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Field trial manual

Principles, planning and Implementation of Agricultural Field Trials

By Peter Kurt Hansen with staff of the
Shifting Cultivation Research Sub-programme

Shifting Cultivation Research Sub-programme
Lao Swedish Forestry Programme
Luang Prabang, Lao P.D.R
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Preface

This manual introduces the principles and methods of field trial experiments. It was originally intended for staff of the Lao Swedish Forestry Programme and for staff in its associated target districts. Most of these officials have little theoretical and practical experience in carrying out field trials. The manual therefore tries to enable staff to do agricultural experiments without going deeply into theory and advanced methods. The text follows the content of practical training courses I gave to research staff during 1993-95, and the manual is meant as a companion to practical training. The text is kept short to provide an overview of the subject and to make the manual more accessible to staff with no or little experience in field trial research. I have also tried to write in a way that will simplify translation into Lao.

Statitical analysis, trial evaluation and presentation of data are not covered in this manual, but will hopefully be included in a second volume.

I am grateful for comments and suggestions given by staff of the Shifting Cultivation Research Sub-programme and by the Head, Houmchitsavath Sodarak. Houmchitsavath also carried out the difficult task of translating the manual from English to Lao.

Comments from the readers are very much welcome.

Table of Contents

List of Figures

1 Introduction

1.1 Research

Research can be defined as a systematic way of obtaining new or additional information. The various scientific disciplines-(such as physics, agronomy, sociology, etc.) have different methods and approaches to obtain and evaluate data.

Two types of agricultural and forestry research can be distinguished:

– Experimental research, and

– Descriptive research (also called observational or non-experimental research)

Using an experimental approach, the researcher applies various treatment to the object under investigation. All factors except the treatments should ideally be kept equal, so differences in the various groups can be attributed to the treatment.

In descriptive research treatments are not applied to the object under investigation. Instead, the researcher studies the existing conditions that occur, for instance, in a population, in a geographical area or in a field. The research often studies the differences that exist within or between the investigated objects. This may be differences between samples occurring at the same time; or it may be differences that occur over time in the same sample. Surveys are examples of descriptive research.

Certain types of investigation are suited for experimental research and others for descriptive research. To solve a certain problem, it is often useful to carry out both descriptive and experimental investigations. For instance, to help solve the problem of nematodes in upland rice we may initially do sonic observational research:

– Identify the extent and distribution of the nematode problem in farmers' fields.

– Take crop cuts in farmers' fields to see if the nematode infestation is related to yield.

– Ask a sample of farmers about the relationship between years of continuous cultivation and crop yields.

We may then go on to do some experiments, for instance:

– Cultivate 50 different varieties of upland rice in a nematode infested field and see if the varieties differ in the degree of infestation.

– Kill all nematodes in part of each plot to see if there is a yield difference from the treated and the untreated soil.

– Carry out a rotation trial with other crops to see if the following rice yields differ between plots under continuous rice and plots with alternative crops planted in the previous year.

– This manual describes the principles and methods of experimental research used in agriculture and forestry.

1.2 What is a field trial?

Field trial research is a form of experimental research. It is a systematic way of comparing plant production technologies on a small piece of land. The different methods that we compare are called treatments. In a field trial we try to keep all factors equal that can influence the quantity or quality of plant production, except the different treatments. Examples of treatments are different varieties of a crop species, different planting dates of a crop, different levels of fertilizers applied to a crop, and different crop rotations.

The area where a treatment is applied is called a plot. The trial therefore consists of several plots that together form the trial area.

The treatments are usually repeated several times in the research field. One full set of treatments is called a replication. Normally, we use 3-6 replications in a trial. If only one replication were used we would not be able to say whether differences in yields from the various plots were caused by the treatment or by the production conditions in the plots, or by errors in the implementation. By using several replications and applying statistical procedures we can get an impression of what caused differences between treatment and between plots.

Where the soil conditions are very heterogeneous or the production conditions are difficult to control, a high number of replications is desirable. In shilling cultivation fields the experimental error is often very high, and the number of replications should therefore not be less than 4.

Replication A	1	3	2	5	4
Replication B	4	1	2	3	5
Replication C	5	4	3	1	2
Replication D	2	5	3	2	1

In the example above, the trial area consists of 5 treatments x 4 replication = 20 plots

1.3 Types Of field trials

Field trials can he characterized in different ways depending on the purpose, target group and location. Most agricultural and forestry field trials in Laos are adaptive research trials. This means that trials aim at testing already known technology, and at modifying the technology to the local conditions. This kind of research is therefore sometimes called technology verification trials. Adaptive agricultural research would normally be expected to produce useful results within and relatively short time, usually 2-4 years. Some research aims at generating new technology, such as new crop varieties or new cropping systems, and is therefore called technology generating trials.

Two types of agricultural trials can be distinguished. Species and variety trials compare the performance of different crops and varieties under local conditions. Cropping system trials compare the performance of plants under different kinds of management, such as different:

- Types of tillage
- Planting times
- Planting methods
- Plant spacings
- Crop rotations
- Types of intercropping
- Pest protection methods
- Types or quantities of fertilizers

In cropping system trials the varieties used must be known and tested locally to ensure that they arc suitable under the given production conditions. Untested varieties or species should not be used because there is a risk that they are unsuitable to the local conditions. Thus, we would not know if the failure of a cropping system is caused by the cropping system or by the species or varieties used in the trial. Variety and species trials are therefore normally necessary when starting trials in a new area or in an weakly defined agro-ecological zone.

Field trials can be carried out as on-station trials and as on-farm trials. On-station trials are often used to test new technologies and to screen innovations before introduction to farmers. On-station trials are normally easy to manage and to access, and a great degree of control can be held over the research conditions. The on-station trials may therefore be monitored more closely than on-farm trials and it is therefore feasible to use a greater number of observations and treatments than in on-farm trials.

However, the conditions on research stations are often very different from those in farmers' fields. Thus, the soil conditions may represent only a few of the soil types encountered in farmers' fields.

Furthermore, the management inputs may be unrealistically high compared to what farmers apply, e.g., regarding weeding and pest control. The timing of operation is also often better at the research stations. The crop yields obtained at stations are therefore frequently much higher than what is achieved by farmers.

Many technologies that looked promising in on-station field trials failed when introduced to farmers because the conditions and management at the station were too unrealistic for farmers. This has been the case with many soil conservation measures that were effective in reducing erosion in small trials, but were impossible for farmers to maintain when implemented on an entire field. For instance, planting hedgerows every 8 meters along a slope may reduce soil erosion, but would mean that an average farmers in Northern Laos with 1.5 ha under cultivation needs to maintain 1.8 km of hedgerows.

Consequently; on-station trials are useful for screening crops and technologies that are new to an area, for carrying out long-term trials, for trials that require detailed data collection, and for training staff in carrying out field trials. On-farm trials are useful for testing promising technologies, for testing technology under different conditions and for studying farmers' adoption and adaptation of technology.

2 Principles and components of field trials

2.1 Treatments

Field trial experiments compare two or more treatments with each other. In an experiment that compares five rice varieties the treatments are: var. I, var.2, var.3, var.4, var.5

A fundamental principle of experiments is that all factors except the treatments arc kept as constant as possible. This means that all five varieties are managed equally. If they received different care we would not know if different yields were caused by the different management or if they were caused by some varieties being better than other varieties.

- Other examples of treatments are:
- Different levels of nitrogen fertilizer: 0, 30, 60, and 90 kg/ha (4 treatments).
- Different frequencies of weeding: 0, I, 2, 3, and 4 weedings during the season (5 treatments).
- Rice rotated with different crops: rice, soybean, cow pea and maize (4 treatments)
- Teak provenances from Huey Sai, Pak Lai, Pak On and Chiang Mai (4 treatments).

When deciding on the treatments to be carried out we must take care that they are comparable. We may want to compare a traditional management method with an improved system using fertilizers and new varieties and tractor plowing. However, this would be difficult to do in a simple experiment because we would not know what causes differences in yields (or other variables). Is it the fertilizers, the plowing, the new varieties or is it a combination?

The treatments should be also realistic under the environmental and socio-economic conditions, especially when doing on-farm research. However, if we restrict the research to treatments we know will work we may also he reducing the possibility of finding new technologies.

2.2 Sources of variance

The objective of field trials is to compare various treatments. The different treatment will give different yields and other results. However, other factors also influence the trials and the yields obtained from the plots. These factors include:

- Soil heterogeneity within the trial area
- The effect of adjacent plots, e.g., root competition between two adjacent plots
- Errors made in implementing the trial, e.g., non-uniform management or external disturbances.

The effects of soil heterogeneity and adjacent plots can assessed with the help of a suitable trial design and statistical procedures. The effect of errors can be so great that the treatment differences become meaningless. It is therefore important that errors are minimized to produce statistically valid research results. Chapter xx will discuss some ways of eliminating or coping with these problems.

2.3 Plots

An experimental plot is the area where one treatment of one replication is assigned. The normal size of a plot is 5-40 square meters. Very small plots give a lot of uncertainty because:

- Unusual soil conditions can have a great effect
- The death of a few plants would mean the loss of a large percentage of the total plan population

– The border effect is great.

Large plots can give more reliable results, but are costly and laborious to take care of.

In most experimental designs all plots in a trial are of equal size, but they differ widely between different trials. A suitable plot size depends on:

– The plant species:	Genetically similar plants need fewer individuals than genetically very heterogeneous plants populations.
– The plant spacing:	Densely spaced crops need smaller plots because the total plant population is more important than the total area.
– The availability of seed:	Small plots must be used if there is only little seed available
– The management methods:	The plot may have to fit to the working width of machines and tools.
– The data requirement:	Destructive data collection during the season requires larger plots to supply enough plant material for both sampling and yield measurement
– The kind of trial:	Fertilizer trials usually need larger area than variety trials.
– The area available for the trial:	The total trial area is often restricted which will dictate the size of the plots or the number of replications.
– The soil heterogeneity:	Where soil fertility varies a lot within short distances relatively large plots are best.
– The number of replication:	Where many replications are needed the plot size normally has to be reduced to fit the available land.

The dimensions of the plot (i.e., the plot shape) must also be considered. The best plot shape depends on:

– The shape of the research area.

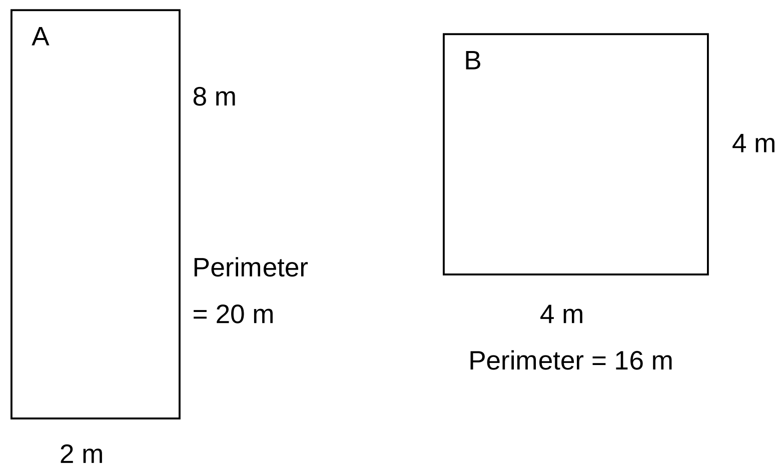
– The degree of border effect expected in the particular trial.

– The soil heterogeneity.

– External factors that are likely to affect the experiment more in one direction than in others.

Rectangular plots are best where the soil fertility changes in one direction (e.g., down the slope). In that case the long side of the plot should be in the direction of the soil fertility gradient (e.g., down the slope). Rectangular plots are also best when machines are used for sowing and harvest because the machines then have to turn fewer times.

Square plots are normally used where the soil fertility gradient is unknown or where the fertility gradient is equally large in both directions. The use of square plots means that the plots are distributed equally over the trial area. Moreover, square plots have a smaller perimeter than a rectangular plot of the same size. Adjacent square plots are therefore likely to affect each other less than in rectangular plots.



2.4 Replications

A full set of treatments is called a replication. The number of replications is the number of times the full set of treatments are repeated in the trial.

Replication are used to be able to test each treatment in several locations in the research area. By doing so there is a greater chance that each treatment is tested under the different conditions in the field.

Furthermore, by using statistical procedures we may evaluate whether differences in trial results (e.g. yields) are caused by the treatment, by differences in the plots, or by experimental errors.

The ideal number of replications depends on the expected magnitude of experimental error. If the experimental error is high more replications should be used. Four replications are most common in field trials carried out at research stations, but often vary between 3 and 8.

If the replications are not adjacent to each other, even more replications are necessary. In farmers' field experiments where the replications are distributed in several fields 10-15 replications may be necessary. In such cases, it is common to use only one or two replication per field, but implement the trial in 5-10 fields.

The number of replications also depends on the number of treatments. Normally the degrees of freedom for experimental error [(rep - I)(treatments - 1)] should be more than eight. Thus, if only three treatments are compared, the number of replications should ideally be six or more [(6-1)(3-1)] = 10.

2.5 Experimental design

The assignment of treatments to different plots in the trial area depends on the experimental design. It is very important to follow the principles of the experimental design, because it will facilitate correct assessment of the trial.

The experimental design depends on:

- The soil heterogeneity
- The type of treatments
- The number of treatments
- The degree of precision needed.

There are many different types of experimental design: trials can be single-factor or multi-factor experiments and treatments can be assigned to different plots in a systematic way or in a random way. The must common trials design is the random complete block design, which is described below

Random Complete Block Design

The Random Complete Block Design (RCB) is used in experiments where:

– The number of treatments is small (usually <10).

– The soil fertility gradient goes in one direction

The RCB design is characterized by:

– Each block contains all treatments in the trial

– The assignment of treatments within each block is random

Example of RCB design with 5 treatments in 4 replications

Rep. 1	2	1	4	3	5
Rep. 2	2	3	5	4	1
Rep. 3	3	4	1	5	2
Rep. 4	4	2	1	3	5

The RCB design is easy to analyze and it is easy to compensate for missing data. Any number of replication is possible, but is usually 3-8.

2.6 Blocking

Blocking is done to help eliminate some of the problems caused by different production conditions within the trial area (especially soil fertility differences). Blocking means assigning each set of treatments (replication) to a part of the trial area where the conditions are relatively uniform. The goal of blocking is to minimize the difference between plots in one block, which means maximizing the difference between blocks.

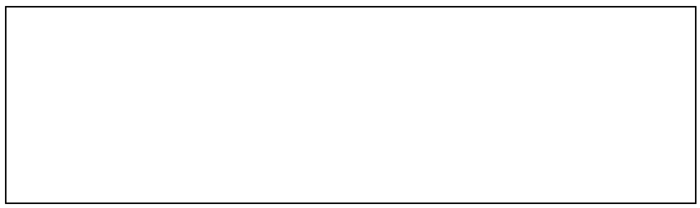
With the help of statistical methods we can distinguish the differences between blocks from the effect of the treatments. Consequently, the comparison of treatments can be more precise.

In a RCB design one replication (the full set of treatments) is assigned to one block.

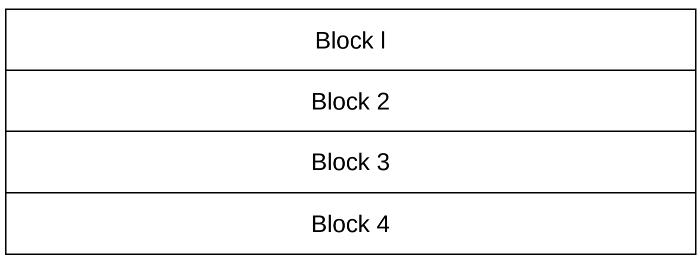
Where the direction of the soil fertility gradient is known, the blocks should be placed so the differences in soil fertility are as large as possible between the blocks. Consequently, the difference within a block is minimized. This may mean that one block has very fertile soil, one block has bad soil and two blocks have medium properties.

When doing research on sloping land, blocks are normally long and rectangular, laid out across the slope direction. This is because erosion and drainage in the soil is likely to make the differences in soil fertility moisture conditions and weed competition larger between the top and bottom of the slope than between the "left" and "right" side of the field.

Square blocks are best where the fertility gradient is not known or where it does not exist, which is often the case on flat land. A square block is likely to be best because adjacent plots are more likely to be homogeneous than plots that are far from each other.

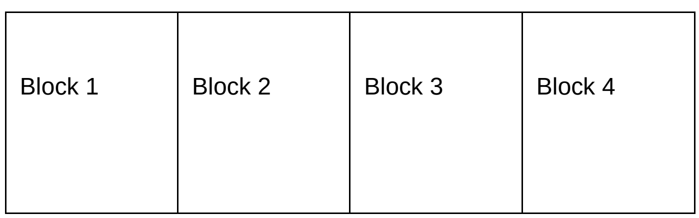


Blocking this piece of land in the best way would normally depend on the fertility gradient or other factors that are likely to affect the productivity of the plots.



This is the correct blocking if the fertility gradient is going from the top to the bottom

⇧ ⇩



This is the correct blocking if the fertility gradient is going from left to right

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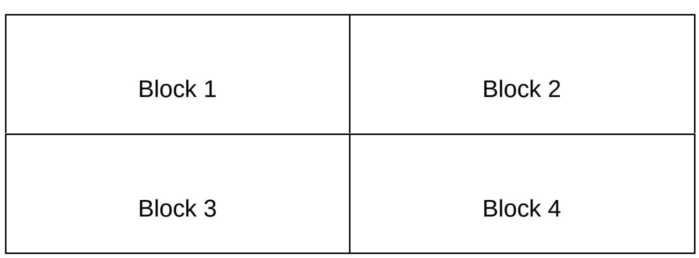

This is the correct blocking if the fertility gradient is going both up and down and from left to right; or if there is no known fertility gradient

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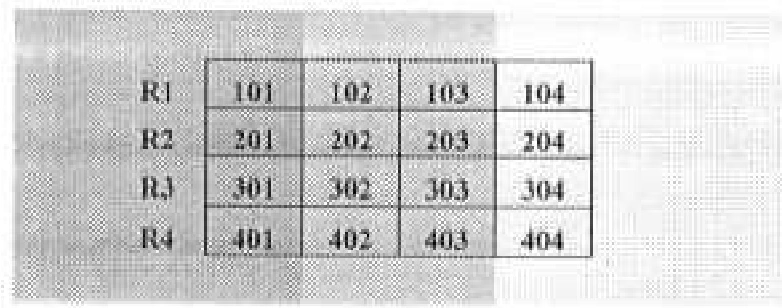
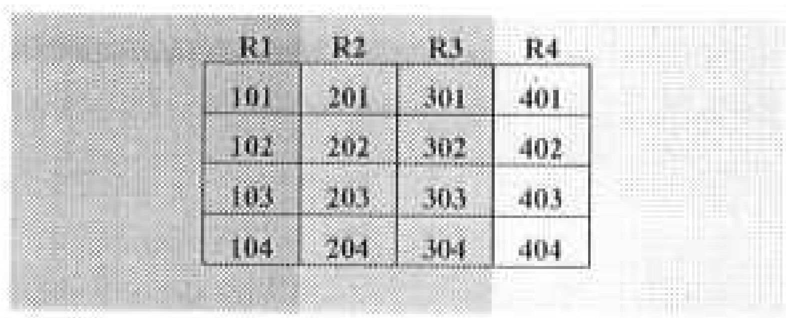
Figure 1. Examples of correct blocking under normal field conditions



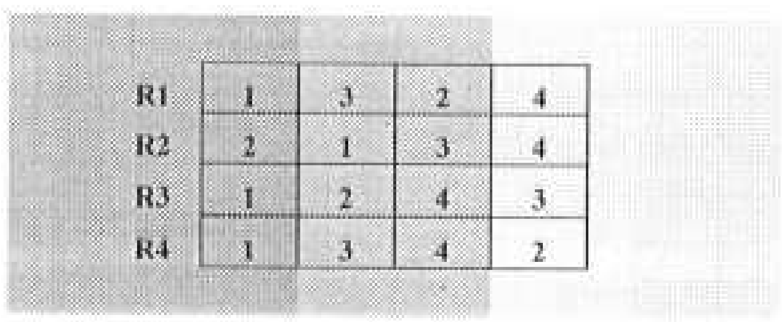
Decreasing fertility ==>

A. Blocking has been done along the nutrient gradient => more difference between plots in a treatment than between block/replication. This is wrong. See the possible consequence in Fig. C.



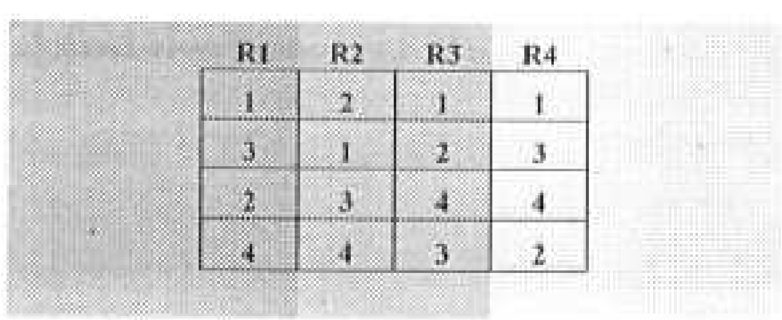
Decreasing fertility ==>

B. Blocking has been done correctly across the main soil fertility gradient. Rep.1 is on the best soil and Rep. 4 on the more infertile soil. Rep. 2 and 3 are on medium soil. See the possible consequences in Fig. D.



Decreasing fertility ==>

C. Because of incorrect blocking treatment 4 is located on the more infertile land, while treatment 1 is found on the left hand side where the soil is much better. Are higher yields of treatment I caused by the treatment or by the better soil?



Decreasing fertility ==>

D. Same distribution of treatments as in Fig. C. but this time with correct blocking. Both treatment 1 and 4 occur on good, medium and poor soil.

Figure 2. Example of inappropriate (A. and C.) and appropriate (B. and D.) blocking technique on land with one-way fertility. Darker areas indicate higher fertility.

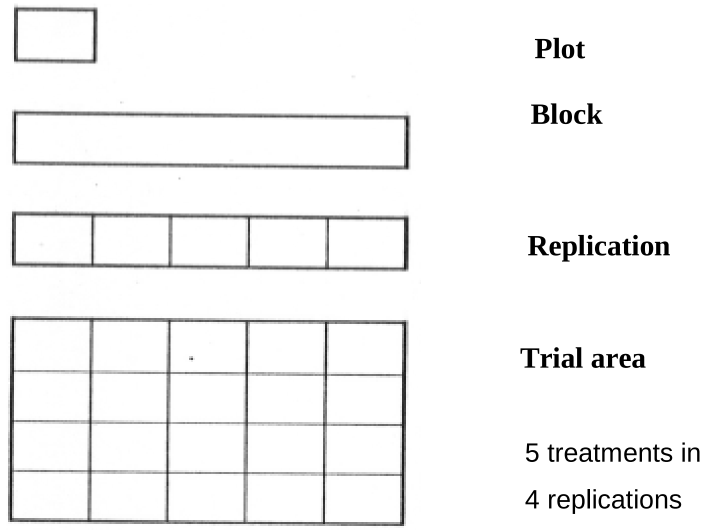


Figure 3. Representation of field trial entities: plot, block, replication and trial area.

2.7 Stages of field trial research

Field trial research includes the following steps:

1. Problem identification
2. Planning the trials
3. Implementation of trials
4. Analysis and evaluation of the results
5. Trial reporting and decimation of recommendations

Chapter 3 to7 describe each of these stages.

3 Problem identification

Applied field trials must be relevant to solving development problems in the target area. The researchers should therefore understand the conditions and problems in the target area. They should also try to evaluate the different solutions and initiatives so they can chose the best and most relevant things to be tested in the field trials. The research work must therefore start by identifying the problems and possible solutions. This may include the following topics:

– Describing the farming systems in the target area.

– Identifying the problems and constraints on agricultural production.

– Identifying the causes of these problems.

– Suggesting possible solutions to the problems.

For such analysis and evaluation data may be obtained from:

1. Reviewing available reports. Books and statistics describing the targeted area, agro-ecological zone or farming system.
2. Interviewing staff of the agricultural and forestry offices, other government officials, and staff of other organizations.
3. Informal interviews and discussions with farmers.
4. Structured interviews with farmers using questionnaires.
5. Field observations

3.1 Target area identification

Step 1. Identify the target area and (he targeted agro-ecological zone(s), farming system or populations.

The geographical area or the targeted agro-ecological zones, farming systems or populations will depend on the mandate of the research organization. These things are normally already decided upon before the researchers start their work. However, it is important that the researchers are aware of their research mandate. Consequently, the target area, population, agro-ecological zone and farming systems should be described in a report and discussed among the researchers.

3.2 Description target area

Step 2. Describe the production conditions and land-use in the target area.

These aspects can be covered in more or less detail depending on the accessible information and the resources available for further data collection. The description may be improved over the years as a better understanding evolves, but at least a general outline should be made before the start of a research program. The following topics may be covered in the description.

Environment

Geomorphology:	Elevation classes, land-form, geology and drainage.
Climate:	Climatic data, climatic stratification, cropping seasons, climatic constraints.
Soil conditions:	Soil types, distribution of soil types, soil related constraints.
Vegetation:	Geographical and ecological distribution of vegetation types.

Socio-economy

Population:	Numbers, cultural groups, population growth, occupation, and past and current movements of people.
Economy:	Income and income distribution, primary, secondary and tertiary sectors.
Infrastructure:	Road and river access, market centers, electrification, communication.
Credit facilities:	Sources of credit and use of credit, what kind of farmers have access to credit and who has not.
Public services:	Education, health, extension,
Industry:	Kinds of processing and manufacturing
Community organization:	Village based organization and their activities

Land-use

Farming systems:	Relative importance of shifting cultivation systems, permanent upland cropping, paddy production, horticulture and fruit tree production.
Crop production:	Kinds of crops, area, yields, constraints.
Irrigation:	Area and proportion of land under irrigation, sources of irrigation, irrigation potential.
Animal production:	Kinds of animals, numbers, distribution, fodder production systems, constraints.
Forestry:	Kinds of forestry, logging concessions and plantations.
Other forest use:	Kinds and importance of non-wood forest products.
Conservation areas:	Deliniation and area, vegetation types, settlements, status of the management plans.
Hydropower:	Current and planned hydropower schemes.

3.3 Description development work

Step 3. Describe and evaluate the current development work in the area.

Official development strategy and plans for the area or the sector.

Current and past extension and development work carried out in the target or sample area.

Current and past research carried out in the target or sample area.

3.4 Problem description and analysis

Step 4. Evaluate the problems and constraints on land-use.

What are the main problems related to low productivity and sustainability of land-use in the target or sample area?

Evidence from secondary sources.

Evidence from farmers

Evidence from field observations

Evidence from extension staff and organizations

Evidence from research staff and organizations

Write a list of problems for each source of evidence. Sometimes the various groups may express the same core problem with different words, so you must try to formulate similar problems under one entry.

Some of the problems mentioned may be the cause of a certain problem, in which case it should be listed in step 6 below. For instance, farmers may say that a main problem is that the fallow periods are too young. However, this is a cause of the problems observed in the field, e.g., too many weeds, low fertility or pest problems.

Try to find the problems that are common to the different sources. For the stated problems that differ between the sources try to analyze why they are different. The differences probably reflects the different priorities and knowledge of the sources.

Make a list and compare the problems primarily mentioned by farmers and a list of problems identified by other sources of information.

3.5 Problem ranking

Step 5. Rank the land-use problems according to their importance

The importance of the stated problems and constraints should now be assessed. You may consider the following factors (or others).

– The proportion of farmers affected by the problem.

– The proportion of land affected by the problem.

– The magnitude of the yield loss caused by the problem.

– The threat to sustainability in the area.

– Relevance to the research mandate of your organization or project.

The ranking may be done by assigning each factor a score of low or a high importance.

3.6 Identification of solutions

Step 6. Suggest possible solutions

Once you have chosen what problems to address, you should make a list of possible solutions to solve the problem. If weed infestation by Imperata cylindrical is a major problem in upland rice, possible solutions could be:

– Hoeing the land in February

– Tractor plowing the land in February

– Use herbicides during the early growth stages around April

– Use longer fallow periods to shade out the grasses.

– Use different kinds of improved fallows to shade out the Imperata grass.

It is often a good idea to do further studies before trials are carried out. One step is to study the literature on the topic. Secondly you can do further studies in the field of the distribution of the problem, what kind of environment it occurs in, the kind of farms affected, the timing of the problem and how farmers currently try to solve the problem. Sometimes good solutions to the problems are already available from research and extension elsewhere. In such cases new trials may not be necessary, or you only need to do verification trials in farmers' field to see if the technology is suitable in your target area. Before you establish a trial it could also be useful to discuss the problem and suggested solutions and treatments with farmers and extension officers.

4 Planning the trial

4.1 Formulating the trial objective

When formulating the trial objective we should try to include information on:

The kind of crop(s)

The treatments.

The variable(s) we are collecting data on.

An example is:

Objective: comparison of yield, maturation and blast resistance 20 local varieties of upland rice from Luang Prabang Province

This wording tells us: what kind of crop we are testing (upland rice), the treatments we are applying (20 local varieties from Luang Prabang Province) and the variables we are collecting data on (yield, maturation and blast resistance).

The objective should only state what can realistically be achieved from the trial. You should neither understate or overstate the objective. An understatement would be: *"Compare different rice varieties", whereas "Find a solution to the rice deficiency problem in Northern Laos"* would be an overstatement. It is very important that the objective is worded correctly because it will help you chose the right treatments, make clear to everybody what you are trying to do and the kind of aspects the evaluation of the trial should stress.

4.2 Criteria for choosing the trial area

The ideal area for carrying out field trials should fulfill the following criteria:

- Be representative of the kind of environment your trial results will be used in. This may include climate, altitude, soil properties, slope, vegetation, and past management.
- Be uniform in slope, soil properties, sun exposure, past management. Be relatively easy to get to.
- Be protected from domestic and wild animals. On-station trials are usually fenced.

It is often impossible to find trial areas that fulfill all the criteria listed above. Intelligent compromises must then be made. In many cases research stations are not typical of the target area, or only of a small part of the target area. This is one reason why on-station research often fails to produce results useful for extension.

4.3 Selecting the trial treatments

The choice of treatments depends on the objective of the trial. You should consider if the results from the trial will meet the objective of the trial and if they can help solve the identified problem.

If possible, a control treatment should be included in the trial. There are two types of control treatment:

1. Local technology (e.g., a local variety in a variety trial, the plant spacing used by most farmers, the local tillage methods, local weeding practices).
2. Zero treatment (e.g., no weeding in a weeding trial, no fertilizer in a fertilizer trial)

If a control treatment is not included it is difficult to evaluate the potentials and benefits of new technologies because we do not know if they are better than the local methods or the non-use of production inputs.

4.4 Data requirements

What kinds of data are necessary to collect from a field trial? The yield and quality of the harvest product are usually the most important variables because they will decide whether or not a new technology will be adopted by farmers. However, other data should also be collected to help determine other differences between treatments, e.g., about the development of the plants, their susceptibility to plant diseases, incidence of insect pests, the labor input for different treatments, etc. Such data will help the researcher determine the reasons for differences between trial treatments. Information should also be collected on the weather conditions and their apparent effect on the plant growth.

The data requirements should be determined when the trial is planned and data collection forms should be made in advance. In these forms an entry should be made for each plot just like the collection of yield data. However, it is often difficult to select all the right criteria from the start of the trial, so you should be prepared to collect other data and modify your data forms. You should also make it a habit of writing notes of what you see in the field, e.g., about pest or insect attacks (species, dates, damage, distribution).

In selecting the data requirements you must think of the objective of the trial. There is no reason to collect irrelevant data that require a lot of work to collect and will complicate the analysis of the results. For on-farm trials (and sometimes also on-station trials) farmers should help select the criteria for evaluating the trials because their criteria will eventually determine the adoption of new technology.

4.5 Plot numbering

Each plot in an experiment is assigned a unique number. The number has three figures. The first figure refers to the replication number. The last two figures refer to the specific plot number. Thus, plot number 101 means replication 1, plot no. 01. Plot 212 means replication 2, plot no. 12. The sketch below shows the plot numbering of a trial with four replications and four treatments.

Block 4 / Rep. 4	401	402	403	404
Block 3 / Rep. 3	301	302	303	304
Block 2 / Rep. 2	201	202	203	204
Block 1 / Rep. 1	101	102	103	104

It is best if plot numbering in done the same way in all trials, e.g., by starting in the nearest left corner of the field when seen from the usual access route

4.6 Randomization

A very important principle of field trial experiments is that the assignment of treatments to individual plots is done in a random way. This will give each treatment the same chance of being assigned to a certain plot.

The easiest way of randomizing is by drawing lots. First give each treatment a number (1, 2, 3, 4 etc.) Then write a number for each treatment on identical pieces of paper. With five treatment you need five identical pieces of paper. Put the paper slips in a box and start drawing them up one by one. The first number is assigned to the first plot in replication no. 1. The second slip (i.e. treatment) is assigned to the second plot in replication no. 1. After replication no. 1 has been completed you put all slips back in the box and start all over for replication no 2 and continue until plots have been assigned a treatment.

Example: In a trial with five treatments, the sequence of the first five draws could be: 2, 3, 5, 1, 4. In this case the assignment of treatments in the first block (replication I) is:

101	102	103	104	105	Plot number
2	3	5	1	4	Treatment

You should never change the assignment of treatments, even is replications of one treatment seem to be grouped together in one part of the field. 'Random' means that the treatments are assigned to plots in a random way, not that a certain treatment is distributed in different parts of the trial area.

4.7 Code labeling

A code number is used to designate the treatment and to show the location of each plot in a trial. The same code is used to mark bags and boxes containing material for different treatments, samples from the plots, and to mark the bags where harvest products are collected.

The code label should show:

– The year the trial was established.

– The location of the trial, usually in code (e.g., a number for a certain farmer or an abbreviation).

– The trial number.

– The plot number, and

– The treatment number.

At Ban Thong Khang Station we use this labeling system (example):

96 BTK - # 22 - 101 – 6

Meaning:

Trial established in 1996

Ban Thong Khang station

Trial no. 22

Plot no 101

Treatment 6

4.8 Field signs

As mentioned above, each plot must be marked with a field sign so the plots and treatments can be identified easily. The sign will show the plot label, e.g.,

96 BTK - # 22 - 101 - 6

The signs are placed in a systematic way in the corner of the plot.

I	**I**	**I**	**I**	**I**
I	**I**	**I**	**I**	**I**
I	**I**	**I**	**I**	**I**

The field signs should be prepared and put in the field before sowing starts. Remember to check and recheck that the treatments and the plot allocation is correct - compare signs and research plan, and compare the placement of sign with the trial plan

4.9 Making the trial plan

A full trial plan must be made before field work starts. A standard form should be used for all trials to give a good overview and ensure that all aspects have been considered. The trial plan can look like the example below.

Trial plan

Name	The name given to the trial
Location	Name of station, district and province, or Name of farmer, village, district and Province
Trial no.	The code of the trial, e.g., 96 BTK #1
Year(s)	The year the trial will start and end, e.g., 1996-99
Researcher	The person responsible for implementation
Crop(s)	The name of the crop(s) used in the trial
Objective	The objective of the trial
Treatments	The treatments to be tested, including the number given to the treatment
Replications	The number of replications
Plot size	The dimensions and area of the individual plot, e.g., 4 x 5 m = 12 m^2
Border rows	The number of border rows to be excluded from harvesting, e.g., two outer rows of the plot
Harvest area	The area that will be harvested for yield measurement, i.e., the plot area minus the area occupied by the border rows: e.g., 3.6 x 4.6 in = 16.56 m^2
Unplanted alleys	The width of implanted alleys between plots, e.g., "40 cm"
Guard rows	The number of guard rows around the trial, e.g., "2 rows"
Trial area	The dimensions and total area occupied by the trial. This includes the plots, implanted alleys and the guard rows. Example: xx x xx = x m^2 This can only

	be written after you have selected the kind of blocking.
Trial design	The kind of design. We would normally use the random complete block design (RCB).
Operations	The kinds and planned timing of farm operations.
Acquisition of planting material	Seed sources, names of species and varieties.
Acquisition of materials	Kinds of materials needed, source.
Land clearing	Removal of fallow vegetation of weeds and crop residues from last year.
Tillage	Hoeing, plowing, harrowing, etc.
Fertilizing	Amount, kind and application time of fertilizers.
Time of sowing	Expected date of sowing.
Method of sowing	Broadcasting, rill sowing or dibble sowing.
Seeds per hill	Number of seed per planting hole (if applicable).
Row distance	Distance between rows, e.g., "50 cm".
Rows per plot	Number of rows per plot, e.g., "8 rows per plot".
Planting distance within row	Distance between hills in the row, e.g., "20 cm".
Hills per row	Number of planting holes per row, e.g., 25 holes per row"
Hills per plot	Number hills per row multiplied by the number of rows per plot, e.g. "25 holes per row x 8 rows per plot = 200 planting holes".
Seeds per plot	Seeds per hill x hills per plot.
Thinning	Planned time of thinning, number of remaining plants per hill or per meter.
Weeding	Method(s), number and timing of weedings, e.g., 'hand weeding three times starting 2 weeks after crop emergence. Second and third weeding depends on need".
Plant protection	Kind and timing of plant protection measures.
Harvesting	Expected time of or development stage at harvest, method of harvesting, threshing and drying.
Cleaning	Method of cleaning
Sampling	Amount of harvest to be sampled per plot.
Laboratory work	variable to be tested in the laboratory. Equilibration of moisture content, 1000 grain weight, quality assessment, etc.
Measurements and observations	*Measurements and observations must be made and recorded for each plot. An entire Block/replication must be finished before going*

	to the next. The kind of data depends on the trial objective and the kinds of crops being used. Data collection forms should be made.
Seed testing	Percent of damaged or off-type seed, germination percentage in laboratory.
Plant development	Date plants reach various development stages.
External factors	Time and effects of pests, weeds, the weather and other external factors.
Operations	The management operations carried out, the date and comments.
Measurements	Yield, yield components, maturity, qualitative characteristics. etc.
Budget plan	*Investments are normally kept out of the budget of individual trials*
Seed	Kinds of seed, unit costs, number of units needed, total.
Other inputs	Kinds of input, unit costs, number of units needed, total. Inputs could be hand tools, field signs, plastic bags, fertilizers, pesticides, diesel,
Labor	Kinds of operations, workdays need, daily rate, total. May also include other hired services.
Per diem	Per diem for staff when staying over night away from duty station.
Laboratory tests	Kinds of test, unit costs, number of units, total. Could be analyses of soil, plant material
Total budget	

Trial layout

The trial lay-out is a sketch that should contain the:

- Trial number and name
- Plot numbers
- Treatment
- Replication
- Dimension of the plots
- Dimensions of the trial area
- Remarks on the width of unplanted alleys and guard rows (if any).

Example:

Trial layout: 96 BTK # 4 Soybean variety trial

24 + 1 m = 25 m

		6 m	6 m	6 m	6 m
	4 m	401 1	402 3	403 2	404 4
16 + 1 m= 17 m	4 m	301 2	302 1	303 3	304 4
	4 m	201 1	202 2	203 4	204 3
	4 m	101 4	102 3	103 2	104 1

2 guard row x 25 cm are planted around the trial area.

5 Trial implementation

5.1 Soil preparation

Soil tillage in the research fields should normally be done in the manner of local farmers given similar production conditions and aims. No tillage is normal in shining cultivation fields using fallow land older then 2-3 years (unless infestated with grasses), and similar practice should be applied in the research field Care must be taken when choosing the equipment, the time of operation, the operators, the mode of operation because tillage can easily increase the soil heterogeneity due to uneven application.

Tractor tillage is easiest and likely to be more uniform with a two-wheel tractor, unless large areas can be worked with a four-wheel tractor. To help secure uniform tillage, the researcher should check that the tractor operator is skilled at the work. Also, the quality of the tillage and the settings of the plough and harrow must be checked outside the research area before work starts. When tilling the research fields, turnings should always be done outside the trial areas. It would therefore be necessary to know the location of the trial areas at the time of tillage.

In shilling cultivation areas soil tillage is usually done by hoeing. This may increase the soil heterogeneity because several people normally cooperate on this task, but vary in their hoeing depth and degree of aggregate destruction. Also, hoeing takes a long time and may stretch over several days, which can cause differences in soil moisture contents. Priority should be given to completing one field in a single day. If that is not possible, the blocks/replications must be finished one by one.

5.2 Fertilization

Fertilizer application is not common in shining cultivation areas of Laos, and would therefore not be carried out in on-farm experiments. At research stations where the land is used continuously for several years, it may be necessary to apply a basic dressing of fertilizers. The kind and amount of fertilizer would depend on the soil conditions and the crop being produced. However, in field trials aiming at helping small farmers the fertilizer rate should be quite modest. The available nutrients should not be much larger than in farmers' fields.

Soil chemical data may be used to identify possible nutrient deficiency problems. If these problems seems large, corrective fertilizer application should be considered. Soil samples are taken from the top 20 cm of soil. One soil sample should be collected from each 100 - 400 m^2 area. The soil sample should consist of 20-40 sub-samples. The samples should be air dried before being sent for analysis Inorganic fertilizers are used because the amount and the nutrient content is easy to control and calculate. Manure, compost and green-manure should not be used, unless they are part of the treatments.

5.3 Seed management

Before implementing a trial the seed should be:

- Cleaned of straw, gravel, weed seed and other impurities
- Sorted to eliminate small, deformed and visually different grains.
- Tested for germination percentage to help calculate the number of seed that needs to be planted and to see if the seed batch is suitable for trial purposes.
- Weighed to calculate the 1000 grain weight, which is used to estimate the amount of seed needed in the trial.

For some species it may also be necessary to **treat the seed** to help them germinate. The kind of treatment depends on the species and variety. Crops like cereals and pulses normally do not need any treatment, but rice may benefit from hot water treatment (see below). Grass and pasture legumes may need either hot water treatment or cold treatment. **Hot water treatment** is done by heating water to 70-80 degrees (boil the water and let it cool for 10 minutes) and pour it into a container with the seed. The seed should remain in the water for 5 minutes to one day depending on the species. This method is also effective for many tree species. **Cold treatment** may be suitable for temperate zone crops and done by putting the seed in a refrigiator or deep freezer for 1-2 days. Some tree seed may need **burning or scratching** of the surface to have them germinate.

Cleaning and sorting can in most cases he done manually in the type of winnowing tray used by farmers to clean their rice. If large seed quantities are needed it may be economical to use winnowing machines and sieves if available. Seed obtained from commercial suppliers and research stations is normally already cleaned already. Seed obtained from farmers should be checked carefully. Preferably, such seed should be taken from field plots that were monitored during the previous year or season. This is to make sure that the seed is of the right kind and from healthy plants.

A germination test is done to check if the vitality of the seed is sufficiently high. The acceptable lower limit of germination percentage depends on the species and varieties. Cereals and maize should not have less than 80 % germination and pulses no less than 60 %. Pasture species can have as little as 10 % germination and still be considered suitable.

The test is also done to calculate how many seed needs to be planted. For instance, if we want four plants to emerge per planting hole and the germination percentage is 80, it is safest to plant five of six seed per planting hole.

Before carrying out the germination test the seed should be treated (hot water, cold or no treatment) in the same way as will be used in the trial. Otherwise we would not get an impression of the germination percentage expected in the field.

The germination test can be done in flat, closed containers, e.g., Petri dishes. Moist filter paper, cloth of tissue paper is put in the bottom to provide the necessary moisture for germination. Large seeds, such as many tree seeds, may be testing in trays containing moist sand, into which the seed are pressed lightly. Samples or 50-100 seed are counted and transfered to the containers. Two to four samples are usually adequate to obtain reasonably precise data.

The samples are stored in the shade, ideally, at a temperature of 20-25 degrees. The containers should be inspected every day to see if the seeds have started to germinate and to see if more water is needed. There should be a bit of condensation inside the lid, but there should not be free water in the container. Records are kept of the number of seed that has germinated each day.

Work is easier if seeds are removed from the container after they have germinated and been recorded. This eliminates the need of counting seed more than once, reduces the risk of the samples drying out, and prevents sprouts from entangling or lifting off the lid.

A data collection form should be filled out for each batch of seed being tested. The form should also contain information on the source, price and 1000 grain weight of the seed. The form may look like the example below. The entries in *italics* are an example of a soybean test.

Seed testing form		Researcher:		Date:
Species: *Soybean*		Variety: *Sor Jor 4*		Price: *1000 K/kg*
Seed source: *HDK station, Vientiane*			Seed treatment: *none*	
Harvest year *1996* month *March*			Start of test: *15 April 1996*	
1000 grain weight: *138* g/1000 grain			Germination: *93* %	
Container no. *1 /1, 2, 3*	No. of seed germinated			
Day	Sample 1	Sample 2	Sample 3	Sample 4
15/4 0				
17/4 2	3	4	3	
18/4 3	10	9	12	
19/4 4	22	19	28	
20/4 5	32	31	23	
21/4 6	22	30	22	
22/4 7	3	0	5	
23/4 8	0	0	0	
24/4 9	0	0	0	
24/4 10	0	0	0	
Total	92	93	93	
Seed at start no.	100	100	100	
Germination %	92	93	93	
Comments:	*Mean germination percentage = 92 + 93 + 93 / 3 = 278 / 3 = 93%* *High and uniform germination between samples*			

The **thousand grain weight** states the weight of 1000 grains (for large seeds, especially tree seeds, a 100 grain weight is often used instead). It is measured to help calculate the amount of seed that needs to be bought and the amount of seed to be planted in each plot.

The test is done by weighing a sample of 100 seed and multiplying the weight by 10. You should weigh 5 samples to gel a good precision in your assessment

The record of the individual sample should be taken with one decimal precision. For very small seed you may have to take bigger sample, e.g. 200 seed (and multiply by 5) or 500 seed (and multiply by 2). Otherwise your scale may not be able to give a precise figure.

If you do not have a scale that is sufficiently precise you can bring the seed to a pharmacy or gold shop and ask to use their scales. In that case, count the seed first and put them in labeled bags (batch, source, species, variety and number of seed) so you do not waste time in the shop and spread seed everywhere.

When you know the 1000 grain weight you can do various calculations

If the 1000 grain weight of the soybean variety 'Sor Jor 4' is 128 grammes per 1000 seed, you know that one grain weighs 128 g divided by 1000 = 0.128 g. Note that the 1000 grain weight equals the weight of one grain in milligrammes. Thus, one grain of the soybean variety weight on average 128 mg.

If you want to know how many grammes of seed you need to plant in each plot you should calculate the number of seed needed, multiply that number with the thousand grain weight and divide it with 1000. For instance, in a soybean variety trial one treatment is the variety 'Sor Jor 4' from above. The plot size is 4 x 4 meters; the plant spacing is 40 x 40 cm. Consequently, you have 10 rows with ten planting holes in each row. This is equal to 100 planting holes. If you want to plant 3 seed per hole you need a total of 300 seed. How much does this weigh?

$$\frac{300 seed \times 128 g}{1000 seed} = 38.4 g$$

Round this figure up to 50 g per plot to ensure that enough seeds are available. If the treatment is carried out in 4 replications you must make 4 bags with 50 g each. The bags should be labeled with the trial number, the plot number, the treatment number and the name of the variety. For instance:

4 - 101 - 2 - Sor Jor 4

Storage of seed from one year to another can be a problem because of diseases, insects, rodents and unfavorable physical environment (high temperatures and humidity). The best way of storing seed is in cool-rooms, but this requires special facilities and electricity, which is not available for little research and extension organizations. To prevent insect and rodent attacks, the seed can be stored in the metal containers originally used for bisquits. They cost about 500 Kip each and the little window makes it easy to see what kind of seed is inside. Bags containing different seed samples can be kept in a single container, if they are well labeled. However, the bags should not be too big, otherwise they are difficult to get out of the container and you may damage the bags.

Before storage, make sure that the seeds are really dry to keep them healthy and free of diseases. You may treat the seed with insecticides and fungicides, but then make absolutely sure that this is written on the container. It could be disastrous if somebody ate the seed. Also remember not to give the seed to animals.

Seed storage pesticides available in Laos include:

Name	Usage	Dose	Price

Labeling of the seeds is very important, because it is impossible to distinguish between different batches and varieties of seed. The container and bags can be marked outside with a permanent marker. However, you should always put a slip of paper inside that tells the:

– Name of the variety,

– Seed source

– Year and month of harvest

– 1000 grain weight, and

– Germination percentage and date when last tested.

Seed sources

For seed of known varieties it is therefore best to buy new seed every year.

Local varieties (or populations) are often used as control treatment. For instance, if rice varieties collected in different parts of Laos are compared in a trial, at least one treatment should be a variety that is commonly used by farmers in the local area. Without such a control treatment it would be difficult to assess if the new varieties are better than the local rice. It is important to select a well known local variety and discuss its properties with farmers. The local variety should be obtained from local farmers, not from rice merchants or rice mills.

5.4 Data collection

5.4.1 Sampling

Many different kinds of observations and measurements can be made in the field trial. For example, in a soybean variety trial comparing four varieties, we may be interested in counting the number of leaves per plant at flowering. We could do this by counting the leaves of all plants, but obviously this would be far too time consuming. Instead we may randomly select a sample to represent each plot. This sample may consist of. e.g., 5 percent of the plant hills. Sampling is when we select part of a population to represent the whole.

Sampling is done because it is:

Quicker and cheaper

Only part of the whole population is actually measured which therefore requires less work and resources.

Sometimes more precise.

The smaller amount of work means that fewer people need to be involved, thus minimizing the risk of diffeences between people collecting data. The smaller amount of work also reduces the risk of people getting bored or tired, which could affect the quality of the work.

Possible to destroy the sample.

Some tests may require that the sample is destroyed. This could be tests of, e.g., dry matter contents in young grass, or of the nitrogen content in soybean leaves at flowering. It would be impossible to test the entire population since there would be nothing left of the population.

Sampling that requires the removal, destruction or heavy disturbance of the samples is called **destructive sampling** if measurement can be made with little damage to the sample it is callled **non-destructive sampling.**

For samling

The **sampling unit** is the unit that measurments and observations are made on. This may be a single plant, a plant hill, an area unit or a plant part, etc. In the example above the sampling unit was a hill of soybean. The sampling unit depends on the crop species, the objective of the trial, and on the purpose of the observation.

The **sample size:** The number of units to be sampled from each plot. In the example above the sample size is 5 % of the sample units of each plot. Using a large sample (e.g. 50 sampling units out of 100 units in the population) may give very precise data (the sample data are very close to the data that could be obtained from measuring all the sampling units in the plot). However, the labor requirement would be too big. Using very small samples (e.g. two sampling units out of 100) will be very easy to carry out, but the data are not likely to be very precise. The optimal sample size depends on the variation between sample units and on the resources available for data collection.

The **sampling method** is the method used to select sampling units. The sampling method can be either systematic or random. The systematic sampling design is easier to construct, but may be less precise if systematic variations occur in the population sample.

In the **systematic sampling** the interval between sampling units is constant. If the population is 200 plants and you want to sample 20 plants the sampling interval is 200: 20 = 10'. Thus every tenth plant will be sampled. The first plant to be sampled must be selected randomly.

In the **random sampling** each population unit is assigned a number, e.g. 1-200. With the help of a 'table of random number' twenty numbers between 1-200 are selected. This is done by listing the numbers from a random place in the table:

183422975498420834477238424185463870898790900349810943442598734983495

Since the largest population number is a three figure number, the list is split into three figure numbers:

183 422 975 498 420 834 477 238 424 185 463 870 898 790 900 349 810 943 442 598 734 983 495

Numbers larger than 200 are reduced by 200, 400, 600 or 800 to reach a number within the range 1-200. Consequently the list is transformed into:

183 22 175 98 20 34 77 38 24 185 63 70 98 190 100 149 10 143 42 198 134 183 95

The first 20 number in this list are the plants to be sampled, but repeats are only listed once:

183 22 175 08 20 34 77 38 24 185 63 70 190 100 149 10 143 42 198 134

The same sampling design can be repeated for each plot in one replication. However, a new design must be used for each replication.

Remember that data obtained from each plot must be kept separate to make statistical analysis possible.

5.4.2 Measuring yield

Yield data must be collected with great care as there are many possibilities of making mistakes. You may have to go through the following steps:

Remove the guard rows, if any, around the trial area.

For replication 1 remove the border row(s) of each plot. If destructive plot sampling was used the sampling area is also removed.

Count and note down the number of hills or plants in each plot. Where plants or hills are missing we would normally refrain from harvesting the four plants/hills nearest to the gap. The total number of plants or hills harvested are then noted down. Later this figure will be compared to the number of hills/plants there should have been if all plants had survived

Harvest each plot individually. Complete one block at a time, not one treatment at a time. Do not forget that for the statistical analysis we must have data for each plot, not only each treatment.

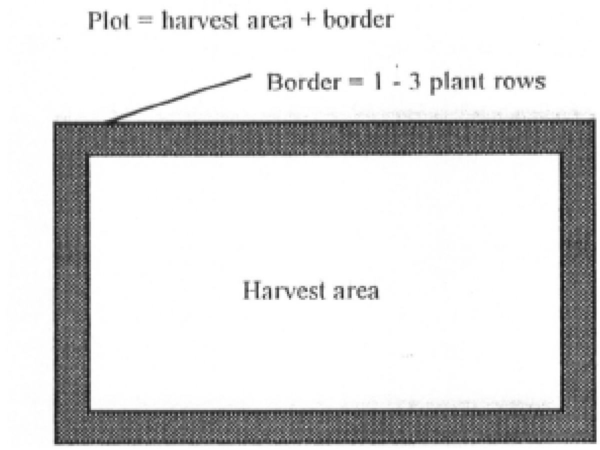
Thresh and clean the grain as soon as possible

Weigh a sample of the clean seed from each plot.

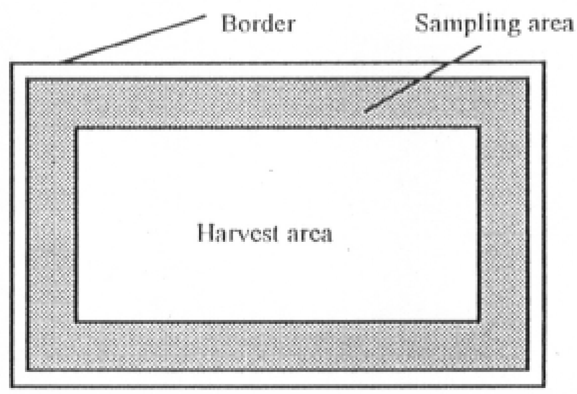
Air dry the sample or measure the moisture contents is you have a moisture meter.

Calculate the weight of the yield from each plot on the basis of the air-dry weight or of the standard moisture content.

Compensate for differences in the harvest area or number of plants/hills being harvested.



Each plot normally consist of a border area of 1-2 plant rows and a harvest area within the borders. The production from the border areas will not be included in the plot yield. Yields are calculated on the basis of the harvest area, not the entire plot area.



Where destructive sampling is used, the sampling is done outside the central harvest area but within the border area. An example of destructive sampling is measurement of the protein content in grasses during different growth stages. Crop yields are calculated on the basis of the harvest area.

Immediately after harvest you must measure the yield. Later this yield must be adjusted for moisture contents and impurities, such as straw, pods, hulls, and undesirable grains.

It is of course very important that plants from different plots are not mixed up. Every care must be made to avoid this. The unthreshed crop from each plot maybe put into individual net-bags where they can dry in the sun and await threshing and cleaning. The net bags must be marked in duplicates with the trial number, plot number and treatment. One marker is tied outside the bag for easy identification and one marker is kept inside the bag for backup.

After the crop has been threshed and cleaned it is weighed. The data are recorded individually for each plot.

If you have an instrument to measure the moisture content of the crop you should record this for each plot. Later you can adjust the yield according to a standard moisture content. If you do not have a moisture meter you must ensure that the crop is thoroughly sun-dried and that the plots have been dried equally before you take the final measurements.

In many cases it is not practical to handle the entire harvest from all the plots. Then you can take a sample of the harvest of each plot. You must be careful to collect representative samples. You should record the following data from each plot: The total harvest,

If you have been measuring yields in farmers' fields it is usually too much work to dry, clean and measure the entire harvest. Then a sample must be made of the gross harvest product. The table below shows an example of the calculations.

	A	B	C	D	E
Plot	Gross harvest	Gross sample	Net sample	Adjustment Factor (C/B)	Net Harvest (A x D)
101	3545	345	305	0.88	3120
102	2300	500	450	0.90	2070
103					
104					
201					
202					
.					
.					
.					
404					

The sample you take should not be too small because that would increase the uncertainty in your measurements. For most crops 2-300 grams are a minimum. Even larger samples are necessary if your scale's graduation is larger than 1 gram. If you cannot take a finely graduated scale to the field then keep the gross sample in a plastic bag and measure the sample when you get back to the office. Remember that moist samples only keep 1-3 days in a plastic bag.

6 Problems and how to cope with them

6.1 Soil heterogeneity

Differences in soil fertility is a major cause of error in field trials. The soil heterogeneity may be of two kind: a patchy distribution of soil fertility and a gradual change in fertility from one part of the field to another. In upland field, especially recently cleared shilling cultivation fields, both type of soil fertility distribution are common. Ash deposits, termite mounds, decomposing roots, tree stumps, cow dung and intercropping are all likely to increase the patchy fertility distribution.

On sloping land the fertility gradient usually follows the slope; fertility being higher in the lower part of the field. This is caused by erosion cum sedimentation, leaching of nutrients, and internal drainage. These factors may also affect the competition from weeds and pests.

After land has been used for trials the different treatments would often have lead to increased soil heterogeneity. Consequently, it may be necessary to stop further trials on that land for 1-3 years during which time the land is managed uniformly.

To reduce the interference of soil heterogeneity in the trials it is important to lay out the trials in an appropriate way with proper blocking and plot shape.

6.2 Border effect

Plants along the edge of a plot and in the center of the plot usually perform differently. This so called border effect is caused by:

– Un-planted alleys between plots.

– Open areas surrounding the trial area.

– Adjacent treatments vary in their competitiveness for light, water, and nutrients.

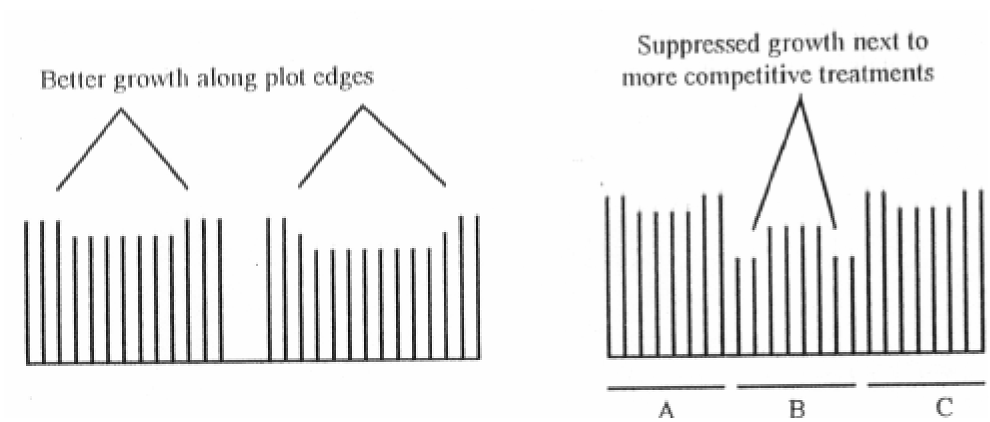


Figure 4. Schematic view of border effects on plant height

It is important to minimize the border effects because the yields are not representative of the production conditions that occur in real fields. The border effect can be minimized by:

1. Excluding 1-2 plant rows along the plot edges from the yield assessment and other data collection. These 1-2 rows are called the borders.
2. Not using implanted alleys between plots. If implanted alleys are necessary to keep treatments separated and to facilitate access, the alley should be as narrow as possible, preferably not more than 50 cm.

3. Planting 2-3 rows of plants around the edge of the experiment. These rows are called guard rows. In the trial plan extra area must he calculated for the guard rows. If unplanted alleys were used between plots, similar alleys should be put between the guard rows and the adjacent plots.

6.3 Missing plants and hills

In most field trials a uniform plant spacing and density is necessary to compare the treatments. However, gaps in the plant population often occurs because of problems with seed germination, pest attacks, careless weeding, etc.

Where gaps have occurred the adjacent plants often grow much better, because of more light, moisture and nutrients. The adjacent plants are therefore not representative for the real field conditions. Therefore, the surrounding four hills or plants adjacent to the gap should be excluded from the yield measurement and any observation or sampling.

If more than 20 % of the plants or hills are missing (including those adjacent to the gap) the results from the plot cannot be used. If 5-20 percent of the plants or hills are missing, it is possible to compensate for the loss by dividing the total yield with the number of harvested hills/plants and multiply this figure with the planned number of hills/plants.

Example: if the yield was 360 from a plot where 100 hills were planned and 90 hills were actually harvested the compensated yield would be 360 g x 100 \ 90 = 400 g.

The risk of missing hills or plants can be reduced by:

– Testing the seed before sowing and adjust the seed rate according to the germination percentage

– Plant more seed than you need in the final plant stand, and thin out the surplus plants.

– Remove the least viable surplus plants.

– Re-sow where gaps have occurred shortly after sowing.

– Transplant plants from the guard rows.

6.4 Outlier results

When comparing the results of a treatment, one replication may be very different from the mean of the other replications. Such an unusual result will often make the whole trial non-significant in statistical term.

However, it may be possible to eliminate the unusual result from the analysis. This requires that the unusual result was caused by an error in the trial implementation or that it was caused by external factors, such as damage by domestic animals. The field notes taken during trial implementation may tell you the cause of the unusual result. Elimination of the result also requires that the difference between the unusual result and the mean of the treatment is really large. An 'outlier test' is carried out to determine if a result is sufficiently different from the treatment mean to eliminate it from the statistical analysis.

An outlier test compares the standard deviation of the "normal" results with the deviation of the possible outlier result from the mean of the "normal" results. The unusual result can be considered an outlier if its deviation from the mean is more than four times greater than the standard deviation of the normal results. In that case the unusual result can be eliminated from the statistical analysis. The plot result will then be considered as missing (see 6.5).

Example:

In a variety trial using four replications one variety yielded 50, 44, 47 and 22 kg per plot. The low yield in replication four may be caused by a buffalo entering the plot early in the season. An outlier test is performed to see if the result is sufficiently different from the other replications.

The mean yield of replication 1, 2 and 3 is calculated: 50 + 44 + 47 \ 3 = 47

The standard deviation of the three replications is calculated:

$$\frac{(50-47)^2+(44-47)^2+(47-47)^2}{3-1}$$

$$\frac{3^2+3^2+0}{2}=9$$

The deviation of the possible outlier is: 47 - 22 = 25

Consequently, the unusual result is not an outlier, since its deviation is less than 4 times the standard deviation of the other replications (25 \ 9 = 2.7).

If the unusual result had been as low as 10 kg, it would have been an outlier:

47 - 10 = 37

37 \ 9 = 4.1

6.5 Missing plot data

Sometimes results are missing from one plot. This may be because of loss of data or because the result was an outlier (6.4). The missing plot data may be compensated for. In block design this is done by using the data from the other replications of the same treatment and the data from the other plots in the block where the data are missing.

The following formula is used:

$$\frac{t\times \mathrm{T}+r\times R-S}{(t-1)(r-1)}$$

t = number of treatment

T = Sum of the results of treatments of the missing plot

r = Number of replication

R = Sum of the results of the block with the missing plot

S = The grand sum of all plots

Example

Rice variety trial 4 treatments in 4 replications. Treatment 1 in block 1 is missing. Yield in kg\plot

4 2.2	2 3.2	1 1.6	3 1.8
2 3.4	4 2.5	1 1.9	3 2.1
1 1.8	3 2.3	2 3.5	4 2.6
3 2.3	1 missing	4 2.8	2 4.0

The missing plot data is calculated as:

$$\frac{4 \times 5.3 + 4 \times 9.1 - 38}{3 \times 3}$$

= 2.2 kg \ plot

6.6 Residual effects

The different treatments of field trials will vary in their effect on the following crop. It is therefore sometimes best if a trial is followed by a period with no trials of one to three years. During those years the land should receive uniform management to level out the differences caused by the original trial treatments. The area can be used for simple production, for propagation of seed, or it can be put fallow. The number of years the land need to be kept of trials depends on the impact the different treatments had on the plots. In a trial testing different rice varieties with similar biomass production no rest or only a single trial-free year may be needed. 1-3 years may be needed after comparing different crop rotations or intercropping systems. The longest periods are needed for trials that directly affects the soil conditions, e.g., fertilizer trials, liming, or tillage. In these cases 2-5 trial free years may be necessary. Unless large areas are available on the station such trials may be more suited for on-farm trials. However, sometimes it is valuable to test the effect of different treatments on the following crop. You may, e.g., be interested in investigating the effect of fertilizers on the succeeding crops. In that case all the plots that received different fertilizer treatments should be used for a single crop in the following years.

Another way of coping with a strong residual effect is by blocking the land in year 2 according the treatments in year 1. This means that block 1 in year 2 will consist of the plots used for treatment 1 in the first year. Similarly, block 2 will consist of treatment 2 in the previous year, etc. Normally, the number of blocks in year two will be equal to the number of treatments in year 1, and the number treatment in year 2 will equal the number of blocks in year 1. This kind of blocking is only suitable if the residual effect is stronger than the block difference in year 1.

Year 1

Block A	1	3	2	4
Block B	2	1	4	3
Block C	2	3	4	1
Block D	4	1	2	3

Year 2

Block A			
	Block A		
			Block A
	Block A		

Year 1

Block A	1	3	2	4
Block B	2	1	4	3
Block C	2	3	4	1
Block D	4	1	2	3

Year 2

Block A	Block C	Block B	Block D
Block B	Block A	Block D	Block C
Block B	Block C	Block D	Block A
Block D	Block A	Block B	Block C

Year 2

A 3	C 1	B 4	D 2
B 1	A 4	D 1	C 3
B 2	C 2	D 4	A 2
D 3	A 1	B 3	C 4

6.7 Annual differences

Plant production vary considerably from year to year. This is mostly caused by weather conditions and their interaction with other factors, such as pests, weeds, and timing of farm operations. The performance of various treatments likewise vary between years. It is therefore difficult to make conclusions and extension recommendations based on only one cropping season. A trial should therefore be repeated for 2-4 years, unless it is deemed totally useless.

Some modification can be made from year to year, but it is normally best simply to repeat the trial. This will ensure that a proper statistical analysis can be done. Furthermore, it is difficult to predict the performance of treatments based only on one year. Thus, treatments that performed extremely bad in one year (and were considered eliminated from the trial sometimes very well in the second year.

7 On-farm research

Field trials carried at research stations may be useful in testing new technology under relatively controlled conditions. However, such trials often says little about the suitability for the new technology under the environmental and socio-economic conditions that face farmers.

7.1 Technology generation

Technology generating trials usually compare several treatments under standards experimental conditions. Such trials may be carried out both at research stations and in farmers' fields. The statistical procedures and trial designs are usually similar whether carried out as on-station or on-farm trials.

7.2 Technology verification

A large number of farms are included, but the number of treatment and replications per field are kept small. Technologies that have proved useful in environments similar to a given target area may be tested in simple technology verification trials. A lot of experience in upland agriculture is already available from research and development projects in Laos and neighboring countries. It should therefore not be necessary to repeat the more complicated technology generating trials. Instead, a successful technology may simply be tested in farmers' fields by comparing it to the local methods or crop varieties. Technology verification trials may be a first step in extension of new methods and are therefore often carried out by extension staff rather than by researchers.

SELECTION OF TEST FARMS

The test farms should represent the target area in terms of environment, socio-economic conditions and land-use. Since different conditions exist in the target area it is necessary first to define what kind of farms the research is targeted at. Within the target area there may be farms you do not want to work with, e.g., farm with large paddy holdings or farms far from roads. For the possible The criteria for defining the farms may be based on the kind of land-use, the cultural composition, the size of the farm, the relatively wealth of families.

8 Demonstrations

Demonstration of new technology can take place on a research and extension station or in farmers' fields. The purpose is normally to show farmers, extension workers and other parties the differences between local and improved technologies. The new methods have normally been tested in local field trials, and only proven or promising technologies should be demonstrated. Demonstrations are one way of spreading research results to farmers and extension workers. Once a new technology has proved useful in a certain environment it is normally the work of extension workers to carry out the demonstrations

Demonstrations are usually not replicated, the plots are bigger than trial plots (preferably at least 100 m2), and the number of treatments is usually limited to 2-4. One of the treatments should be of local technology. The demonstration becomes clearer if the site is surrounded by the local control treatment.

The front edge of the demonstration area should be straight line along the lower side of the slope and have a path running all along the edge.

The demonstration site should preferably be easy to access, so many farmers have opportunity to visit the site.

Discussion should be encouraged by providing readily comprehensible information through field signs, hand-out, etc. A board explaining the different treatments and their locations should be made. Results from previous field trials can be presented in a pamphlet, which also provide extension recommendations. During visits to demonstration sites in farmers' fields the field owner should be available, and preferable be explaining and discussing.

Research fields can be used for demonstrations and discussions with and between farmers. However, it is often difficult to see the differences between treatments. Also, farmers may be introduced to untested technologies that later fails.

9 Equipment

The equipment needed to do field trials does not have to be very sophisticated

Measuring tapes

Two tapes of 30 meters each, and one tape of 50 meter. Metal tapes are best because they do not stretch and are more durable.

Plastic bags

Meteorological equipment

The minimum requirement for meteorological equipment is a Minimum/Maximum thermometer and a rain gauge. Recordings should be made every day at the same time, preferable at 18.30 hours. The data should be put into a form kept in the shelter where the thermometer is kept.

The average daily temperature can be calculated as the mean of the daily maximum and minimum temperature. If you have a thermograph, the hourly temperatures are added together and divided by 24 to give the mean daily temperature. In addition, the minimum and the maximum temperatures are recorded. When you present the data for mean daily temperature it is important that you state the method of calculation.

The rainfall should also be recorded at least daily. The rain gauge must be placed on level ground away from obstacles that can affect the entry of water in the gauge. The distance to any obstacle should be a least 2 times the height of the obstacle. The top of the gauge should be placed about 30 cm above ground level.

The mean daily temperature for every 10 days period should be calculated. Also, the total rainfall during the 10 days should be added up.

10 Field trial management

The management of individual trials are usually left to the various researcher. However, a number of activities are the responsibility of the research manager. A manager is normally necessary if more than 3-4 researchers are working in the organization. For larger organizations the research manager should have one or several assistants.

The research manager's work is mainly administrative, including:

- Ensuring that materials are available at the appropriate time.
- Checking that seed are ordered in time.
- Ensuring that all equipment works and is maintained properly (meteorological equipment, moisture meters, scales, drying ovens, computers, etc.).
- Ensuring that weather data are recorded correctly.
- Ensuring that funds are available to the researchers when they need money.
- Managing the laborers, including payment, availability of sufficient number of labors, and training of laborers.
- Making work and budget plans in cooperation with the researchers, usually annual, quarterly and monthly plans.
- Making the administrative summary reports and financial summaries.
- Monitoring of work progress: implementation according to work plans, identification of constraints, seek ways of overcoming the constraints, suggesting improvements.
- Keeping copies of all trial results, data on climate and soil conditions, and of the various administrative reports, correspondence, procurement orders, etc.
- Keeping records of the trials areas and past trials and treatments on each trial area and plot
- Taking responsibility for visitors, e.g., farmer groups, extension workers, development projects, government officers and donor representatives.
- Keeping lists of unit costs for various inputs used in the field trials, such as labor requirements for various tasks, materials, seed, transport, per diem, etc. This will greatly ease work planning, budgeting and monitoring.
- Keeping lists of relevant research organization, development projects, government agencies and departments, etc., including addresses, telephone and fax numbers and contact persons.
- Making staff training programmes, study tours, and other staff development initiatives.

The research manager should try to delegate as much responsibility as possible to the researchers, other staff and workers. The research manager should therefore facilitate the flow of information within the research group and involve the staff in the various administrative tasks. However, the ultimate responsibility of the tasks listed above should rest with the manager.