and analysis of data.

KWANCHAI A. GOMEZ

# 1 PLOT SIZE, SHAPE, ANDORIENTATION

*Experimental plot* refers to the unit on which random assignment of treatments is made. The *size of the plot,* therefore, refers not only to the harvest area but to the whole unit receiving the treatment. The *shape of the plot* refers to the ratio of its length to its width. The *orientation of plots,* on the other hand, refers to the choice of direction along which the lengths of the plots will be placed. The orientation of plots naturally is not defined for square plots.

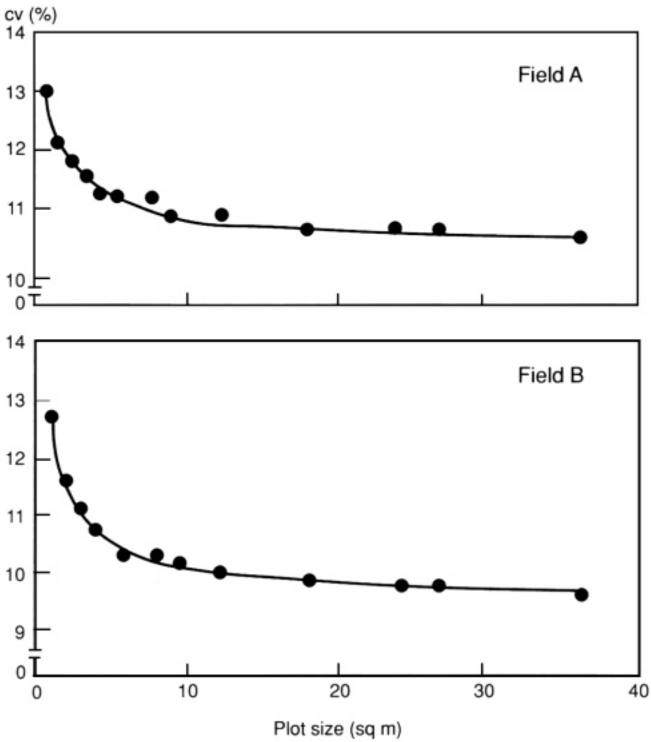
**Effects of plot size, shape, orientation.** The size, shape, and orientation of a plot can greatly affect the magnitude of experimental error in a field trial. Too small plots may give unreliable results; unnecessarily large plots waste time and resources. A square plot, with its minimum perimeter, exposes the smallest number of plants to border effects. Orientation of plots can reduce or increase the effects of fertility gradients in the field.

In general, experimental error decreases as plot size increases, but the reduction is not proportional.

Plot size not only affects variability but may also bring about bias in the experimental results. Plots should be wide enough to permit the removal of border rows when necessary (see chapter 7 for details on border effects).

For a specified area of land, the number of replications decreases as the plot size is increased. Consequently a gain in precision from increased plot size is accompanied by a loss of precision from reduced number of replications (see chapter 2 for details on number of replications). But in general, as long as the minimum plot size is reached, a larger increase in precision can be expected with an increase in number of replications.

**How to choose plot size, shape, orientation.** In rice field experiments, plots commonly range from 8 to 25 sq m. Whatever size and shape of plots you choose, make sure that an area not smaller than 5 sq m, free from all types of competition and border effects, is available for harvesting and determining plot yield. Consider the following when choosing plot size and shape.




**Relation of coefficient of variation to plot size based on rice yield data from two uniformity trials.**

*Type of experiment.* The cultural practices related to the experiment can dictate the size and shape of plots for ease of operations. Fertilizer trials require larger plots than variety yield tests. Irrigation studies may require even larger plots. In insecticide or herbicide trials where the chemicals are to be sprayed, the width of the plot may be governed by the range of coverage of the sprayer used.

*Soil heterogeneity.* When soil heterogeneity is patchy (that is, when correlation between productivity of adjacent areas is low), a large plot should be used. The choice of plot shape is not critical when soil variation is as great in one direction as it is in another. On the other hand, if a gradient is present, plots should have their longest dimension in the direction of greatest variation. Therefore when the fertility gradient of the experimental field is known, a rectangular plot with appropriate orientation will give higher precision (see chapter 6 on orienting plots to reduce the effects of soil heterogeneity). But when the fertility pattern of the area is not known it is safer to use square plots (they will not give the best precision, nor will they give the worst).

*Border effects.* In experiments where border effects might be appreciable, square plots are desirable because they have minimum perimeter for a given plot size. In varietal yield tests where varietal competition is expected, plots with at least six rows should be used to allow exclusion of one row on each side of the plot, thus leaving four center rows for harvest.

*Scarcity of seeds.* When the seed supply is limited (as in early generations of crosses), you may have to use very small plots. Two points should be kept in mind. First, consider the magnitude of the difference in plant characters among the test selections. If characters like plant height, tillering capacity, or growth duration differ greatly, the effect of varietal competition can not be properly controlled in very small plots. Thus, bias may enter into the results. Second, a very refined field technique is essential to ensure accuracy because, with small plots, small errors often are greatly magnified. When small plots are needed, you must be willing to bear the higher costs that result from using a more refined technique than the techniques generally used with large plots.

*Measurement of characters other than yield.* When several plant characters are to be measured, you may need extra plants for sampling, especially when the measurement requires the destruction of plants at early growth stages as in the determination of dry matter production or leaf area index. Provide a large enough area to ensure against plant competition which could result when sample plants are pulled out (see chapter 16).

# 2 NUMBER OF REPLICATIONS

How often a complete set of treatments is repeated in an experiment is called the number of replications. Several quadrats (small harvest cuts) sampled from a large area planted to a variety, or multiple observations from a plot, do not represent a true replication. They are subsamples and their variability constitutes a sampling error instead of an experimental error. This distinction is missed by many agricultural researchers.

**Effect of replication.** Replication is required in an experiment to provide a measure of experimental error. Moreover, one of the simplest means of increasing precision is increasing the number of replications. Beyond a certain number of replications, however, the improvement in precision is too small to be worth the additional cost. When such a point is reached and the required precision is still not attained, other means besides increasing the number of replications must be used.

**How to determine number of replications.** The number of replications you need depends on the magnitude of experimental error likely to be obtained in the experiment and the degree of precision you want.

The magnitude of experimental error in an experiment is generally prescribed as the value of coefficient of variation based on the most important character (usually yield) likely to be obtained in the experiment. The level of the coefficient of variation likely to be obtained varies from one experiment station to another and from one type of experiment to another. At the IRRI experimental farm, the average coefficient of variation based on grain yield is about 8 percent for varietal yield tests and 10 percent for other agronomic trials. At other localities, the level of the coefficient of variation may be different from the level at IRRI depending upon the degree of soil heterogeneity in the experimental fields and the type of field plot technique employed.

The degree of precision desired is generally prescribed either as the standard error of the treatment means, or as the magnitude of treatment difference that can be detected.

Four replications are commonly used in rice field experiments at IRRI. The number of replications you need may differ greatly from this figure. Tables 1 and 2 show how many

**Table 1. Estimated standard error of a treatment mean as a percentage of the mean for varying number of replications and coefficients of variation (cv).**

| Replications (no.) | Standard error (%) | | | |
|---|---|---|---|---|
| | cv = 8% | cv = 10% | cv = 12% | cv = 14% |
| 2 | 5.7 | 7.1 | 8.5 | 9.9 |
| 3 | 4.6 | 5.8 | 6.9 | 8.1 |
| 4 | 4.0 | 5.0 | 6.0 | 7.0 |
| 5 | 3.6 | 4.5 | 5.4 | 6.3 |
| 6 | 3.3 | 4.1 | 4.9 | 5.7 |
| 7 | 3.0 | 3.8 | 4.5 | 5.3 |
| 8 | 2.8 | 3.5 | 4.2 | 5.0 |

**Table 2. Estimated percentage difference between two treatment means that can be detected with 95% confidence for varying number of replications and coefficients of variation (cv).**

| Replications (no.) | Detectable difference (%) | | | |
|---|---|---|---|---|
| | CV = 8% | CV = 10% | CV = 12% | CV = 14% |
| 2 | 18.1 | 22.6 | 27.1 | 31.7 |
| 3 | 13.7 | 17.2 | 20.6 | 24.0 |
| 4 | 11.6 | 14.5 | 17.4 | 20.3 |
| 5 | 10.3 | 12.9 | 15.4 | 18.0 |
| 6 | 9.3 | 11.6 | 14.0 | 16.3 |
| 7 | 8.6 | 10.7 | 12.9 | 15.0 |
| 8 | 8.9 | 10.0 | 12.0 | 14.0 |

replications to use for a prescribed degree of precision under the magnitude of experimental error likely to be encountered in your experiment. For example, if the experiment is likely to have about 10 percent coefficient of variation, you need four replications to obtain a treatment mean with a standard error of not more than 5 percent. With four replications and a coefficient of variation of 10 percent, you can expect to detect, with 95 percent confidence, any difference between two treatment means equivalent to 13.5 percent of the mean value. With a mean yield of 6 t/ha, the detectable difference of 14.5 percent implies an amount of 0.9 t/ha. That is, with four replications and a coefficient of variation of 10 percent, you can expect to detect differences of not less than 0.9 t/ha between treatment means.

In addition to the above consideration, you must also make sure that the number of replications you choose will provide not less than 10 degrees of freedom for estimating experimental error. For example, with three treatments in a randomized complete block design, four replications are not sufficient because they provide only six degrees of freedom for error. When in doubt consult a statistician.

# 3 EXPERIMENTAL DESIGN

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 rice 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

*Incomplete block designs*

**Balanced lattice**

- large number of treatments
- number of treatments is a squared value, say, $p^2$
- number of replications is $p + 1$
- number of plots per block is $p$ (thus if, for example, number of treatments, $p^2$, is 36, the number of replications, $p + 1$, must be 7, and the number of plots per block, $p$, must be 6)
- same precision for all comparisons between pairs of treatments

**Partially balanced lattice**

- large number of treatments
- number of treatments is a squared value, say, $p^2$
- any number of replications is possible
- number of plots per block is $p$ (thus if, for example, the number of treatments $p^2$, is 36, any number of replications may be used, but the number of plots per block, $p$, must be 6)
- some pairs of treatments will have higher precision than others

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

*Incomplete block designs*

**Balanced lattice**

- large number of treatment combinations
- number of treatment combinations is a squared value, say, $p^2$
- number of replications is $p + 1$
- number of plots per block is $p$ (thus if, for example, the number of treatment combinations, $p^2$, is 36, the number of replications, $p + 1$, must be 7, and the number of plots per block, $p$, must be 6)
- same precision for all comparisons between pairs of treatment combinations

**Confounding**

- more than two factors involved
- accuracy on certain high-order interactions can be sacrificed

*Split-plot designs*

**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

**Split-split plot**

- at least three factors involved
- the factors are not equally important
- the least important factor is assigned to main plots, the moderate one to subplots, and the most important one to sub-subplots
- one (or more) of the factors may require larger area than that of the subplot used

**Strip-plot**

- at least two factors involved
- the factors require areas larger than the size of subplot used
- interaction effect more important than main effects

# 4 BLOCKING

Blocking refers to the assignment of a group of plots or treatments to a block of land with relatively homogeneous soil. It is one of the simplest and most effective ways of coping with soil heterogeneity.

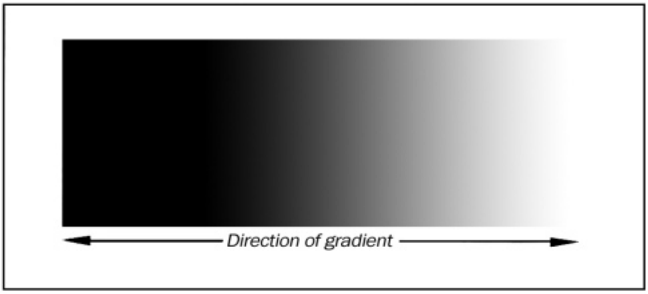
**Effect of blocking.** The variation among blocks can be removed from the experimental error through blocking; thus error is reduced and the precision of an experiment is increased. The larger the differences among blocks, the greater the reduction in the experimental error. Hence, proper blocking should produce large differences among blocks, leaving plots within a block more homogeneous.

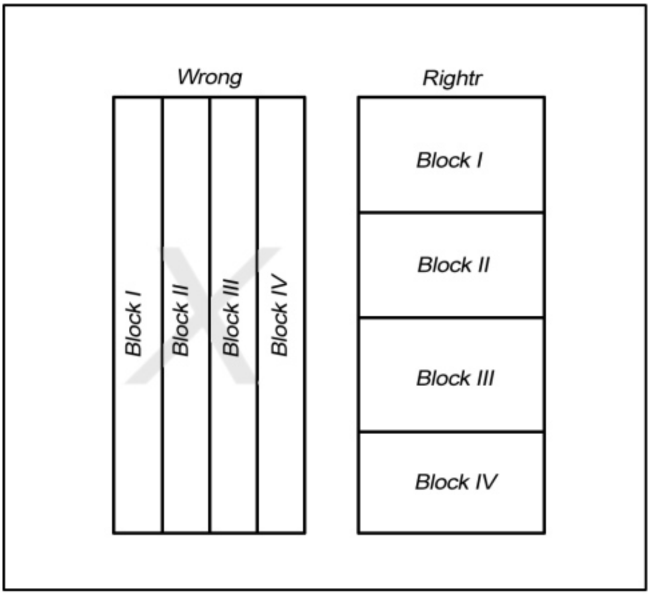
**How to use blocking.** When the fertility pattern of the experimental field is known, orient the blocks so that soil differences between blocks are maximized and those within blocks are minimized. For example, for a field with a uni-directional fertility gradient along the length of the field, blocking 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.

Conduct all management operations and data collection "on a per-block basis" to control any variation that may occur in the management and operation processes as well as in the datacollection. In other words, whenever a source of variation

**Schematic diagram of a uni-directional fertility gradient.**






**When the fertility pattern of the field is not known, blocks should be as nearly square as possible.**

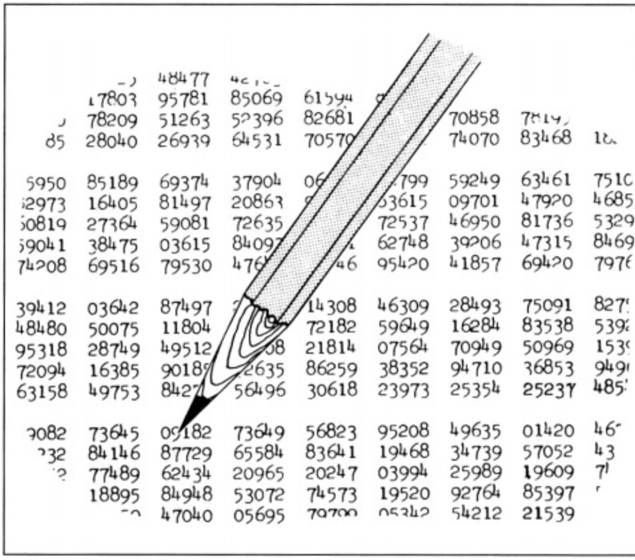
exists, attempt to have the major portion of the variation separated by blocks.

For instance, when an operation (for example, application of treatments, measurement of data) can not be completed for the whole experiment in 1 day, at least complete the work for all plots in a block. In this way, the difference, if any, from day to day can be controlled by "blocking."

The same technique can be used to handle variation among operators. Whenever an operation is known to be affected by the operator (for example, application of fertilizer or insecticide, measurement of plant height), each operator should be assigned to different blocks.

# 5 RANDOMIZATION

Randomization is one of the basic principles of experimental design. It makes valid the estimate of experimental error which is essential for comparing treatments. It is a procedure for allocating treatments so that each experimental plot has the same chance of receiving any treatment.




**Locating a starting point in the table of random numbers.**

**How to randomize.** The process of randomization can be done with a table of random numbers or by drawing lots. The use of both methods is shown below for randomization and laying out of plots in a randomized complete block design with six treatments and four replications.

**Random number table.** First, locate a starting point in a table of random numbers (Appendix Table 1). Do this by pointing to a number in the table with your eyes closed. Use this number as the starting point. On a piece of paper write six consecutive three-digit numbers beginning at the starting point and reading to the right or downward.

For example, starting at the intersection of the sixteenth row and the twelfth column read downward vertically to get six three-digit numbers:

| | *Sequence* |
|---|---|
| 918 | 1 |
| 772 | 2 |
| 243 | 3 |
| 494 | 4 |
| 704 | 5 |
| 549 | 6 |

Second, rank the selected numbers from the smallest to the largest. Thus continuing the example:

| | *Sequence* | *Rank* |
|---|---|---|
| 918 | 1 | 6 |
| 772 | 2 | 5 |
| 243 | 3 | 1 |
| 494 | 4 | 2 |
| 704 | 5 | 4 |
| 549 | 6 | 3 |

Third, use the rank as the treatment number and use the sequence in which the treatment numbers occurred as the plot number in the block to which the corresponding treatment will be assigned. Thus in this example, assign treatment no. 6 to the first plot, treatment no. 5 to the second, treatment no. 1 to the third, treatment no. 2 to the fourth, treatment no. 4 to the fifth, and treatment no. 3 to the sixth.

The layout of the first block:

| *Plot no.* | *Block I* |
|---|---|
| 1 | treatment no. **6** |
| 2 | treatment no. **5** |
| 3 | treatment no. **1** |
| 4 | treatment no. **2** |
| 5 | treatment no. **4** |
| 6 | treatment no. **3** |

Fourth, repeat the first three steps for Block II, then for Block III, and finally for Block IV.

**Drawing lots.** First, write the numbers 1 to 6 (there are six treatments) on six equal-sized pieces of paper. Fold and place them in a box.

Second, shake the box to ensure thorough mixing of the slips of paper: then pick out one slip of paper. Write down the number and, without returning the slip of paper already taken, pick out the second slip of paper. Repeat the process until all the six pieces of paper are taken out.

For example, the numbers written on the slips of paper may appear in this sequence:

| *Sequence* | *Number on paper* |
|---|---|
| 1 | 4 |
| 2 | 2 |
| 3 | 1 |
| 4 | 5 |
| 5 | 6 |
| 6 | 3 |

Third, assign the six treatments to the six plots in the first block by using the number on paper as the treatment number and the sequence as the plot number in the block.

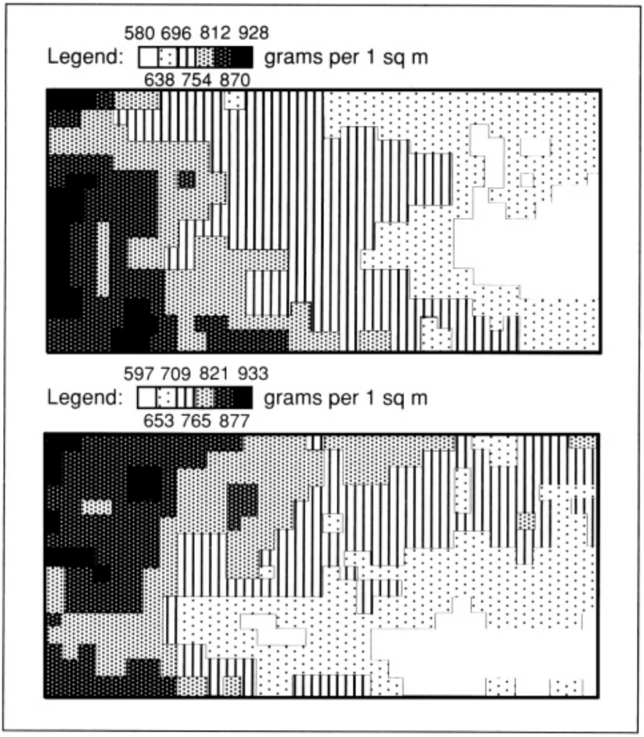
The layout of the first block is, therefore:

| *Plot no.* | *Block I* |
|---|---|
| 1 | treatment no. **4** |
| 2 | treatment no. **2** |
| 3 | treatment no. **1** |
| 4 | treatment no. **5** |
| 5 | treatment no. **6** |
| 6 | treatment no. **3** |

Fourth, repeat the first three steps for Block II, then for Block III, and finally for Block IV.

# 6 SOIL HETEROGENEITY

Soil heterogeneity refers to the non-uniformity of soil from one part of the field to another. Even within a small area, soil can vary greatly in texture, drainage, moisture, and available nutrients. This variability is generally present even in a field that seems uniform. Uniformity trials at IRRI's experimental farm have shown considerable variation in rice yields from one part of a field to another. The more common type of soil heterogeneity in a lowland rice field is a gradual change in productivity from one side of the field to the other, rather than patchy differences in productivity.




**Fertility contour maps of grain yield of rice from uniformity trials in two fields at the IRRI experimental farm. Yields in each field range from about 5.8 to 9.3 t/ha.**

**Effect of soil heterogeneity.** Soil heterogeneity is a major contributor to error in field experiments. It introduces a degree of uncertainty into inferences made from yield data of crops. If not properly controlled, it increases experimental error and thus lowers the precision of experimental results.

**Minimizing soil heterogeneity.** Some ways to minimize soil heterogeneity:

¢ Avoid areas that have been previously used for experiments involving treatments that may have a differential effect on soil conditions. Treatments involving fertilizer, varieties varying in growth duration, or different plant spacings may have such an effect. In such areas, one or more uniform plantings should precede an experimental planting. If you must use the area immediately, choose a design that allows for additional "blocking" based on the treatments used in previous experiments (see chapter 10).

■ Avoid areas in which alleys were left unplanted between plots in the previous crop. In such areas, one or more uniform plantings should precede experimental planting. If you must use the area immediately, keep the size and location of unplanted alleys fixed in succeeding experiments (see chapter 11).

■ Choose areas where the history of the land use is available. Such information may help you identify the possible causes of added heterogeneity from previous croppings so that appropriate remedies can be made.

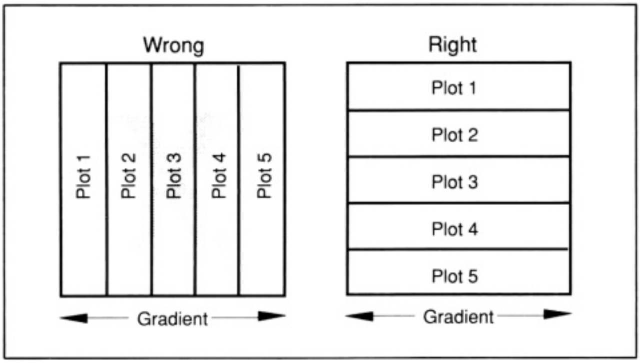
■ If possible, conduct a uniformity trial in the prospective experimental area; that is, plant the whole area with a single variety of the crop and use uniform cultural and management practices. Uniform planting will help reduce the heterogeneity of the soil somewhat, and the uniformity yield data (data from harvests of small units throughout the area) can be used to describe the soil heterogeneity pattern of the area for proper orientation of plots and blocks (see below) in succeeding experiments conducted in this area and to increase the precision of these experiments by the use of covariance technique.

**Reducing the effects of soil heterogeneity.** While little can be done to eliminate or reduce soil heterogeneity itself, proper experimental techniques can considerably reduce the effects of soil heterogeneity on experimental results.

*Choose proper experimental design.* Choose an experimental design with appropriate blocking, either a complete or an incomplete block arrangement, to fit the pattern of soil heterogeneity. For instance, with a moderate number of treatments, a randomized complete block design can be used to take care of uni-directional fertility gradient in the area; a Latin square design can be used for a bi-directional gradient (see chapter 3 for details on experimental design).

*Choose proper plot size and shape.* Choose the size and shape of plot that minimizes the effect of soil heterogeneity. For instance, use a relatively larger plot for the patchy type of soil heterogeneity (that is, when correlation between productivity of adjacent areas is low); use a square plot when the fertility pattern of the area is unknown (see chapter 1 for details on choice of plot size and shape).

*Properly orient plots and blocks.* Position the blocks so that soil differences between blocks are maximized and plots




**Orienting plots within a block to reduce the effect of a uni-directional fertility gradient.**

within the same block are as uniform as possible (see chapter 4 for blocking technique). On the other hand, arrange the plots so that the variation among plots within the same block is small. Orient the plots so that each covers the direction of the greatest variation in the block (see chapter 1 for information on orientation of plots).

*Increase number of replications.* For the same degree of precision, more replications are required with heterogenous soil than with homogeneous soil.

# 7 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 (only yield data are presented below).

**Effect of unplanted borders.** 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. Occasionally the yield may be increased by more than 100 percent (Table 3). On the other hand, yields of the second row may be decreased. A yield reduction in the second row can be expected when fertility is high or when the

**Table 3. Grain yield of rows of IR8 bordering unplanted borders of different widths, under two fertilizer treatments. IRRI, 1969 dry season.**

| Width of the unplanted space (cm) | Yield (t/ha) | | | | | |
|---|---|---|---|---|---|---|
| | 0 kg/ha N | | | 120 kg/ha N | | |
| | Row 1[a] | Row 2 | Center rows | Row 1 | Row 2 | Center rows |
| 40 | 6.01* | 4.08 | 4.12 | 9.69** | 6.31 | 6.88 |
| 60 | 6.91** | 4.35 | 4.28 | 11.53** | 5.81 | 6.20 |
| 100 | 9.12** | 4.39 | 4.38 | 13.35** | 6.24* | 7.09 |

*Significantly different from the center rows at the 5% level. **Significantly different from the center rows at the 1% level. [a]Row 1 refers to the outermost row and row 2 to the second outermost row

**Table 4. Grain yield of rows of IR8 bordering IR127-80-1 and Peta, [a] under two fertilizer treatments. IRRI, 1969 dry season.**

| Row | Yield (t/ha) | | | |
|---|---|---|---|---|
| | Bordering IR127-80-1 | | Bordering Peta | |
| | 0 kg/ha N | 120 kg/ha N | 0 kg/ha N | 120 kg/ha N |
| 1 | 4.91** | 6.33 | 3.36** | 4.58** |
| 2 | 3.95 | 5.83 | 3.70 | 4.88** |
| 3 | 3.87 | 5.93 | 3.74 | 5.21 * |
| Center rows | 4.04 | 5.89 | 4.04 | 5.89 |

*Significantly different from the center rows at the 5% level. **Significantly different from the center rows at the l% level [a]IRE is short and high-tillering. IR127-80-1 is medium-short and low-tillering: Peta is tall and medium-tillering

unplanted space is wider than 60 cm (the discussion in this chapter refers to a row distance of 20 cm).

**Effect of varietal competition.** When adjacent plots are planted to varieties differing in plant height, tillering ability, or growth duration, one or two border rows are generally affected depending upon the characters that differ and the magnitude of their differences (Table 4). Higher tillering or taller varieties tend to suppress the yield of border rows in adjacent plots. When varieties with different growth durations are grown side-by-side, border rows of the variety with the shorter growth duration tend to have higher yields than rows in the center of the plot. The effect of varietal competition may reach the third row if the adjacent plants lodge.

**Effect of fertilizer competition.** When adjacent plots receive different fertilizer treatments, border effects can be expected if plots are not separated by a levee (bund). Even immobile nitrogen fertilizer applied before transplanting may be moved

Table 5. Effect of movement of transplanters and orientation of plot rows on fertilizer competition in unfertilized IR8 plots. IRRI, 1969 dry season.

| Row | Grain yield (t/ha) | | |
|---|---|---|---|
| | Incomlng side[a] | Outgoing side[b] | Check[c] |
| 1 | 8.59** | 6.91 | 6.31 |
| 2 | 4.98 | 4.58 | 4.36 |
| 3 | 4.86 | 4.12 | 4.54 |
| 4 | 4.52 | 3.97 | 4.32 |
| 5 | 4 68 | 3.73 | 4.36 |

**Significantly different from the check at the 1% level. [a]Side of the plot first reached by transplanters coming from an adjacent fertilized (120 kg ha N) plot. [b]Side opposite incoming side. [c]Adjacent to unfertilized plot

from one plot to another as transplanters pass through the field (Table 5).

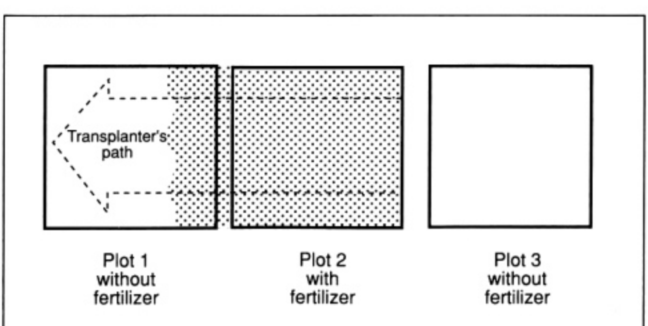
**Preventing or minimizing border effects.** Border effects can be avoided or minimized in several ways.

■ Avoid the use of all unplanted alley to separate experimental plots. If an unplanted alley is needed, it should not be wider than 40 cm.

■ Because unplanted borders around an experiment are generally wider than those between plots, plant a few rows of a uniform border variety around the perimeter of an experiment to minimize the effect of unplanted borders on plots located along the sides of the field.

■ When varieties to be tested vary greatly in plant height, tillering ability, or growth duration, choose an experimental design that groups homogeneous varieties, particularly by height. This will reduce the number of rows needed as borders against varietal competition effect.

■ Construct a levee (bund) between plots receiving different fertilizer treatments.




If transplanters move from a fertilized to unfertilized plot, they may inadvertently move some of the fertilizer.

■ If fertilizer is applied before transplanting, avoid placing plots receiving widely different fertilizer levels along the path of transplanters.

**Coping with border effects.** Do not measure agronomic characters, grain yield, or yield components from border rows that are likely to have border effects. How many rows to exclude depends on the type of border effects. When in doubt and when the plot size is large enough, exclude at least two border rows (or two end hills) or a 30-cm area on each side of the plot.

# 8 MISSING HILLS

In transplanted rice, a missing hill refers to the spot where a hill of transplanted seedlings died before maturity.

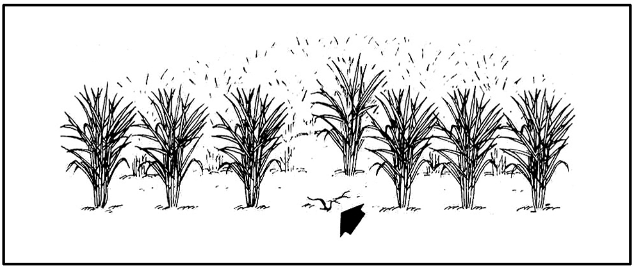
**Effects of missing hills.** The presence of a missing hill means that not all hills in the plot have been subjected to the same plant spacing and plant competition. In experimental plots, rice plants immediately adjacent to a missing hill perform differently than normal hills (hills surrounded by living hills). These hills generally grow more vigorously and yield more than normal hills. The magnitude of yield increase or the degree of yield compensation, however, differs with variety, plant spacing, fertility level, and crop season (Table 6).

Thus, the occurrence of missing hills poses two major problems: How to determine yield of plots with one or more

**Table 6. Percentage increase in grain yield of hills surrounding a missing hill, for two varieties, two plant spacings, and two fertilizer treatments. IRRI, 1970.**

| Distance from the missing hill (cm) | Yield increase (%) | | | |
|---|---|---|---|---|
| | IR22 | | IR127-80-1 | |
| | 0 kg/ha N | 120 kg ha N | 0 kg/ha N | 120 kg/ha N |
| | *Dry season* | | | |
| 20 | 39** | 40** | 17** | 26** |
| 25 | 23** | 22** | 19** | 19** |
| | *Wet season* | | | |
| 20 | 29** | 18** | 28** | 21** |
| 25 | 25** | 8 | 19** | 10 |

** Significant at the 1% level.



Missing hill.

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 percent 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.

**Minimizing missing hills.** Several practices can reduce the percentage of missing hills that occur in rice experimental plots.

*Level the field thoroughly.* This practice ensures a uniform water level which prevents killing of hills with too much or too little water.

*Handle the seedlings with care.* When pulling seedlings from the seedbed, exercise great care to minimize damage to the seedlings, especially from wilting. Keep the roots of seedlings waiting to be transplanted thoroughly buried in mud.

*Use young and healthy seedlings.* Discard weak and damaged seedlings at transplanting. For the ordinary wetbed nursery, 18-day-old or 21-day-old seedlings should be transplanted. The use of too young or too old seedlings can result in a high mortality rate.

*Use trained transplanters.* Untrained transplanters tend to break seedlings while transplanting and are generally not able to maintain a uniform depth of planting.

*Protect plants against pests and diseases.* Many missing hills are caused by pest and disease infestation.

*Replant dead hills.* To be effective, replanting must be done properly (see chapter 9).

# 9 REPLANTING DEAD HILLS

To reduce the percentage of missing hills in experimental plots, dead hills are generally replanted. Questions that are commonly raised: Does the replanted hill perform normally? For how long should replanting be carried out? What type of replanting material should be used?

**Effect of replanting.** Regardless of when the replanting is done or what type of replanting material is used, replanted hills perform differently from normal hills. The grain yield of the replanted hill is lower than that of the normal hills, even if replanting is done as early as 5 days after transplanting (Table 7). The later the replanting is done, the higher the reduction in yield. For best results use plants thinned from border hills for replanting. Replanting with seedlings taken from the original seedbed gives poor results.

**Purpose of replanting.** Since replanted hills perform differently from normal hills, they can not be included in the harvest

**Table 7. Grain yield of a replanted hill (variety IR5) as compared with the normal hills (fertilized), for different times of replanting and different sources of replanting material. IRRI, 1971 dry season.**

| Replanting (days after transplanting) | Yield (g/hill) | | |
|---|---|---|---|
| | Seedlings from original seedbed | Seedlings left at ends of rows | Seedlings thinned from border hills |
| 5 | 20.5** | 21.6** | 24.1* |
| 7 | 21.0** | 21.2** | 25.0 |
| 9 | 21.1** | 22.0** | 26.4 |
| 13 | 9.7** | 18.3** | 22.9** |
| 15 | 6.9** | 11.4** | 15.8 |
| 23 | 3.2** | 6.0** | 9.2** |
| Normal hills | 27.3 | 26.5 | 28.2 |

*Significantly different from the normal hills at the 5% level. **Significantly different from the normal hills at the 1% level.

or in the measurement of any agronomic character. But replanting, if done properly, can protect the surrounding hills. that is, it keeps surrounding hills from performing abnormally. On the other hand, if dead hills are not replanted, the surrounding hills will be affected and hence must be excluded from harvest (see chapter 8). Thus replanting dead hills greatly minimizes the reduction in the number of hills harvested.

**Recommended procedure for replanting.** All hills that die earlier than 3 weeks after transplanting should be replanted to keep the performance of the surrounding hills normal.

For replanting material, use plants thinned from border hills, especially those bordering an unplanted space. Where thinning from border hills does not provide sufficient replanting material, use seedlings left in bunches at the ends of rows. Each bunch should not contain more than 10 to 15 seedlings.

Mark all replanted hills and exclude them from measurements of grain yield, yield components, and agronomic characters.

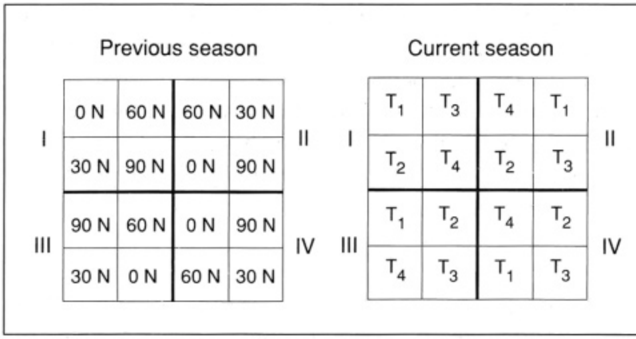
# RESIDUAL EFFECT OF FERTILIZER 10

Residual effect of fertilizer refers to the effect, on the current crop, of fertilizer applied to previous crops.

**Influence of residual fertilizer.** The residual effect of fertilizer can greatly affect yields. In one experiment at the IRRI farm a 13 percent increase in yield was caused by the application of 120 kg/ha of nitrogen to the previous crop (Table 8). If not properly controlled, the residual effect of fertilizer may cause bias in the experimental results and increase the magnitude of experimental error.

**Table 8. Performance of IR22 plants (unfertilized) grown in areas fertilized with different nitrogen rates in two preceding seasons. IRRI, 1971 dry season.**

| Nitrogen applied preceding seasons (kg/ha) | Grain yield (t/ha) | Plant ht (cm) | Panicles (no./hill) | Filled grains (no./panicle) |
|---|---|---|---|---|
| 0 | 3.64 | 73.9 | 9.3 | 62.8 |
| 60 | 3.75 | 74.0 | 9.5 | 62.9 |
| 120 | 4.10 | 75.0 | 10.1 | 68.2 |
| LSD (5%) | 0.32 | n.s. | n.s. | 4.6 |




**Example of blocking to avoid residual effect of fertilizer. Fertilizer trial in previous seasons had four rates of nitrogenarranged in a randomized complete block design with four replications. For an experiment in the current season, involving four treatments, the previous rates of fertilizer application can be used as the bases for double grouping in conjunction with a latin square design.**

**Preventing residual effect of fertilizer.** Several things can be done to prevent residual effect of fertilizer. Avoid using fields that were used forafertilizer trial in the previous season. If possible, iet the soil dry out before planting the succeeding crop. To improve soil uniformity, grow a unifonn crop with close spacing and a low fertilizer level.

**Coping with residual effect of fertilizer.** If you must use the problem area immediately, choose an experimental design that allows for additional "blocking" based on the levels of nitrogen applied in the previous season.

# 11 RESIDUAL EFFECT OF UNPLANTED ALLEYS

In rice experiments, it is not uncommon for plots to be separated by unplanted alleys. These alleys facilitate the application of certain treatments and the gathering of data. At times the alleys may also reduce the effects of interplot competition. But plants grown in previously unplanted areas may perform differently from those grown on a continually cropped area. This phenomenon is referred to as residual effect of unplanted alleys.

**Influence of residual effect of unplanted alleys.** Plants grown in previously unplanted areas perform better than those grown in continually cropped areas (Table 9). Hence, unplanted alleys are a possible source of additional soil variabil-

Table 9. Performance of IR22 grown on previously planted and unplanted areas. IRRI, 1970 dry season.

| Type of area | Grain yield (t/ha) | Plant ht (cm) | Panicles (no. hill) |
|---|---|---|---|
| Previously unplanted | 7.41 | 89.1 | 15.5 |
| Previously planted | 6.42 | 88.0 | 14.0 |
| Difference | 0.99** | 1.1* | 1.5** |

*Significant at the 5% level. **Significant at the 1% level

ity and, hence, of additional error for experiments in succeeding crops.

**Minimizing residual effect of unplanted alleys.** In experimental fields that are to be cropped successively avoid separating plots with unplanted alleys. One way is to lay out the plots so they are next to each other without an alley in between. Because interplot competition may be higher when plots are immediately next to each other the plot size can be increased to provide one or two extra rows as borders. Another way to eliminate unplanted alleys is to plant a common variety between all plots. The variety planted between plots will serve as a marker to visually separate adjacent plots.

When unplanted alleys have been used in the previous season, make a uniform planting if possible in the whole area with close spacing and low fertilizer level for at least one crop season before conducting any experiment there.

If you cannot avoid using unplanted alleys and the area is also needed for immediate planting, keep size and location of the alleys fixed in succeeding experiments.

# NUMBER OF SEEDLINGS PER HILL 12

Rice researchers use varying number of plants per hill, except when they want to measure tillering capacity (for which one plant per hill is necessary). They often ask, however: (1) Does it matter if a varying number of plants per hill is used in an experiment? (2) If the same number of plants per hill should be used throughout the experiment, what is the optimum number?

**Effect of variable number of plants per hill.** Grain yield and many yield components vary with the number of plants per hill (Table 10). Thus, the use of a variable number of plants per hill

**Table 10. Grain yield and yield components of IR127-80-1 (90kg/ha N) as affected by the number of plants per hill. IRRI, 1971 wet season.**

| Plants (no./hill) | Yield (t/ha) | Panicles (no./hill) | Filled grains (no /panicle) | Unfilled grains (%) | Panicle length (cm) |
|---|---|---|---|---|---|
| 1 | 2.87 | 4.4 | 161 | 45.7 | 22.0 |
| 2 | 3.52 | 5.8 | 146 | 43.3 | 21.6 |
| 3 | 2.93 | 5.9 | 110 | 45.9 | 20.6 |
| 4 | 3.56 | 8.0 | 108 | 34.3 | 19.5 |
| 6 | 3.76 | 7.4 | 116 | 36.1 | 19.5 |
| LSD (5%) | 0.52 | 1.5 | 24 | n.s. | 1.3 |

**Table 11. Percentage of missing hills as affected by the number of plants per hill. IRRI, 1971 dry season.**

| Plants (no./hill) | Missing hills (%) | | | | |
|---|---|---|---|---|---|
| | 0 kg/ha N | | 120 kg/ha N | | Mean[a] |
| | IR127-80-1 | IR844-86-1 | IR127-80-1 | IR844-86-1 | |
| 1 | 27.1 | 13.8 | 24.3 | 11.9 | 19.3 a |
| 2 | 16.6 | 11.9 | 13.3 | 7.1 | 12.2 b |
| 3 | 11.8 | 8.8 | 14.2 | 5.1 | 10.0 b |
| 4 | 8.8 | 10.1 | 8.3 | 2.2 | 7.3 c |
| 6 | 6.4 | 11.4 | 7.2 | 1.8 | 6.7 c |

[a]Any two means followed by the same letter are not significantly different at the 5% level.

in a plot can be expected to increase the variability among hills, thereby requiring a larger sample size for measuring various rice characters.

**Recommended number of seedlings per hill.** Unless tillering capacity is to be assessed. avoid using one plant per hill since it gives a very high occurrence of missing hills (Table 11). In general, use two to four seedlings per hill. Plant the same number of seedlings per hill throughout the whole experiment.

# 13 OFF-TYPES

Off-types are plants whose genotypes differ from those of the majority of plants in the plot. They result from unpurified seed stocks or from volunteer plants that sprout from seeds dropped from the previous crop.

**Effect of off-types.** The presence of off-types increases heterogeneity among plants in a plot and introduces undesirable plant competition. Since their presence is usually de-

Off-type.

tected at later stages when the difference in certain plant characters is clearly seen, a remedial operation cannot be performed early.

**Preventing off-types.** To keep fields free of off-types.

- Seeds for planting should come from a purified seed stock.
- Seedbeds must be free of dropped seeds.
- When several varieties are involved, seedbeds of the individual varieties should be distinctly separated.
- Volunteer plants from previous rice crops should be destroyed before and after transplanting.

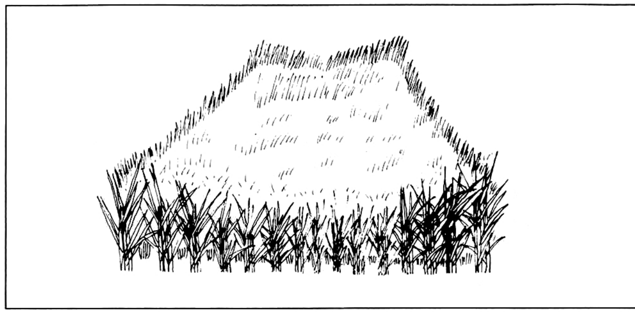
**Coping with off-types.** When you notice off-types earlier than 3 weeks after transplanting, rogue (pull out the off-types) and replant. Follow the procedures for replanting dead hills outlined in chapter 9.

If you notice off-types later than 3 weeks after transplanting, do not rogue; simply mark or tag the off-types so that they can be excluded from harvest and from measurements of any agronomic character. At harvest remove the off-types and determine plot yield by adjusting grain weight to the same number of hills as that of the normal plots (see chapter 17 for computational procedure).

# PEST AND DISEASE DAMAGE 14

While experimental field plots usually get maximum protection against pests and diseases, occasional damage cannot be totally avoided.

Seedlings near the edge of the seedbed tend to be larger than the rest.



**Effect on experiment.** Damage from pests and diseases usually occurs in spots, resulting in an increase in variation both among plots and within plots and, consequently, in experimental error. Moreover, the nonuniformity of the incidence can greatly affect the treatment comparisons.

**Minimizing effects of damage.** When a plot is damaged, do not take samples from plants damaged by pests and diseases for measuring any agronomic character (unless your objective is to evaluate damage).

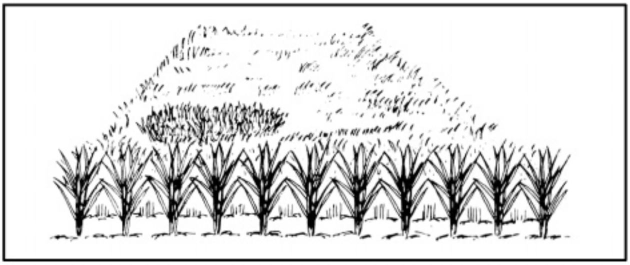
When incidence in each plot does not involve a large number of plants, say, when not more than 20 percent of the plants in any plot is damaged, exclude damaged plants from the harvest of each plot. Later, convert the grain weight of each plot based on the number of hills in the normal plots (see chapter 17).

When only a few plots are heavily damaged, do not collect samples from these plots. They should be treated as "missing data" when the data are analyzed.

When damage is moderate to heavy, quite nonuniform from plot to plot, and measurable, harvest all plants in each plot in the usual manner. Collect data on pest and disease incidence for every plot. Use covariance analysis with the data on the incidences as covariates.

# 15 MINOR SOURCES OF VARIATION

Minor sources of variation should be controlled if you want a high degree of precision and if you can afford the cost.



**Dung from carabaos used during land preparation can increase soil heterogeneity in a field with low fertility.**

**Application of fertilizer.** Variability is generally higher in fertilized fields than in unfertilized fields primarily because of nonuniform application of fertilizer. Several things to keep in mind:

■ Do not apply fertilizer to compensate for areas of the field that have seemingly poor fertility.

■ Fertillizer applied to a small plot tends to concentrate in the center of the plot because operators generally try not to spill the fertilizer outside the area specified.

■ When fertilizer is to be applied to a large field, the field can first be divided into smaller sections and the amount of fertilizer to be applied can be computed for each subsection separately. This results in more uniform application.

**Choice of seedlings.** Seedlings raised in any type of seedbed, generally vary in vigor. Seedlings located along the perimeter are usually bigger than those in the center. Choosing uniform seedlings for transplanting can increase the homogeneity of plants in the field. To ensure sufficient seedlings, raise more seedlings than you need.

**Carabao dung.** Carabao (water buffalo) dung causes additional soil heterogeneity. In fields with low fertility, it usually results in a circular spot of very vigorous plants. When carabaos are used to prepare the land, dung should be removed from the experimental area.

# 16 PLOT SAMPLING

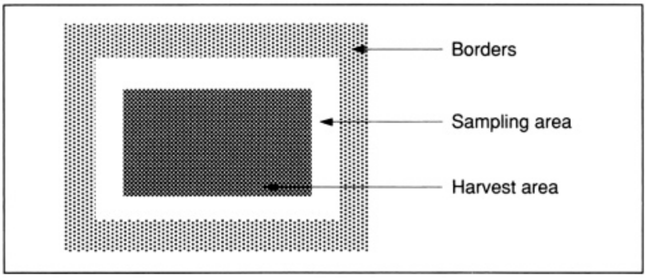
A sampling method is a procedure for selecting a fraction of a total population to represent that population accurately. When the total population to be sampled is an experimental plot as in replicated field trials, the sampling procedure is referred to as plot sampling. A plot sampling technique is 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.

**What plot sampling involves.** A sampling method specifies (1) the sampling unit—the unit upon which measurements are to be made (commonly used sampling units in rice experiments are a single hill, four adjacent hills, a 1-sq-m area, a panicle); (2) the method of selecting the sampling units from a plot; and (3) the sample size—the number of sampling units to be taken from each plot.

**What you should know about plot sampling.** Although it is most 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. When several characters to be measured require different sampling schemes, a compromise may be necessary.

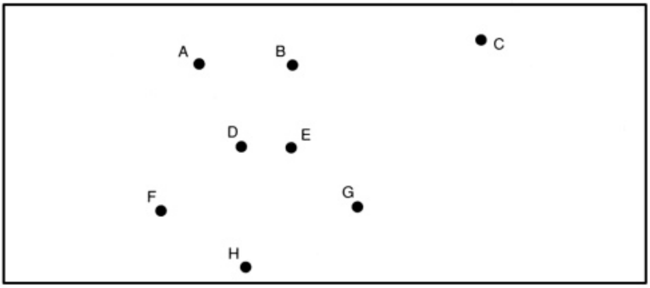
Whenever possible, select sampling units at random. The same random units can be used for all plots in the same replication. Different sets of random units, however, must be used for different replications. For randomization technique see chapter 5.

**When sampling requires destruction of plants or frequent trampling of plots reserve the center portion of the plot for harvesting and sample in the rest of the plot, excluding border rows.**

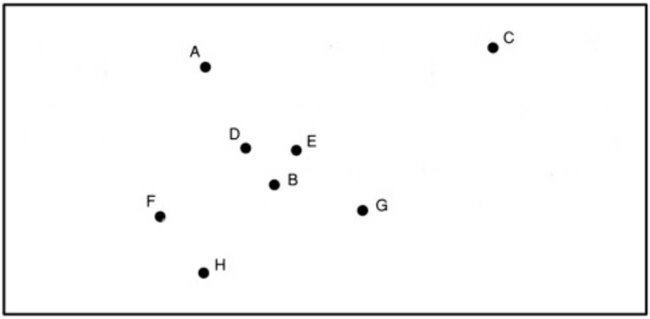


When your sampling procedure requires the destruction of sample plants and frequent trampling of the plots, you may wish to separate the sample area from the rest of the plot. You can do this provided that the two areas are uniform and that randomization is still used in the sampling area. A common practice is to leave an area in the center of the plot for harvesting and use the surrounding areas for sampling.

For measuring the same character, say, height, at different growth stages, use the same sample plants at all stages of observation. If sampling is very frequent, change one-third (or one-fourth) of the samples at each stage of measurement to avoid possible effects from frequent handling of the sample plants. For example, in measuring plant height using eight sample hills per plot, the randomization at the first stage of observation may give the following positions of sample hills:




For the second stage of observation, retain six of the first eight sample hills and apply randomization technique to select two additional hills. The set of eight sample hills for the second stage of observation may be:




Hills B and H are the two newly selected hills.

For suggested sampling unit and sample size for a particular character, see chapters 17 to 22.

# 17 MEASURING GRAIN YIELDS

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 percent moisture.

**How to measure grain yield.** After discarding border areas on all four sides of a plot (see chapter 7 for appropriate size of border areas), harvest as large an area as possible. For reliable results, 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 percent 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. The coefficient $A$ can be read directly from Appendix Table 2 or computed:

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

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 (see chapter 8). When off-types are present, remove all of them from the harvest (see chapter 13). 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 percent,

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

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.

Do not harvest any plot in which the number of hills has been reduced by more than 20 percent. Treat such a plot as "missing data" when the data is analyzed.

**Handling damage from pests and diseases.** Sometimes factors you cannot control cause damage but have nothing to do with the treatments, as when plants are damaged by rats. When that occurs one approach is to exclude all damaged plants from the harvest and adjust grain weight of each plot based on the number of hills in the normal plots (see above formula), provided that the reduction of the number of hills in the plot is not more than 20 percent. Another approach is to measure the damage in each plot before harvesting all of each plot including damaged plants (see chapter 14). Apply covariance technique with the measure of damage as covariate.

When in doubt, consult a statistician.

**When plants are destroyed in previous sampling.** Make sure that the harvest area does not include plants adjacent to areas left empty from sampling for characters whose measurement involved destruction of plants at early growth stages.

# MEASURING PLANT HEIGHT AND TILLERNUMBER 18

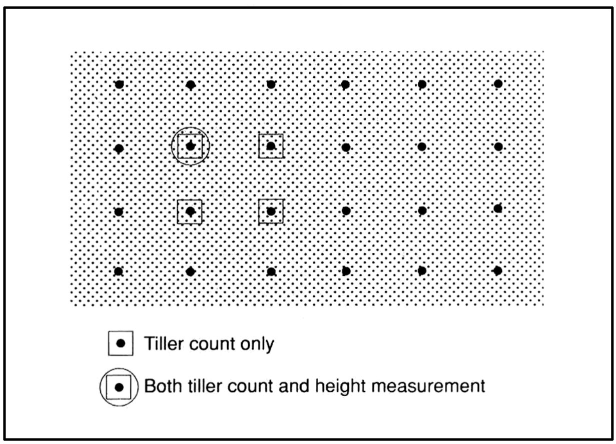
For seedlings or juvenile plants, *plant height* is the distance from ground level to the tip of the tallest leaf. For mature plants, it is the distance from ground level to the tip of the tallest panicle. Tiller number is the number of tillers per unit area or the number of tillers per plant when single-plant hills have been used. At harvest, tillers can be separated into productive and unproductive tillers.

**Sampling.** For plant height measurement, a single-hill sampling unit is optimum; for tiller count, a two-hill x two-hill sampling unit is optimum (Table 12). Since the two characters are usually measured at the same time, a two-hill x two-hill

**Table 12. Comparable variance, expressed as percentage of the mean, among sampling units of different sizes and shapes for measuring plant height and tiller number, under different fertilizer treatments.**

| Sampling unit (hill × hill) | Coefficient of variation (%) | | | |
|---|---|---|---|---|
| | Plant ht | | Tiller no. | |
| | 0 kg/ha N | 120 kg/ha N | 0 kg/ha N | 120 kg/ha N |
| 1 ´ 1 | 4.4 | 3.1 | 33.6 | 31.8 |
| 1 ´ 2 | 4.9 | 3.4 | 33.4 | 31.4 |
| 1 ´ 3 | 4.8 | 3.7 | 30.3 | 31.2 |
| 1 ´ 4 | 5.6 | 3.8 | 28.3 | 30.1 |
| 2 ´ 2 | 5.6 | 3.8 | 26.2 | 29.5 |

sampling unit should be used. Count tillers on all four hills of each unit but measure plant height on only one hill per unit:




For plant height, the coefficient of sampling variation is slightly higher at early growth stages, but the difference is not appreciable. For tiller number, the coefficient of sampling variation does not vary with the growth stage (Table 13). Thus, the same sample size can be used at all growth stages.

Fertilizer application causes a small increase in the coefficient of sampling variation of tiller number but not in that of plant height. Thus, to obtain the same degree of precision, a slightly larger sample size may be required for tiller count in fertilized plots than in unfertilized plots.

Sample size, or the number of two-hill x two-hill sampling units to be taken per plot, for varying degrees of precision desired can be determined from Table 14. Usually three two-hill x two-hill sampling units per plot (giving a total of 12 hills for tiller count and three hills for plant height) are sufficient.

**Table 13. Coefficients of variation among two-hill × two-hill sampling units for plant height and tiller number, under different fertilizer treatments,**

| Growth stage (days after transplanting) | Coefficient of variation (%) | | | |
|---|---|---|---|---|
| | Plant ht | | Tiller no | |
| | 0 kg ha N | 120 kg/ha N | 0 kg/ha N | 120 kg/ha N |
| 30 | 66 | 56 | 10.1 | 14.0 |
| 44 | 68 | 49 | 10.3 | 10.6 |
| 58 | 46 | 50 | 10.2 | 11.1 |
| Harvest | 49 | | 4210.8 | 11.8 |

**Table 14. Estimated standard error of a plot mean for the measurement of plant height and tiller number for different sample sizes based on two-hill × two-hill sampling units[a].**

| Sample size | Standard error (%) | |
|---|---|---|
| | Plant ht | Tiller no |
| 2 | 3.1 | 8.7 |
| 3 | 2.5 | 7.1 |
| 4 | 2.2 | 6.2 |
| 5 | 2.0 | 5.5 |
| 6 | 1.8 | 5.0 |
| 7 | 1.6 | 4.7 |
| 8 | 1.5 | 4.4 |

[a]Plant height is measured from only one hill out of each two-hill x two-hill sampling unit selected, while tiller count is made on all four hills per unit. [b]No. of two-hill x two hill sampling units per plot

When measurements are to he made at various growth stages to examine the growth pattern, use the same sample plants for all stages. That is, there is no need to select new sampling units at each growth stage. If sampling is very frequent, change a fraction of the samples at each growth stage to avoid possible effects from frequent handling of the sample plants (see chapter 16).

Measurements of tiller number and especially of plant height can be greatly affected by observers. Try to avoid changing observers from plot to plot within a block. If you must change observers, change them from block to block (see chapter 4).

# MEASURING YIELD COMPONENTS 19

Some important yield components of rice are *panicle number*—the number, at maturity, of fully exserted and grain-bearing panicles per plant or per unit area; *number of filled grains per panicle*—the average number of fully developed grains per panicle; *percentage of unfilled grains*—the proportion of poorly developed or totally undeveloped grains: *grain*

**Table 15. Estimated standard error of a plot mean for measuring yield components for different sample sizes based on two-hill × two-hill sampling unit.**

| Sample size[a] | Standard error (%) | | | |
|---|---|---|---|---|
| | No. of panicles | No. of filled grains per panicle | Percentage unfilled grains | 100-grain wt |
| 2 | 8.7 | 4.3 | 10.1 | 1.7 |
| 3 | 7.1 | 3.6 | 8.2 | 1.4 |
| 4 | 6.2 | 3.1 | 7.1 | 1.2 |
| 5 | 5.5 | 2.8 | 6.4 | 1.1 |
| 6 | 5.0 | 2.5 | 5.8 | 1.0 |
| 7 | 4.7 | 2.3 | 5.4 | 0.9 |
| 8 | 4.4 | 2.2 | 5.0 | 0.9 |

[a]No. of two-hill × two-hill sampling units per plot.

weight—the weight of fully developed grains, commonly reported on the basis of 100 grains or 1,000 grains.

**How to measure yield components.** First, select at random $n$ two-hill × two-hill sampling units from the test area (excluding borders) of each plot. These sample hills must not be hills that were replanted or that are adjacent to a missing hill. Table 15 shows number of sampling units, $n$, to be taken for a specific degree of precision for each character. Usually, $n = 3$ (12 hills per plot) gives an adequate level of precision for most commonly measured yield components.

Second, count the total number of panicles ($P$) from all sample hills.

Third, from each sample hill, separate the center or middle panicle (based on height of the individual tillers) from the rest of the panicles.

Fourth, thresh and bulk the grains from the center panicles from all sample hills and separate the filled grains from the unfilled grains. To separate unfilled grains from filled grains, use a seed separator, the salt-water (sp gr 1.06) method, or the manual method. Count the filled grains ($f$) and the unfilled grains ($u$) and weigh the filled grains ($w$).

Fifth, thresh the grains from the rest of the panicles of all sample hills and separate unfilled grains from the filled grains. Then count the unfilled grains ($U$) and weigh the filled grains ($W$).

Sixth, compute the number of panicles per hill, number of filled grains per panicle, percentage of unfilled grains, and 100-grain weight:

$$\text{No. of panicles/hill} = \frac{P}{4n}$$

$$\text{No. of filled grains/panicle} = \frac{f}{w} \times \frac{W + w}{P}$$

$$\text{Percentage of unfilled grains} = \frac{U + u}{f(W + w)/W + U + u} \times 100$$

$$\text{100-grain wt} = \frac{w}{f} \times 100$$

**Pointers.** Weigh the filled grains in the fourth and fifth steps simultaneously to ensure that the grains of the two parts have a similar moisture content.

If you are determining yield components to compare computed yield with measured yield, in addition to obtaining the weight of filled grains in the fifth step, determine the percentage of moisture content of the filled grains ( $M$ ). Then at 14 percent moisture

$$\text{100 grain wt} = \frac{100 - M}{86} \times \frac{w}{f} \times 100$$

When a seed counter is available, you can count filled grains of all sample hills without having to take sub-samples of middle panicles, as was done in the third and fourth steps.

# MEASURING LEAF AREA INDEX 20

The leaf area index (LAI) is the area of the leaf surface per unit area of land surface. Methods of measuring LAI are given for two conditions, one in which leaves are not removed from plants, and another in which leaves are removed.

**Measuring LAI with leaves not removed from plants.** Select at random $n$ hills from each plot, making sure that each hill is surrounded by living hills. The values of $n$ for any specific degree of precision are given in Table 16. In general. $n$ = 10 is sufficient.

**Table 16. Estimated standard error of a plot mean (not including measurement error) for measuring leaf area index for varying sample size.**

| Sample Size [a] | Standard error (%) | |
|---|---|---|
| | Unfertilized | Fertilized |
| 2 | 20.2 | 30.0 |
| 3 | 16.4 | 24.5 |
| 4 | 14.2 | 21.2 |
| 5 | 12.7 | 19.0 |
| 6 | 11.6 | 17.3 |
| 7 | 10.8 | 16.1 |
| 8 | 10.1 | 15.0 |
| 9 | 9.5 | 14.2 |
| 10 | 9.0 | 13.4 |
| 12 | 8.2 | 12.3 |
| 14 | 7.6 | 11.4 |

[a]No. of hills per plot. To take care of a higher measurement error when leaves are not removed a slightly larger sample size is required.

Count the tillers for each sample hill in each plot.

Measure the length and maximum width of each leaf on the middle tiller and compute the area of each leaf based on the length-width method:

$$\text{Leaf area} = K \times l \times w$$

where $K$ is the "adjustment factor." $l$ is the length, and $w$ is the width. The value of $K$ varies with the shape of the leaf which in turn is affectedby the variety, nutritional status, andgrowth stage of the leaf. Under most conditions, however, the value 0.75 can be used for all stages of growth except the seedling stage and maturity for which the value 0.67 should be used.

Compute the leaf area per hill and leaf area index:

$$\text{Leaf area hill} = \text{total leaf area of middle tiller} \times \text{total number of tillers}$$

$$\text{LAI} = \frac{\text{Sum of leaf area/hill of } n \text{ sample hills (sq cm)}}{\text{area of land covered by } n \text{ hills (sq cm)}}$$

**Measuring LAI with leaves removed from plants.** Select at random $n$ hills from each plot, making sure that the hills are surrounded by living hills. The values of $n$ for any specific degree of precision are given in Table 16. In general, $n = 8$ is sufficient.

For each plot remove the sample hills from the soil.

From each sample hill, separate the middle tiller from the rest of the tillers. Remove all green leaves from the selected tiller. Make sure the leaves do not dry and curl before their leaf areas are measured. To avoid drying and curling, place the sample leaves in a test tube containing a small amount of water. Measure the area of the leaves. With an automatic area meter. you can read all leaves from each sample tiller together. With the length-width method, however, you should obtain the area for each leaf separately. Dry the leaves and weigh.

Remove leaves from the rest of the tillers in the sample hills and obtain their dry weight.

Compute leaf area per hill and leaf area index:

$$\text{Leaf area/hill} = \frac{aW}{w}$$

$$\text{LAI} = \frac{\text{Sum of leaf area/hill of } n \text{ sample hills (sq cm)}}{\text{area of land covered by } n \text{ hills (sq cm)}}$$

where $a$ is the total area of sample tiller, $w$ the dry weight of leaves from sample tiller, and $W$ the dry weight of all leaves in the hill (including those from the sample tiller).

# MEASURING STEM BORER INCIDENCE

# 21

Stem borer incidence is generally determined from the presence in the plot of dead hearts or white heads or both. *Dead hearts* are young tillers that turn brown and die before producing heads. They indicate borer damage during the vegetative phase of the plant. *White heads* are culms with whitish panicles that remain upright. Most grains in these panicles are empty. The incidence of either dead hearts or white heads is generally measured as a percentage.

**Measuring incidence by complete enumeration on infested hills.** Count the number of infested and uninfested tillers in all infested hills in a plot. Then select a sample of 10 uninfested hills and count the tillers.

Compute the percentage incidence ( $P$ ) of the plot:

$$P = \frac{I}{nx + (N-n)y} \times 100$$

where $I$ is the total number of infested tillers from all infested hills, $x$ the average number of tillers per hill from all infested hills, $y$ the average number of tillers per hill from 10 uninfested hills, $n$ the total number of infested hills, and $N$ the total number of hills (infested and uninfested) in a plot.

**Measuring incidence by sampling infested hills.** When resources are limited and complete enumeration of all infested hills in a plot is not feasible, make observations only on every other two rows in a plot. Count the number of infested and uninfested tillers in all infested hills from each two-row unit. Then select a sample of 10 uninfested hills and count the tillers.

Percentage incidence of the plot is computed as before with $N$ as the total number of hills in all the rows examined.

NOTE: The above procedures can also be used for measuring gall midge incidence.

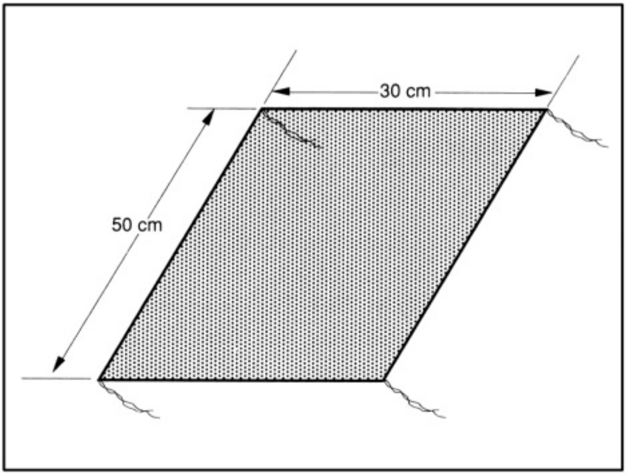
# 22 SAMPLING IN BROADCAST RICE

The greatest difficulty in sampling in broadcast rice plots lies in the identification of sampling units. In transplanted rice, the sampling unit used is based on hills which is not applicable to broadcast rice. In broadcast rice, the sampling unit must be identified in terms of area. But demarcating sampling areas for measuring various rice characters is an additional problem.

The nonuniform plant density in broadcast rice plots also causes higher variability than in transplanted rice. Thus, for most characters the sample size in broadcast rice should be larger than in transplanted rice.

**How to sample broadcast rice.** For grain yield in a broadcast plot, *just before seeding* outline the desired harvest area in the center of the plot with four small stakes connected with string. The string should be tied flush with the soil to avoid any effect on the seeding operation. Thus the string should be durable enough to withstand being covered with mud for the entire crop season. At maturity, harvest all plants in the demarcated area of each plot.

For other plant characters, construct rectangular wire frames, each 50 × 30 sq cm. Place three to four frames at random in




**Wire frame tor sampling agronomic characters, other than yield, in broadcast rice plots.**

each plot *just before seeding.* Various characters, such as tiller count and plant height, can be measured from plants within these units. If measurements are to be made at early growth stages, place these frames at random just outside the harvest area to prevent trampling of the harvest area.

# SAMPLING FOR PROTEIN DETERMINATION

# 23

The measurement of protein content consists of the sampling procedure for selecting the sample grains and the chemical analysis of the selected grains. Since only a small sample is used in the chemical analysis, the sample must be properly selected.

**Selection of sample grains.** For protein analysis of individual plants, take the sample after all grains have been threshed and bulked. Do not sample panicles. For protein analysis of whole plots, take sample grains from the bulk harvest used for plot yield determination. Do not take hill samples.

**Size of sampling unit.** Use 100-grain (or 2-gram) samples and make two determinations per sample. When you only have a grinder with small capacity, 10-grain samples can be used. If you use a 10-grain sample, analyze at least two separate 10-grain samples, without duplicate analysis. Do not use a sample size smaller than 10 grains under any circumstances.

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**Appendix Table 1. Random numbers.**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 14620 | 95430 | 12951 | 81953 | 17629 | 83603 | 09137 | 26453 | 02148 | 30742 |
| 09724 | 85125 | 48477 | 42783 | 70473 | 52491 | 66875 | 93650 | 91487 | 37190 |
| 56919 | 17803 | 95781 | 85069 | 61594 | 85437 | 92086 | 53045 | 31847 | 36207 |
| 97310 | 78209 | 51263 | 52396 | 82681 | 82611 | 70858 | 78195 | 47615 | 23721 |
| 07585 | 28040 | 26939 | 64531 | 70570 | 98412 | 74070 | 83468 | 18295 | 32585 |
| 25950 | 85189 | 69374 | 37904 | 06759 | 70799 | 59249 | 63461 | 75108 | 45703 |
| 82973 | 16405 | 81497 | 20863 | 94072 | 83615 | 09701 | 47920 | 46857 | 31924 |
| 60819 | 27364 | 59081 | 72635 | 49180 | 72537 | 46950 | 81736 | 53290 | 81736 |
| 59041 | 38475 | 03615 | 84093 | 49731 | 62748 | 39206 | 47315 | 84697 | 30853 |
| 74208 | 69516 | 79530 | 47649 | 53046 | 95420 | 41857 | 69420 | 79762 | 01935 |
| 39412 | 03642 | 87497 | 29735 | 14308 | 46309 | 28493 | 75091 | 82753 | 15040 |
| 48480 | 50075 | 11804 | 24956 | 72182 | 59649 | 16284 | 83538 | 53920 | 47192 |
| 95318 | 28749 | 49512 | 35408 | 21814 | 07564 | 70949 | 50969 | 15395 | 26081 |
| 72094 | 16385 | 90185 | 72635 | 86259 | 38352 | 94710 | 36853 | 94969 | 38405 |
| 63158 | 49753 | 84279 | 56496 | 30618 | 23973 | 25354 | 25238 | 48544 | 20405 |
| 19082 | 73645 | 09182 | 73649 | 56823 | 95208 | 49635 | 01420 | 46768 | 45362 |
| 15232 | 84146 | 87729 | 65584 | 83641 | 19468 | 34739 | 57052 | 43056 | 29950 |
| 94252 | 77489 | 62434 | 20965 | 20247 | 03994 | 25989 | 19609 | 74372 | 74151 |
| 72020 | 18895 | 84948 | 53072 | 74573 | 19520 | 92764 | 85397 | 52095 | 18079 |
| 48392 | 06359 | 47040 | 05695 | 79799 | 05342 | 54212 | 21539 | 48207 | 95920 |
| 37950 | 77387 | 35495 | 48192 | 84518 | 30210 | 23805 | 27837 | 24953 | 42610 |
| 09394 | 59842 | 39573 | 51630 | 78548 | 06461 | 06566 | 21752 | 78967 | 45692 |
| 34800 | 28055 | 91570 | 99154 | 39603 | 76846 | 77183 | 50369 | 16501 | 68867 |
| 36435 | 75946 | 85712 | 06293 | 85621 | 97764 | 53126 | 37396 | 57039 | 06096 |
| 28187 | 31824 | 52265 | 80494 | 66428 | 15703 | 05792 | 53376 | 54205 | 91590 |
| 13838 | 79940 | 97007 | 67511 | 87939 | 68417 | 21786 | 09822 | 67510 | 23817 |
| 72201 | 08423 | 41489 | 15498 | 94911 | 79392 | 65362 | 19672 | 93682 | 84190 |
| 63435 | 45192 | 62020 | 47358 | 32286 | 41659 | 31842 | 47269 | 70904 | 62972 |
| 59038 | 96983 | 49218 | 57179 | 08062 | 25074 | 06374 | 96484 | 59159 | 23749 |
| 62367 | 45627 | 58317 | 76928 | 50274 | 28705 | 45060 | 50903 | 66578 | 41465 |
| 71254 | 81686 | 85861 | 63973 | 96086 | 89681 | 50212 | 92829 | 27698 | 62284 |
| 07896 | 62924 | 35682 | 42820 | 43646 | 37385 | 37236 | 16496 | 51396 | 77975 |
| 71433 | 54331 | 58437 | 03542 | 76797 | 50437 | 13576 | 72876 | 02323 | 95237 |
| 54614 | 19092 | 83860 | 11351 | 32533 | 56032 | 42009 | 49745 | 14651 | 80128 |
| 30176 | 71248 | 37983 | 06073 | 89096 | 43498 | 95782 | 70452 | 90804 | 12042 |
| 79072 | 87795 | 23294 | 61602 | 62921 | 38385 | 69546 | 47104 | 72917 | 66273 |
| 75014 | 96754 | 67151 | 82741 | 24283 | 64276 | 78438 | 70757 | 40749 | 85183 |
| 37390 | 75846 | 74579 | 94606 | 54959 | 35310 | 31249 | 15101 | 95390 | 73432 |
| 24524 | 32751 | 28350 | 43090 | 79672 | 94672 | 07091 | 42920 | 46046 | 38083 |
| 26316 | 20378 | 16474 | 62438 | 42496 | 35191 | 49368 | 30074 | 93436 | 29425 |
| 61085 | 96937 | 02520 | 86801 | 30980 | 58479 | 34924 | 25101 | 87373 | 61560 |
| 45836 | 41086 | 41283 | 97460 | 51798 | 29852 | 47271 | 42480 | 94156 | 49341 |
| 92103 | 19679 | 16921 | 65924 | 12521 | 31724 | 60336 | 01968 | 15971 | 07963 |
| 10317 | 82592 | 65205 | 12528 | 24367 | 15817 | 12479 | 52021 | 02350 | 76394 |
| 39764 | 21251 | 41749 | 43789 | 70565 | 35496 | 87172 | 76830 | 41843 | 83489 |
| 83594 | 95692 | 52910 | 23202 | 93736 | 10817 | 53164 | 10724 | 27035 | 67562 |
| 08087 | 01753 | 01787 | 51631 | 74978 | 79608 | 01242 | 07525 | 72656 | 80854 |
| 57819 | 39689 | 32509 | 87540 | 38150 | 47872 | 14614 | 18427 | 06725 | 69326 |
| 96957 | 81060 | 28587 | 60905 | 67404 | 80450 | 21082 | 16074 | 61437 | 24961 |
| 48426 | 43513 | 82950 | 79838 | 45149 | 07143 | 73967 | 23723 | 06909 | 75375 |

**Appendix Table 1. Continued**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 57856 | 87037 | 57196 | 47916 | 15960 | 13036 | 84639 | 30186 | 48347 | 40780 |
| 61684 | 96598 | 28043 | 25325 | 81767 | 20792 | 39823 | 48749 | 79489 | 39329 |
| 06847 | 83825 | 12858 | 18689 | 41319 | 15959 | 38030 | 80057 | 67617 | 18501 |
| 40810 | 85323 | 18076 | 02821 | 94728 | 96808 | 11072 | 39823 | 63756 | 04478 |
| 06461 | 45073 | 88350 | 35246 | 15851 | 16129 | 57460 | 34512 | 10243 | 47635 |
| | | | | | | | | | |
| 82197 | 35028 | 96295 | 95795 | 76553 | 50223 | 37215 | 07692 | 76527 | 80764 |
| 47430 | 50260 | 03643 | 72259 | 71294 | 69176 | 21753 | 58341 | 07468 | 19219 |
| 25043 | 52002 | 84476 | 69512 | 95036 | 69095 | 96340 | 89713 | 06381 | 61522 |
| 34718 | 11667 | 96345 | 60791 | 06387 | 54221 | 40422 | 93251 | 43456 | 89176 |
| 23965 | 59598 | 09746 | 48646 | 47409 | 32406 | 80874 | 74010 | 91548 | 79394 |
| | | | | | | | | | |
| 67207 | 47166 | 44917 | 94177 | 31846 | 73872 | 92835 | 12596 | 64807 | 23978 |
| 08261 | 71627 | 96865 | 75380 | 42735 | 19446 | 78478 | 35681 | 07769 | 18230 |
| 10289 | 93145 | 14456 | 32978 | 82587 | 64377 | 54270 | 47869 | 66444 | 68728 |
| 75622 | 83203 | 14951 | 46603 | 84176 | 17564 | 53965 | 80771 | 10453 | 87972 |
| 62557 | 05584 | 27879 | 08081 | 01467 | 19691 | 39814 | 66538 | 65243 | 76009 |
| | | | | | | | | | |
| 51695 | 70743 | 68481 | 57937 | 62634 | 86727 | 69563 | 29308 | 51729 | 10453 |
| 54839 | 69596 | 25201 | 56536 | 54517 | 86909 | 92927 | 07827 | 28271 | 52075 |
| 75284 | 36241 | 59749 | 81958 | 44318 | 28067 | 67638 | 72196 | 54648 | 36886 |
| 64082 | 68375 | 30361 | 32627 | 38970 | 82481 | 94725 | 56930 | 34939 | 27641 |
| 94649 | 33784 | 84691 | 48334 | 74667 | 48289 | 29629 | 61248 | 47276 | 76161 |
| | | | | | | | | | |
| 25261 | 28316 | 37178 | 82874 | 37083 | 73818 | 78758 | 97096 | 48508 | 26484 |
| 21967 | 90859 | 05692 | 34023 | 09397 | 55027 | 39897 | 51482 | 81867 | 81783 |
| 63749 | 41490 | 72232 | 71710 | 36489 | 15291 | 68579 | 83195 | 60186 | 78142 |
| 63487 | 42869 | 24783 | 80895 | 78641 | 50359 | 20497 | 91381 | 72319 | 83280 |
| 91729 | 08960 | 70364 | 14262 | 76861 | 06406 | 85253 | 57490 | 80497 | 54272 |
| | | | | | | | | | |
| 38532 | 523'6 | 41320 | 29806 | 57594 | 59360 | 50925 | 18752 | 12856 | 09537 |
| 27650 | 57930 | 25216 | 67180 | 42352 | 41671 | 78178 | 09058 | 42479 | 60463 |
| 68318 | 14851 | 96592 | 44278 | 80631 | 82547 | 39787 | 97394 | 98513 | 29634 |
| 91423 | 83067 | 14837 | 03817 | 21850 | 39732 | 18603 | 27174 | 71319 | 82016 |
| 54574 | 54648 | 29265 | 63051 | 07586 | 78418 | 48489 | 05425 | 27931 | 84965 |
| | | | | | | | | | |
| 93987 | 91493 | 61816 | 09628 | 31397 | 17607 | 57095 | 47154 | 40798 | 06217 |
| 59854 | 13847 | 37190 | 47369 | 39657 | 45179 | 06178 | 58918 | 37965 | 32031 |
| 12636 | 51498 | 34352 | 52548 | 57125 | 24634 | 95394 | 71846 | 98148 | 12839 |
| 04856 | 80651 | 35242 | 60595 | 61636 | 97294 | 56276 | 30294 | 62698 | 47548 |
| 92417 | 96727 | 90734 | 84549 | 04236 | 02520 | 29057 | 22102 | 18358 | 95938 |
| | | | | | | | | | |
| 95723 | 05695 | 64543 | 12870 | 17646 | 25542 | 91526 | 91395 | 46359 | 52952 |
| 14398 | 47916 | 56272 | 10835 | 76054 | 67823 | 07381 | 96863 | 72547 | 29368 |
| 97643 | 48258 | 46058 | 34375 | 29890 | 71563 | 82459 | 37210 | 65765 | 82546 |
| 14020 | 16902 | 47286 | 27208 | 09898 | 04837 | 13967 | 24974 | 55274 | 79587 |
| 38715 | 36409 | 52324 | 96537 | 99811 | 60503 | 44262 | 70562 | 82081 | 64785 |
| | | | | | | | | | |
| 70051 | 31424 | 26201 | 88098 | 31019 | 36195 | 23032 | 92648 | 74724 | 68292 |
| 56602 | 58040 | 48323 | 37857 | 99639 | 10700 | 98176 | 34642 | 43428 | 39068 |
| 69874 | 15653 | 70998 | 02969 | 42103 | 01069 | 68736 | 52765 | 23824 | 31235 |
| 35242 | 79841 | 46481 | 17365 | 84609 | 26357 | 60470 | 35212 | 51863 | 00401 |
| 20364 | 89248 | 58280 | 41596 | 87712 | 97928 | 45494 | 78356 | 72100 | 32949 |
| | | | | | | | | | |
| 16572 | 14877 | 42927 | 46635 | 09564 | 45334 | 63012 | 47305 | 27136 | 19428 |
| 74256 | 15507 | 02159 | 21981 | 00649 | 40382 | 43087 | 34506 | 53229 | 08383 |
| 04653 | 48391 | 78424 | 67282 | 46854 | 61980 | 10745 | 73924 | 12717 | 25524 |
| 32077 | 87214 | 14924 | 45190 | 51808 | 30474 | 29771 | 51573 | 82713 | 69487 |
| 46545 | 23074 | 80308 | 52685 | 95334 | 12428 | 50970 | 47019 | 21993 | 43350 |

**Appendix Table 2. Correction factor, A, for adjustment of grain weight at a given moisture content to grain weight at 14% moisture content.**

| Moisture (%) | A | Moisture (%) | A | Moisture (%) | A | Moisture (%) | A |
|---|---|---|---|---|---|---|---|
| 10.00 | 1.0465 | 12.40 | 1.0186 | 14.80 | 0.9907 | 17.20 | 0.9628 |
| 10.04 | 1.0460 | 12.44 | 1.0181 | 14.84 | .9902 | 17.24 | .9623 |
| 10.08 | 1.0456 | 12.48 | 1.0177 | 14.88 | .9898 | 17.28 | .9619 |
| 10.12 | 1.0451 | 12.52 | 1.0172 | 14.92 | .9893 | 17.32 | .9614 |
| 10.16 | 1.0447 | 12.56 | 1.0167 | 14.96 | .9888 | 17.36 | .9609 |
| 10.20 | 1.0442 | 12.60 | 1.0163 | 15.00 | .9884 | 17.40 | .9605 |
| 10.24 | 1.0437 | 12.64 | 1.0158 | 15.04 | .9879 | 17.44 | .9600 |
| 10.28 | 1.0433 | 12.68 | 1.0153 | 15.08 | .9874 | 17.48 | .9595 |
| 10.32 | 1.0428 | 12.72 | 1.0149 | 15.12 | .9870 | 17.52 | .9591 |
| 10.36 | 1.0423 | 12.76 | 1.0144 | 15.16 | .9865 | 17.56 | .9586 |
| 10.40 | 1.0419 | 12.80 | 1.0140 | 15.20 | .9860 | 17.60 | .9581 |
| 10.44 | 1.0414 | 12.84 | 1.0135 | 15.24 | .9856 | 17.64 | .9577 |
| 10.48 | 1.0409 | 12.88 | 1.0130 | 15.28 | .9851 | 17.68 | .9572 |
| 10.52 | 1.0405 | 12.92 | 1.0125 | 15.32 | .9847 | 17.72 | .9567 |
| 10.56 | 1.0400 | 12.96 | 1.0121 | 15.36 | .9842 | 17.76 | .9563 |
| 10.60 | 1.0395 | 13.00 | 1.0116 | 15.40 | .9837 | 17.80 | .9558 |
| 10.64 | 1.0391 | 13.04 | 1.0112 | 15.44 | .9833 | 17.84 | .9553 |
| 10.68 | 1.0386 | 13.08 | 1.0107 | 15.48 | .9828 | 17.88 | .9549 |
| 10.72 | 1.0381 | 13.12 | 1.0102 | 15.52 | .9823 | 17.92 | .9544 |
| 10.76 | 1.0377 | 13.16 | 1.0098 | 15.56 | .9819 | 17.96 | .9540 |
| 10.80 | 1.0372 | 13.20 | 1.0093 | 15.60 | .9814 | 18.00 | .9535 |
| 10.84 | 1.0367 | 13.24 | 1.0089 | 15.64 | .9809 | 18.04 | .9530 |
| 10.88 | 1.0363 | 13.28 | 1.0084 | 15.68 | .9805 | 18.08 | .9526 |
| 10.92 | 1.0358 | 13.32 | 1.0079 | 15.72 | .9800 | 18.12 | .9521 |
| 10.96 | 1.0353 | 13.36 | 1.0074 | 15.76 | .9795 | 18.16 | .9516 |
| 11.00 | 1.0349 | 13.40 | 1.0070 | 15.80 | .9791 | 18.20 | .9512 |
| 11.04 | 1.0344 | 13.44 | 1.0065 | 15.84 | .9786 | 18.24 | .9507 |
| 11.08 | 1.0340 | 13.48 | 1.0060 | 15.88 | .9782 | 18.28 | .9502 |
| 11.12 | 1.0335 | 13.52 | 1.0056 | 15.92 | .9777 | 18.32 | .9498 |
| 11.16 | 1.0330 | 13.56 | 1.0051 | 15.96 | .9772 | 18.36 | .9493 |
| 11.20 | 1.0326 | 13.60 | 1.0047 | 16.00 | .9767 | 18.40 | .9488 |
| 11.24 | 1.0321 | 13.64 | 1.0042 | 16.04 | .9763 | 18.44 | .9484 |
| 11.28 | 1.0316 | 13.68 | 1.0037 | 16.08 | .9758 | 18.48 | .9479 |
| 11.32 | 1.0312 | 13.72 | 1.0033 | 16.12 | .9753 | 18.52 | .9474 |
| 11.36 | 1.0307 | 13.76 | 1.0028 | 16.16 | .9749 | 18.56 | .9470 |
| 11.40 | 1.0302 | 13.80 | 1.0023 | 16.20 | .9744 | 18.60 | .9465 |
| 11.44 | 1.0298 | 13.84 | 1.0019 | 16.24 | .9740 | 18.64 | .9460 |
| 11.48 | 1.0293 | 13.88 | 1.0014 | 16.28 | .9735 | 18.68 | .9456 |
| 11.52 | 1.0288 | 13.92 | 1.0009 | 16.32 | .9730 | 18.72 | .9451 |
| 11.56 | 1.0284 | 13.96 | 1.0005 | 16.36 | .9726 | 18.76 | .9447 |
| 11.60 | 1.0279 | 14.00 | 1.0000 | 16.40 | .9721 | 18.80 | .9442 |
| 11.64 | 1.0274 | 14.04 | 0.9995 | 16.44 | .9716 | 18.84 | .9437 |
| 11.68 | 1.0270 | 14.08 | 0.9991 | 16.48 | .9712 | 18.88 | .9433 |
| 11.72 | 1.0265 | 14.12 | 0.9986 | 16.52 | .9707 | 18.92 | .9428 |
| 11.76 | 1.0260 | 14.16 | 0.9981 | 16.56 | .9702 | 18.96 | .9423 |
| 11.80 | 1.0256 | 14.20 | 0.9977 | 16.60 | .9698 | 19.00 | .9419 |
| 11.84 | 1.0251 | 14.24 | 0.9972 | 16.64 | .9693 | 19.04 | .9414 |
| 11.88 | 1.0247 | 14.28 | 0.9967 | 16.68 | .9688 | 19.08 | .9409 |
| 11.92 | 1.0242 | 14.32 | 0.9963 | 16.72 | .9684 | 19.12 | .9405 |
| 11.96 | 1.0237 | 14.36 | 0.9958 | 16.76 | .9679 | 19.16 | .9400 |
| 12.00 | 1.0232 | 14.40 | 0.9953 | 16.80 | .9674 | 19.20 | .9395 |
| 12.04 | 1.0228 | 14.44 | 0.9949 | 16.84 | .9670 | 19.24 | .9391 |
| 12.08 | 1.0223 | 14.48 | 0.9944 | 16.88 | .9665 | 19.28 | .9386 |
| 12.12 | 1.0219 | 14.52 | 0.9940 | 16.92 | .9660 | 19.32 | .9381 |
| 12.16 | 1.0214 | 14.56 | 0.9935 | 16.96 | .9656 | 19.36 | .9377 |
| 12.20 | 1.0209 | 14.60 | 0.9930 | 17.00 | .9651 | 19.40 | .9372 |
| 12.24 | 1.0205 | 14.64 | 0.9926 | 17.04 | .9647 | 19.44 | .9367 |
| 12.28 | 1.0200 | 14.68 | 0.9921 | 17.08 | .9642 | 19.48 | .9363 |
| 12.32 | 1.0195 | 14.72 | 0.9916 | 17.12 | .9637 | 19.52 | .9358 |
| 12.36 | 1.0191 | 14.76 | 0.9912 | 17.16 | .9630 | 19.56 | .9353 |