Field Experiments with Forages and Crops

Practical Tips for Getting it Right the First Time

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and Peter Horne

Illustrations adapted by Mark Wilson from the original artwork of Praseuth Banchongphakdy and Kongphat Luangrath

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YC and PH
Vientiane, Lao PDR
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WHY IS THIS GUIDE NEEDED?

Agricultural research for smallholder farmers in developing countries is undergoing great change. Many workers now recognise that agricultural technologies cannot be developed without involving farmers. A new grass for feeding animals, a new upland rice variety or a different method of crop management may each be seen by farmers in ways that scientists do not expect. As a result, many field experiments are being moved off research stations and onto farmers' fields so the farmers can actively participate in the development and evaluation of new technologies. Some of this technology development involves monitoring and encouraging farmer innovations and some involves more controlled experiments on farmers' fields. This often means that field experiments are being conducted in remote places by farmers and field workers who may have little practical experience in running formal experiments.

The most common cause of problems with field experiments in these situations is not poor experimental design. Problems usually occur because important, simple procedures are overlooked, such as preventing unwanted livestock from eating the test plants or ensuring that the plots are permanently labelled. This guide provides practical tips for researchers, field workers and students on how to avoid such common mistakes. Many of the examples presented in the guide relate to forages, but the suggestions are also relevant to field experiments with most crop plants.

SOME USEFUL TERMS EXPLAINED

Field experiments are often undertaken to select the best and most appropriate of alternative technologies. These alternatives are called TREATMENTS. Treatments can be things that we can see and hold, such as different varieties or species of forage or different types of fertiliser. Treatments can also be things that we cannot see and hold, such as different sowing depths, different rates of seed application, different methods of sowing or different methods of cultivating soil.

The treatments are applied to areas of land called PLOTS. One complete set of all treatments is called a REPLICATE. Field experiments usually have 3 or more replicates. Replication is necessary because one plot might be damaged or destroyed. It will also confirm that what is observed in one plot also occurs on other plots with the same treatment. If each replicate is kept separate from the other replicate, it is called a BLOCK. Blocks should be used particularly when the site for the trial is not uniform (for example, on sloping land).

VARIABLES are what you measure about each treatment to determine the performance of that treatment. Some examples of variables are plant height, fresh weight, dry weight and seed yield. They can also be factors like protein content of leaves or number of aphids per plant.

Consider, as an example, an experiment testing the effects of N fertiliser on yields of upland rice. The experiment has 5 rates of N application (0, 20, 40, 60, 80 kg/ha of N) with 3 plots for each rate of N application. On each plot, the researcher measured number of seedlings, plant height, weed density and grain yield.

The rates of N application are the TREATMENTS. What the researcher measured are the VARIABLES.

If the site is sloping and growth of the rice was expected to be greater at the bottom of the slope, the experiment might look like Figure 1, which has 3 BLOCKS. This is called a RANDOMISED COMPLETE BLOCK DESIGN.

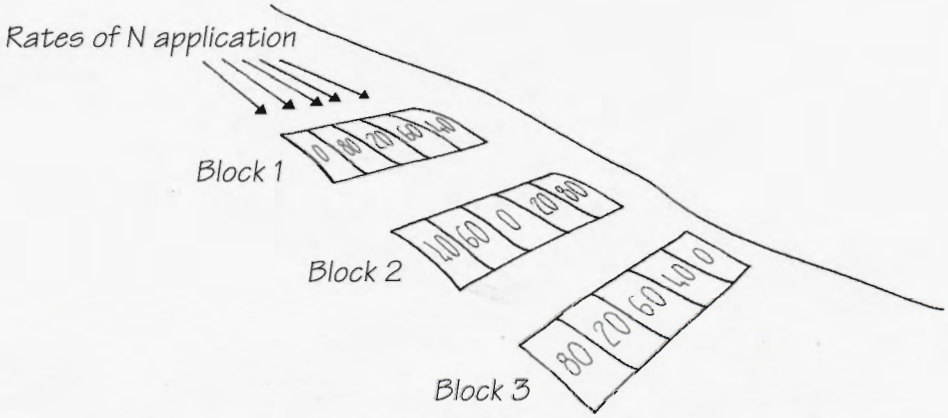


Figure 1: Randomised complete block design

1

Planning and Organising the Experiment

Keep a diary and use it regularly.

Memories are unreliable. In six months time, will you be able to remember how much seed you sowed and on what date? Almost certainly not! So, as soon as you start planning and organising an experiment, keep a diary in which you write down all your plans, decisions, actions, observations, feedback from farmers and any unexpected events.

Maintain regular contact.

Unexpected events often occur during experiments. Farmers and field staff need to know they can contact others for advice and support when dealing with these. Regular contact allows problems and misunderstandings to be resolved quickly.

Maintain regular contact with all people involved. Be flexible in your plans and be prepared to make changes if necessary.

Involve farmers in the experiment as much as possible.

If the aim of your experiment is to identify and develop forages that will be adopted by farmers, you should involve them actively in all stages of the experiment. Farmers are natural researchers who can evaluate and compare treatments for you and help you understand why they prefer one treatment over another.

Explain the aims and procedures of the experiment.

Often, the people responsible for an experiment cannot be contacted when problems arise. If everyone thoroughly understands the aims and procedures of the experiment, they will be better able to identify and deal with problems. This can be achieved by preparing and discussing an outline of the experiment, which includes:

- ***the experiment name*** *(people may use different names for the experiment. Having a standard name for the experiment that is known by everyone will avoid confusion).*
- ***the aims and objectives of the experiment.***
- ***the location.***
- ***plot size and layout.***
- ***the date of sowing/planting.***
- ***design of the experiment*** *(what plants should be planted, where, when and how).*
- ***data collection methods and timing.***
- ***methods of collecting, drying and handling samples.***
- ***the people responsible for each task.***
- ***management of the experiment*** *(for example, sowing rates, rate and time of fertiliser application, measurements, weed control, animal control and pest management).*
- ***when you expect the experiment to be completed.***
- ***who will write the report and where the data should be sent.***

Keep the experimental design as simple as possible.

Simple experimental designs are often the most appropriate, easily managed and easily analysed. Refer to a book on experimental design for examples (e.g. Gomez and Gomez, 1984).

Allow enough time for the experiment to be successfully completed.

Experiments may last for a few months or for several years, depending on the objectives. An experiment that cannot achieve its aims properly is a waste of resources and time. Plan enough time and resources for the experiment to produce the results that will achieve its aims.

Understand your responsibilities.

Before starting an experiment, everyone involved should know what tasks they are expected to do, how to do them and how long they will be involved in the experiment. A simple and effective way of doing this is to have everyone's responsibilities clearly written down and discussed by the group. Each person can then explain his or her responsibilities back to the group to make sure they understand.

Prepare a timetable for the experiment.

To help you plan what you need to do before and during the experiment, organise the activities in a timetable. The most important event is often the time when you have to sow the experiment. This may be, for example, one week after the first wet season rains. You should avoid planting in sub-optimal conditions as establishment failure will affect the future of the experiment. Rain will come at the beginning of the wet season whether you are ready or not! All pre-sowing activities, such

as planning the experiment and organising seed and fertiliser, will have to be completed to make sure you are ready to sow on time. Include other activities like the dates for applying treatments, data collection and field visits in the timetable. If you later make changes to the timetable, write these down in the diary and make sure everyone concerned knows.

Prepare in advance the materials that you need.

Making a list of the things you need before you start an experiment (such as seed and vegetative planting material, fertiliser, labour and tools) will help you plan ahead. It would be very frustrating to make all the preparations for an experiment and then find you don't have the seeds ready. Check that all the equipment you will be using, such as weighing scales, are working properly (see 'Useful tools in the field' on page 37 to remind you of some of the tools you may need).

Protect the quality of your seeds.

Seed is valuable and alive! Seed quality (especially of grass seeds) drops rapidly if it is not stored properly. When you receive seed for your experiment, immediately store it in a cool and dry place. If seed is stored in a hot and humid place, it may be dead by the time it is sown.

A convenient way to package dry seed is in sealed plastic bags. However, do not leave seed, that is stored in plastic bags, exposed to the sun as this can kill the seed.

If you are going to store larger quantities of seed for a long time (>3 months), it is useful to test its quality (germination and viability) before storage. Storing dead seed is not only a waste of time, but can ruin subsequent experiments.

2

Selecting the Experimental Site

Is the site typical of the area you are interested in?

The most important step in selecting a site is to make sure that it is representative of the area of interest. For example, if you want to test forages for farmers who have sandy soils, put the trial on similar soils in their region and not on a site that is more convenient to you.

The experimental site should be as uniform as possible.

Avoid putting the experiment on areas with different soil types, rock outcrops, uneven slope or next to roads, trees and buildings, as these will unevenly affect plant growth.

However, it is often difficult to find uniform sites. You should then arrange your blocks so that the plots in any one block are as alike as possible. Try to minimise the variation within each block. If you have a sloping site that is wetter at the bottom than at the top of the slope, arrange your blocks so that Block 1 *is across the top of the slope,* Block 2 *is further down and so on (see example in the section 'Some useful terms explained'). If soil types are different, arrange your blocks so that the soil is similar within each block.*

Where appropriate, avoid sites prone to erosion.

When soil is left without cover, it is susceptible to erosion. Where possible and appropriate, avoid sloping areas where there is a high risk of damage from erosion and avoid areas where there is a possibility of damage from up-slope runoff.

Where appropriate, avoid sites prone to flooding.

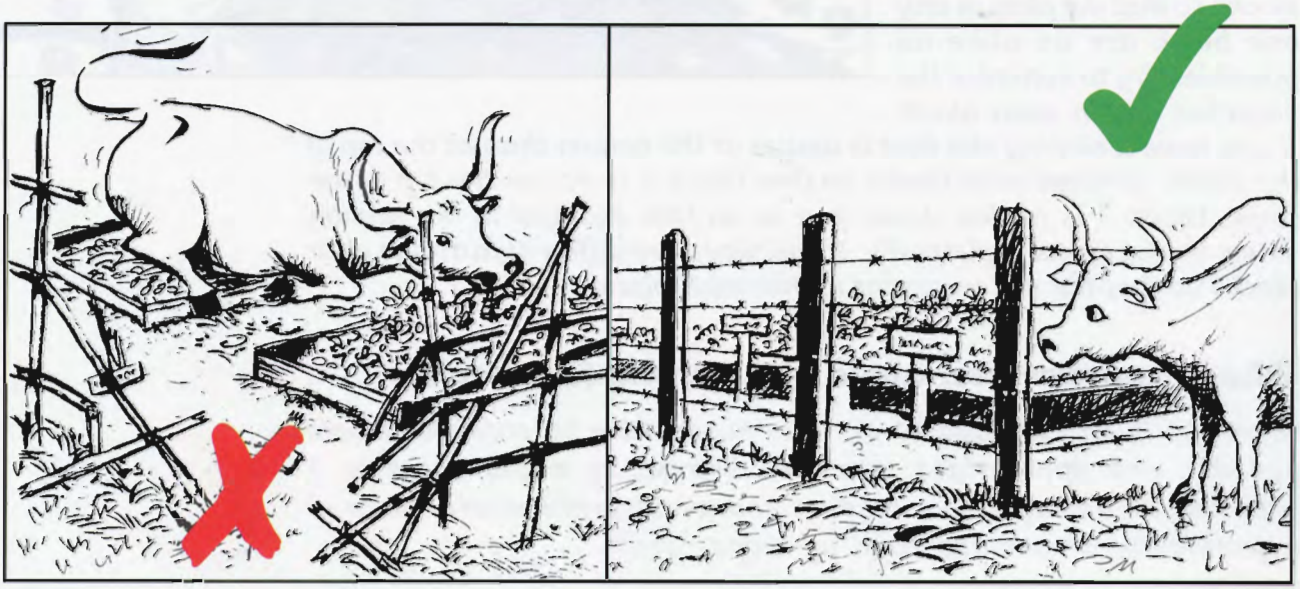
If you are selecting the site in the dry-season, make sure that it is not prone to flooding during the wet season. Flooding can make access to plots difficult and also destroy your experiment.

Make sure the site is available for as long as you need it.

You may not always know exactly how long the experiment will last, so always allow for the possibility of needing to extend the experiment.

Protect the site from livestock and wildlife.

A common problem with field experiments is the destruction of plants by wandering animals, especially during the early stages. Young green plants are very tempting to chickens, cattle, goats, sheep and other animals, so check that the fences around your trial will keep unwanted animals out.



Minimise outside effects on your experiment.

The site chosen for the experiment should not be unevenly affected by other activities. For example, if your experiment is too close to fruit trees where farmers are using herbicide sprays to control weeds, chemicals may drift to your experiment, killing some plants.

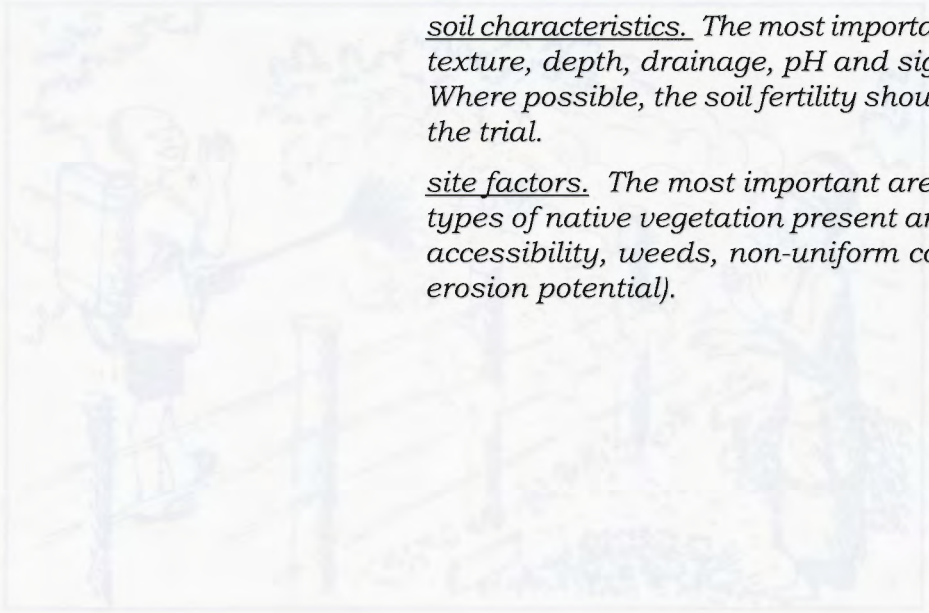
Check how the site has been used before.

The site could have been used previously for an activity that will affect your experiment. An old road, an old building, an area where a tree stump has been burnt or an area that has been fertilised may affect plant growth in some plots but not others. If you know the site history, you can minimise these effects by the way you arrange your blocks or by leaving some empty plots in the design.

Make a description of the site.

A good description of the conditions at the site will help you and other people better understand the results of the experiment. The site description should include:

long-term climatic information (where possible, 10 years of data). The most important data are monthly rainfall, number of rain days per month, mean monthly maximum and minimum temperatures and the lowest and highest temperatures in each year.

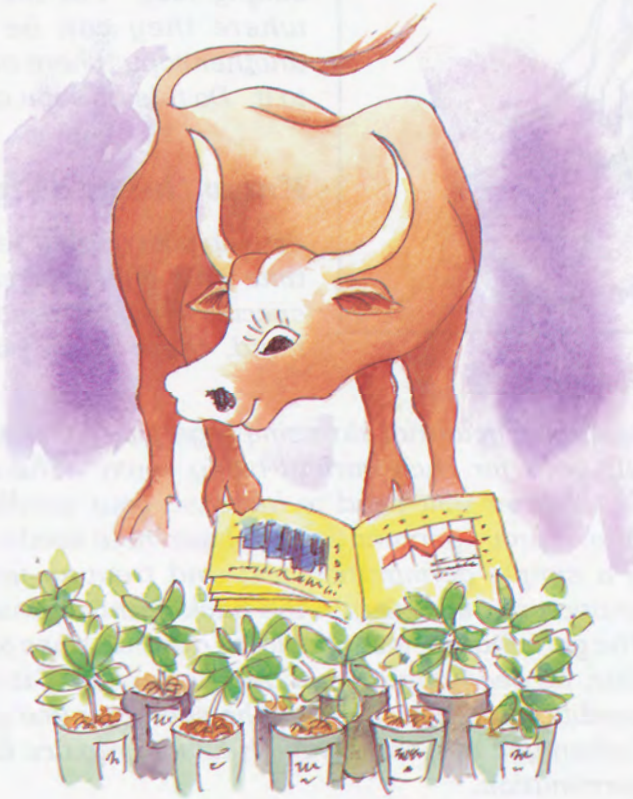


soil characteristics. *The most important data are topsoil and subsoil texture, depth, drainage, pH and significant nutrient deficiencies. Where possible, the soil fertility should be analysed before starting the trial.*

site factors. *The most important are slope, previous land use, the types of native vegetation present and possible problems (such as accessibility, weeds, non-uniform conditions over all the site and erosion potential).*

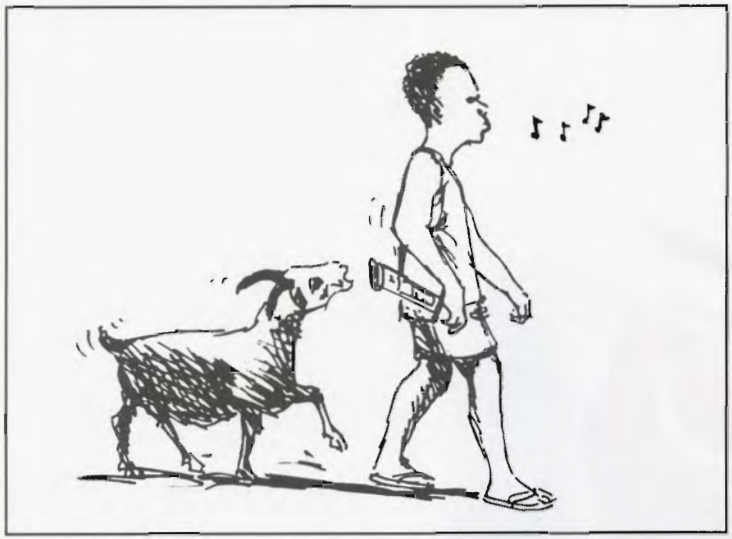
3

Before Going to the Field



Prepare a map of the experiment.

The experiment map should show exactly where the plots are located. This will make the job of the field staff much easier. Mark 'North' on the map. Include all obvious features, such as a road, a stream or a house. Check that everyone involved in the experiment understands the map.



Make more than one copy of the map.

It is essential to have extra copies of the map in case the one you use is eaten by a goat or blown away in a gust of wind, or simply lost. Put the copies of the map where they can be found easily and another copy where only you have access to it. Do this as soon as the map is drawn.

Know the quality of your seed.

Sowing poor quality seed is a waste of your time and effort! You may have a good species for your area, but if the seed is dead, there is no point in sowing your experiment.

Before sowing your trial, do a simple germination test to check the quality of your seed for each variety being sown. The result will help you decide whether you need to increase your seeding rates, treat your seeds to improve germination or obtain new seeds. The procedures for doing a simple germination test and treating your seed to improve germination are included in the back of this manual on pages 38 and 39. The germination test should be done as close to the sowing date as possible, as seed quality can decline rapidly if it is not stored in cool, dry conditions. If you suspect the seed has low germination, test the seed when you still have enough time to replace it, if the results show low germination.

Be careful when weighing treatments for each plot, such as seed or fertiliser.

Ask someone else to double-check your calculations. For example, mistakes can easily be made when converting sowing rates from kg/ha to g/m^2. A simple error like this is impossible to fix once the experiment has been sown.

If you are applying fertiliser, make sure that it is clear whether the quantity being applied refers to the fertiliser or to the element the fertiliser contains (for example, is it 100kg/ha urea or 100kg/ha of N?).

Decide on the appropriate sowing rates.

If you are comparing different species, it can be useful to adjust the sowing rate according to the size and quality of the seed to obtain similar plant densities in each plot. For example, when working with forage legumes, you might use 5 kg/ha for small seeds such as Stylosanthes, 10 kg/ha for medium-sized seeds like Centrosema, and up to 30 kg/ha for large seeds such as Arachis. In grasses, low viability (% of live seed) or low germination percentage may mean you need to increase the sowing rate.

Prepare and label as much as possible before going to the field.

Prepare seed, vegetative planting material, fertiliser and labels indoors before going to the field. Labelling and weighing your seeds outside would be disastrous if sudden gusts of wind or rain storms occur.

Prepare and label one treatment at a time. For example, if you are testing different species, weigh and label

one species at a time. On each label, check that the species and the plot number coincide with the map of the experiment. If you are using tags, they should be strong and not easily torn off or fall apart when wet. A second tag inside each bag may be used as a 'backup' in case the outside tag is destroyed. Use waterproof ink that will not rub or wash off.

Use waterproof bags.

Place treatment materials, such as seed and fertiliser, in waterproof bags. Paper bags can fall apart when placed on wet ground or caught in a sudden rain storm. Label the bags clearly and permanently. Place all the bags for each block into a larger waterproof bag to prevent the smaller bags being damaged or lost.

Prepare backup treatment materials.

Treatment materials, such as fertiliser and seed, may be spilled or lost when being applied. If your experiment site is located a long way from the source of the material, the experiment may be delayed. Where possible, bring extra materials with you to the site.

If you have enough treatment materials, it may be useful to take some pre-weighed backup treatments with you to the site.

Do your legumes need inoculation?

Most legumes have bacteria, called rhizobia, on their roots that provide nitrogen from the air to help the legume grow. Many forage legumes will nodulate freely with native rhizobia in the soil. This can be a major advantage for smallholder farmers who can neither buy nor store inoculant. However, some legumes may have to be inoculated with a culture of special rhizobia. A simple procedure for inoculation is included at the back of this manual on page 43. If no inoculant culture is available, you can use the soil from around healthy, nodulated plants of the same species.

4

Laying Out Plots

Calculate the size of the experiment carefully.

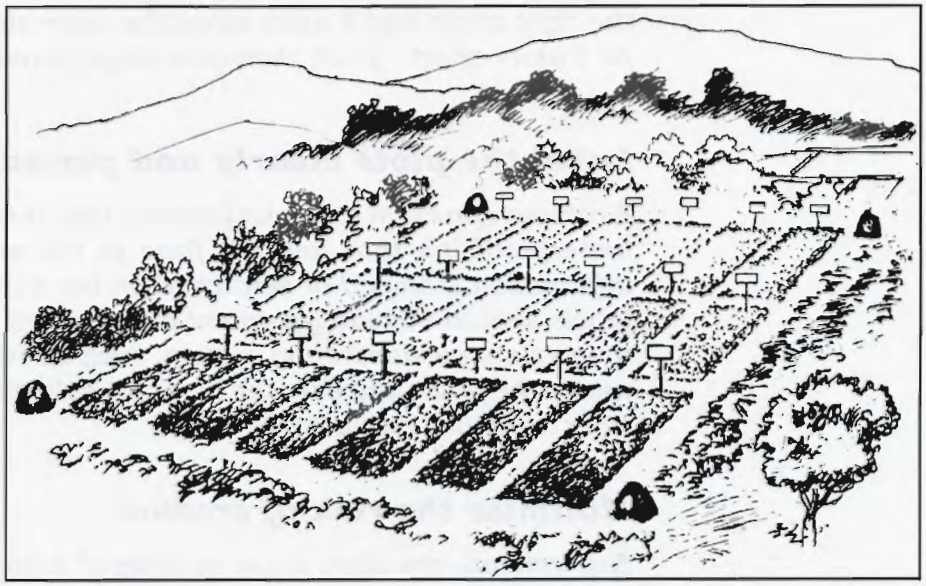
When calculating the overall size of the experiment, don't forget to leave space for pathways between the plots and around the boundary. It is useful to include spare plots within each block in case you later decide to add more treatments.

Double-check your measurements and calculations.

Someone else can usually pick up mistakes you may have made even though you have checked it yourself many times!

Mark the experiment site clearly.

Use easily recognised and long-lasting markers, such as small steel rods with plastic labels tied to them, white-painted pegs or rocks at the corners of plots so that they can be seen from a distance. Wooden pegs may be cheap but they can easily be eaten by termites. Paper labels are lost when it rains.



As well as plot markers, it is useful to have permanent markers, such as large rocks, in at least two fixed points on the site. This will help you find the exact position of the plots if you come back to the experiment site after some years.

Choose the size of plots and plot management to match the aims of the experiment.

Plot sizes will depend on the number of treatments and the aims of the experiment. Plot sizes in forage experiments may range from single rows in small plots for initial species evaluation to very large areas for grazing trials.

Manage the plots in a way that matches the aims of the experiment. For example, if you are evaluating a forage species for fallows in maize crops, do not use management practices that farmers would not use (such as raised beds or trenches around the plots).

Measure your plots carefully.

Guessing the size and shape of your plots can result in large differences in area. Measure each plot when laying it out. A simple way to make right-angles is to use the '3-4-5 rule'. If you mark a point 3 units along one side of the right angle and 4 units along the other side, then the two points should be 5 units apart. If not, then your angle is not 90°.

Label the plots clearly and permanently.

A common problem with plot labels is that they do not last long enough. Use waterproof ink that will not fade in the sun, or use metal labels with information stamped or scratched on the surface. Where appropriate, plot labels should include treatment and species information. It may be useful to use a simple numbering system, such as 101, 102, 103, 201, 202, 203, ..., where the first number is the block or replicate and the second two numbers refer to the plot number.

Minimise the risk of erosion.

Experiments are often sown at times of heavy rain, causing erosion which could damage or ruin the experiment. Where possible, avoid such sites. Otherwise, assess the risk of erosion damage on your site and take measures to reduce that risk (such as planting along the contour, maintaining ground cover in strips (such as paths between blocks) or using diversion drains above the experiment).

5

Managing the Experiment

Always carry a copy of the experiment map.

If labels have been lost, you can still identify plots with the experiment map.

Put all treatments, such as seed packets, on the plots before applying them.

By doing this, you can check that the treatments will be applied to the correct plot. If you have small packets of seeds and fertilisers, put a stone or clump of soil on the packets to stop them being blown away. If it is likely to rain or the work cannot be completed in one day, put all the treatment packets out onto the plots one block or replicate at a time. Do not leave packets of seed exposed to the sun for too long as this can kill the seed.

Check the label on each plot before applying treatments.

Before you apply treatments to the plots, ensure that each plot has been correctly labelled. Double-check that the labels on the treatments match what you have on the map and plot labels.

Choose an appropriate sowing method.

Sowing seeds too deep will mean they cannot emerge from the soil but sowing them on the surface exposes them to risks from erosion and drying. Small seeds are best spread on the surface of the soil and then covered very

lightly with soil (no more than 0.5 cm deep). You can do this by hand raking or by pulling tree branches or a broom back and forth over the sown area. Take care that soil is not dragged from plot to plot. Larger seeds can be sown 1–2 cm deep.

If you are not familiar with some or all of the sown species, sow the experiment in clearly marked rows or plant a few seeds on plots beforehand so you can recognise seedlings of the sown species. If the seed is spread all over the plot, it may cause difficulties later if you cannot recognise the sown species from weeds.

Vegetative planting material (stems or rooted cuttings) should be planted as soon as possible after they are collected. In the case of grass stems, plant two or three stems in one hole with one node above ground and one below ground.

Do you need to control weeds?

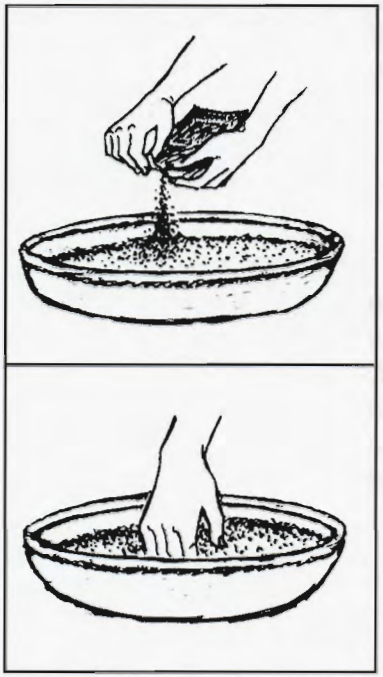
If weeds are not a serious problem, then it is usually best to leave the sown species to compete with them. If you need to control weeds in a small experiment, then hand weeding is often the best method. If weeds are very bad in a few plots, you can weed these back to the same number of weeds as the rest of the experiment. A simple method of reducing weed problems is to let them germinate and then cultivate them out before sowing the experiment.

Do you need seedlings to transplant at a later time?

If you anticipate establishment problems and transplanting is possible, set up a small nursery where extra seeds of the same species are sown at the same time as the main experiment. If the establishment problems do occur, you can transplant seedlings from the nursery without delaying your experiment.

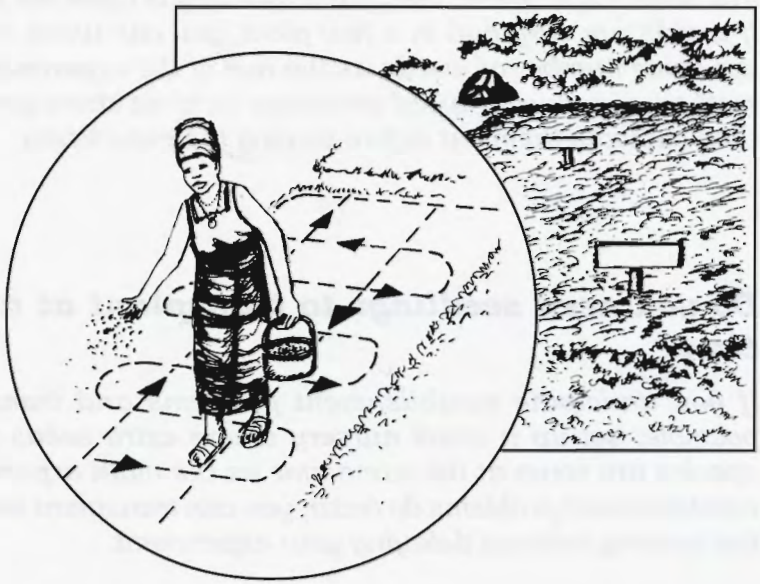
Keep your methods consistent between plots.

If the treatment involves spreading *seed on the surface of the soil, make sure you do this to ALL the plots that receive that treatment. If the treatment involves* sowing *seed into furrows, do this on ALL the plots that receive that treatment. The best way to keep everything consistent is to have the same person apply the treatments to the entire experiment. If this is not possible, make sure each block or replication is completed by one person.*



Within each plot, apply treatments evenly.

It is difficult to spread small amounts of seed evenly. You can spread them more evenly by mixing thoroughly with sand or sawdust. After you have mixed the seed with the sand, divide the mixture into two even piles. Spread the first pile by walking back and forth across the plot. Then spread the second pile by walking at right angles to the way you walked when spreading the first pile. If you are sowing seeds in rows, divide the seeds for the plot according to the number of rows in each plot.



Apply treatments one block or replicate at a time.

Sometimes it is not possible to apply the treatments for the whole experiment on a single day. Whether the treatments are applied in the morning or in the afternoon of one day or over several days could unevenly affect plant establishment. Soil moisture and temperature may change significantly when applying your treatments over more than one day (for example, if there is overnight rainfall). This does not matter provided each block or replicate is completed one at a time and that no block or replicate is left partially finished on any day. For example, if you are to sow an experiment comparing many varieties of maize, sow one whole block or replicate of the trial at a time, rather than sowing each species of maize in all the blocks or replicates.

If you do not have enough planting material of one species for the whole experiment, it is usually much better to complete sowing one block or replicate at a time and leave some blocks or replicates empty, than to reduce the sowing rate for that species in all blocks. Alternatively, if the species is easily propagated or spreads on its own, you could sow the central area of each plot, filling in the outer areas at a later time. If transplanting is possible, you can greatly increase the success of plant establishment by sowing the seed in a well-managed nursery and transplanting individual seedlings to the field plots.

Minimise the effect of one treatment on another.

If the plants in one treatment grow very fast, they can spread quickly. You may need to stop them from moving into other plots or shading other species by cutting them back, or by leaving an alley between plots.

If you have a fertiliser trial, be aware of the movement of fertiliser from one plot to another, especially on sloping land. One way to reduce this is to use large plots for the fertiliser treatments with the varieties or species planted in subplots within these large plots. This is called a SPLIT PLOT DESIGN. Another method is to have a wide space between the plots of different treatments planted with vegetative barriers.

If you are applying an insecticide spray as a treatment to some plots and not others, be careful that spray does not drift onto the other plots. Avoid spraying and applying fertiliser on windy days.

Record any mistakes immediately.

Everyone makes mistakes occasionally! If the wrong treatment is applied to a plot, note the change immediately and make sure everyone knows. Don't forget to note this on the experiment map as well.

DO NOT IGNORE ANY PROBLEMS THAT ARISE! If the experiment has been damaged by insects or flooding, don't think that the experiment is wasted and that no more data can be collected. You may still be able to obtain meaningful results from what might appear to be a ruined experiment. Discuss the problems with other people as they may be able to offer you suggestions on how best to deal with the situation.

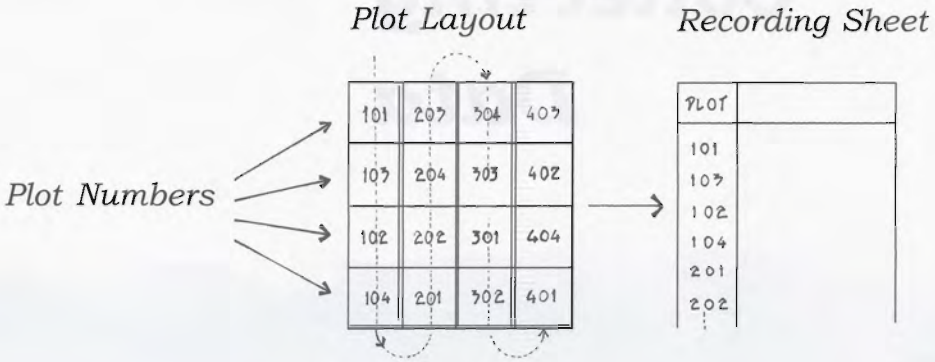
6

Collecting Data

Recording sheets should be clear and self-explanatory.

A good way to reduce error is to have recording sheets with a row for each plot and a column for each variable you will measure. Prepare these before going out into the field.

It is handy to have the plot numbers on the sheet arranged in a way that ensures mobility and consistency when gathering data in the field. This will reduce the chance of data being recorded in the wrong place.



Have a space at the top of each sheet for recording the date and the name of the person collecting the data.

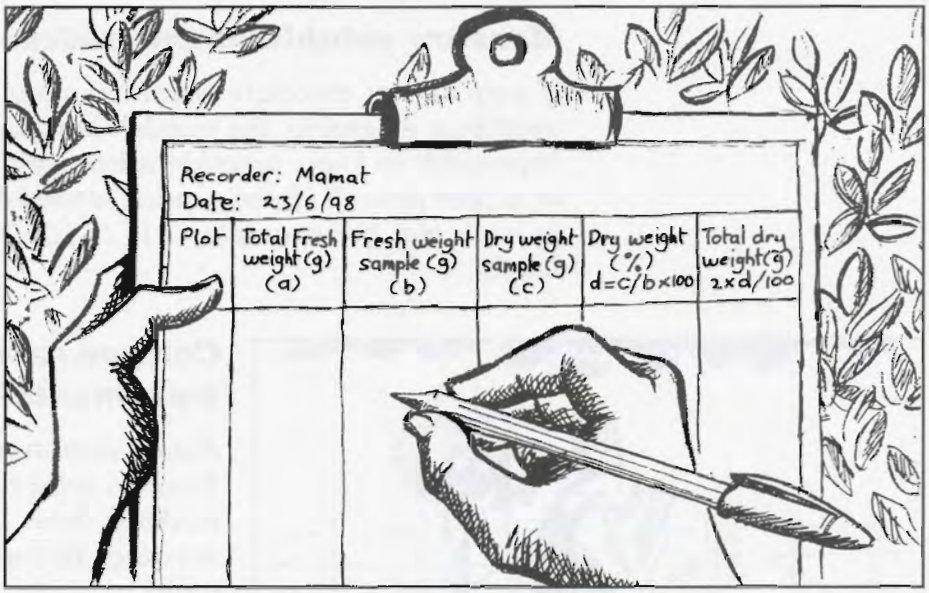
The recording sheets should be clearly written and detailed enough that someone not involved in the experiment can understand what was measured and be able to read the data.

Even in the dry season, your data sheets can get wet. Use pencils or waterproof pens. When in the field, carry your papers in a plastic bag.

Provide extra space on the recording sheets for notes, comments and calculations.

Unforeseen things often happen in experiments, such as flooding or insect damage, that can affect the results of the experiment. Allow extra space on the recording sheets to make notes on what is happening. Additional notes on unexpected events and when they occur will help you to interpret the results later on.

Copying your data from one sheet to another can result in errors. You can reduce these errors by adding extra columns to your data sheets for calculations. For example, when harvesting large plots, you might record the total fresh weight and the fresh weight of a sub-sample in the field and then calculate the total dry weight from the dry weight of the sub-sample. The field data and the calculated results could be on the same recording sheet, as shown.



Data should be collected from one block or replication at a time.

Collecting data from one block or replication at a time will ensure that all the treatments in that block or replication have been measured under similar conditions. Where possible, finish one block or replication before starting on the next and complete the entire block or replication before having a break.

Be consistent when collecting data.

One way to ensure consistency is to use the same person to conduct or supervise harvests and make measurements (especially if the measurements rely on the judgment of the recorder). In forage trials, for example, one common cause of inconsistency is when plants are cut to different heights by different people because they use different methods.

Measure establishment success.

If you do not measure establishment success (e.g. the number of seedlings emerging, the number surviving to mature plants), then it is impossible to know whether a low yield is due to a low plant density, or to poor growth. Even a quick estimate of seedlings per square metre in each plot (for example, 0.1, 1, 10, 20 or 30 seedlings/m^2) is very useful.

Can you rate the performance of the treatments?

Not all data have to be physically measured. You can collect data by looking at plants and ranking them using criteria such as colour, seeding, flowering, disease resistance and yield.

This can be helpful not only as a regular measurement but also if something unexpected happens (such as flooding or insect damage).

You may think that the experiment is destroyed and no data can be collected from the damaged plants. However, you can still get information and make some meaningful conclusions from what may seem like a ruined experiment. For example, if your forage species evaluation experiment has been grazed by wandering animals, you could take a measurement of which species the animals preferred.

You might compare the plots using the following system:

0 = not grazed
1 = lightly grazed
2 = moderately grazed
3 = heavily grazed

If you are rating plots, it is often important to set standards for your rating system. For example, you may be rating the leafiness of new maize varieties on a scale of 1 (low leafiness) to 5 (very leafy). In this case it will be useful to harvest some examples of each rating to measure the percentage of leaf in the sample and therefore know how leafy scores of 1, 2, 3, 4 and 5 really are.

Collect relevant climatic data during the experiment.

Measuring simple climatic variables at the experimental site (in particular, daily rainfall and temperature extremes) is often essential to help understand the results.

Visit the experiment site regularly.

If you check the site regularly with other field workers and farmers, you will be more aware of changes that are occurring in the experiment. Recording particular events, such as the date of flowering, might help you better understand the results at the end of the experiment.

There is also a better chance of correcting any mishaps that might happen, such as chasing goats out of the experiment, repairing fences, replanting after poor establishment or replacing lost plot labels.

7

Harvesting

Understand how to treat the harvested material.

If you have harvested all plant growth simply to compare total yields between treatments, then the samples can be dried in an oven or in the sun after harvest. If you are harvesting seed and want to test its quality (see Partridge, 1996) or if you want to test the chemical composition of the harvested material, you may have to treat the samples differently (for example, there may be specific drying requirements or specific plant parts needed for analysis).

Do not harvest edge plants.

Do not harvest plants on the edge of plots as they often grow differently than the plants in the centre of plots because there is either less or more competition with plants in adjacent areas.

Avoid harvesting plots immediately after rain.

High moisture content in samples can cause errors in yield measurement and soil contamination of leaf samples after heavy rain can cause errors in chemical analysis.

Harvested samples should be representative of the whole plot.

If your plots are small, you can harvest the whole plot, apart from a strip (30–50 cm wide) around the edge. However, if your plots are large, you will need to choose small areas to harvest.

It can be difficult to decide where you should harvest samples to be representative of the whole plot, especially if your plots are growing unevenly. Make sure you use a sampling method that ensures your samples are representative of the whole plot. There are many methods, depending on the uniformity and size of your plots. One is to walk twice across the plot diagonally, taking a metre square sample every few metres (the number of metres depends on the size of the plots). Plan the method of sampling beforehand and follow the same method for all plots.

Cut back all plots after sampling.

If your plots are large enough that you had to harvest sample areas, the entire plot should then be cut back to ensure even regrowth.

Account for weeds in harvested samples.

If your harvest sample contains weeds as well as your sown species, separate them out or, at least, estimate their percentage composition by weight.

Use a simple unbiased method for taking subsamples of harvested material.

The simplest method of sampling harvested material is the 'quartering method'. Divide all the harvested material in half and then divide these two piles in half again. Discard the two diagonally opposite piles. Combine the remaining two piles and repeat the process as many times as is necessary to give you a sample of the size that you need.

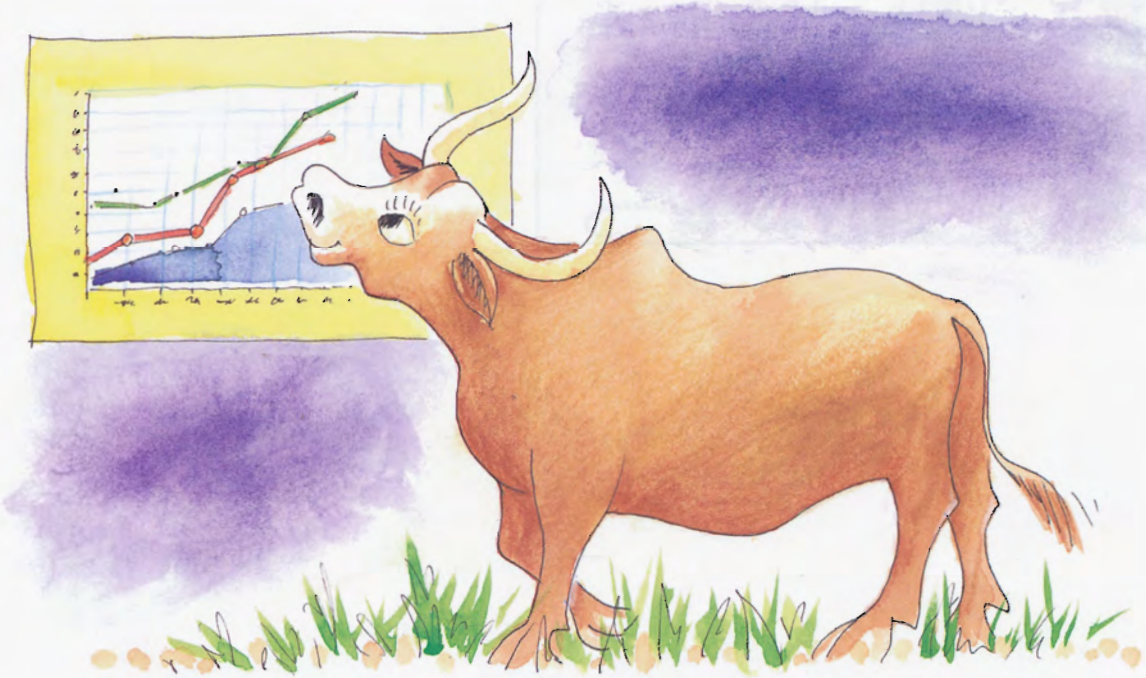
Weigh fresh subsamples in the field at the time of harvest.

Harvested plant material is often dried to calculate the dry matter yield. However, there is often too much harvested material to dry, so it is necessary to weigh all the harvested material in the field and then take a subsample for drying. However, plant water content can change rapidly after harvesting. Therefore, weigh your fresh subsamples at the same time as you weigh the total harvested material. It is useful to write harvest data (such as sample fresh weight) on the sample bags to reduce errors later when analysing the results.

Separate out the unwanted material (such as weeds, stems and dead leaves) from the subsample. It may be useful to weigh each of these separately.

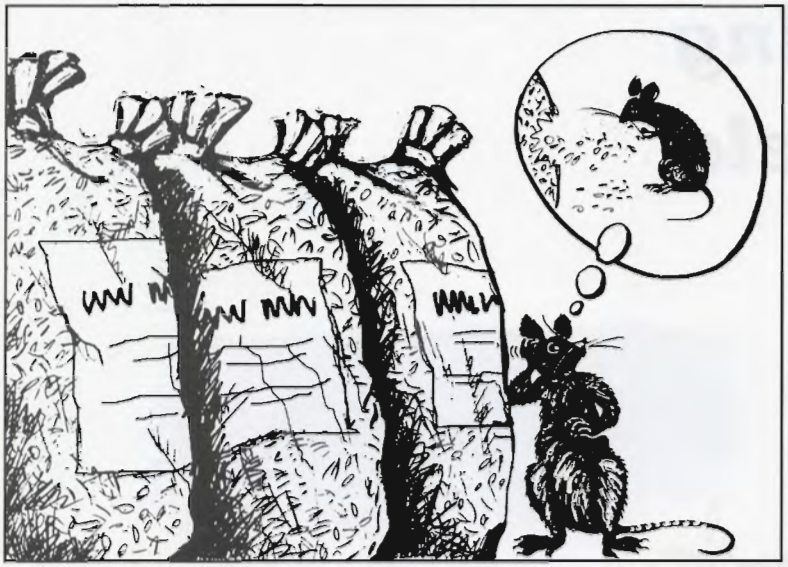
8

After Returning from the Field



Do not leave fresh samples lying around.

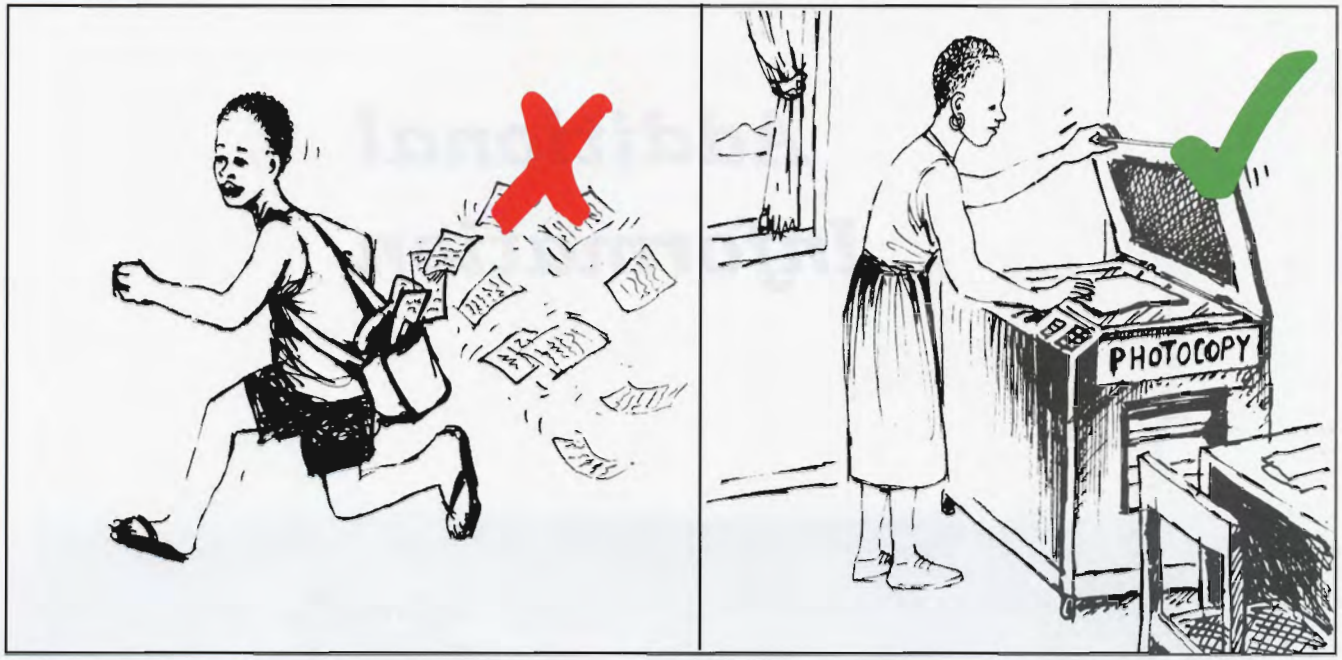
Dry your samples as soon as possible in the sun or in an oven before weighing. If the samples need to be analysed chemically the temperature of the oven should not be higher than 70°C. Do not pack the ovens too full because drying will be slow and the chemical composition of the sample can change. Samples should be left in the oven for 72 hours.



Store dried samples in airtight and pest-proof bags or containers identified with labels on the inside and also with permanent markers on the outside.

Make a copy of the collected data.

It is easy to lose files and offices can burn down. Make at least one copy of your data as soon as possible and keep the original and the copy in separate places. Avoid copying the data by hand, as this introduces more errors.



Analyse your data soon after they are collected.

Mistakes can be quickly detected and corrected if the data are scanned and/or analysed soon after being collected. It is difficult to correct mistakes in the way the data are being collected or recorded if you do not check the data until the end of the trial.

Keep a systematic filing system for the data.

Data sheets are easily lost in the bottom of drawers. Organise your records so information is easily recovered. Simply using paper folders to organise your data can make finding information much easier.

Additional Information

Useful tools in the field

General

- *Ruler*
- *Pens and pencils*
- *Waterproof pens*
- *Clipboard*
- *Paper clips*
- *Sharp knife*
- *Tape*
- *Fencing wire and materials to repair broken fences*
- *Experiment map*
- *Diary*

Laying Out the Plots

- *String (knots tied at every metre is handy for measuring)*
- *Pegs*
- *Labels*
- *Hammer*

Sampling/Harvesting

- *Sickle*
- *Bags—paper, cotton, plastic, net*
- *Tarpaulin for weighing samples*
- *Field balance (spring, beam)*
- *Recording sheets placed in a plastic bag*

Testing seed for germination potential

There are two simple ways to test seed germination potential: a laboratory germination test and an emergence test. Both give only a rough indication of the germination potential of the seed.

1. Laboratory germination test

1. *Wet absorbent paper, such as tissue paper, with clean water and place on a plate. Pour off most excess water.*

2. *Place a known number of seeds (at least 100) on the paper and put a clear lid over it (to prevent moisture loss and to allow some light every day as some species need light for germination). Do not place in full sunlight.*

3. *Check the plate every day and add more water if necessary. The paper should be wet, but not drenched or the seeds will go mouldy. The paper should not be allowed to dry out.*

4. *In the tropics, it is not necessary to put plates in the incubator as a germinating temperature between 25°C and 30°C is quite suitable for most tropical species.*

5. *Count the number of seeds germinated every two or three days, for a total of 14 days for legumes and 21 days for grasses.*

6. *Remove and discard the germinated seeds as you count them so their roots do not get tangled up with each other.*

7. *After you have finished the germination test, add up how many germinated seeds you have removed from the plate, to calculate the percentage germination. For legumes, count the number of hard, unswollen seeds, to calculate the percentage of hard seed.*

2. *Emergence test*

1. *Fill a small tray with moist, fertile, well-structured soil. If you do not have this available, you could mix equal amounts of soil, sand and manure.*

2. *Take a representative sample of seed from your seed lot and sow a known number of these seeds (at least 100) into the soil, just under the surface.*

3. *Place the tray in a shady location with a mild temperature (not too hot or cold). Keep the soil moist but not waterlogged.*

4. *Every two or three days, count the number of seeds emerging for a total of 14 days for legumes and 21 days for grasses. Remove and discard the seedlings as you count them.*

Treating seeds to improve germination

Low germination percentage in seeds can be the result of a high percentage of dead seed or it can be because some of the seed is alive (viable) but is not ready to germinate (dormant).

In legumes, dormancy is often caused by a hard seed coat which is impermeable to water ('hardseededness'). In grasses, the causes of dormancy are more complex, including both physical and chemical factors.

Hardseededness in legumes can be determined by the percentage of apparently normal, hard seed that has not germinated at the end of a standard germination test. Viability (and hence dormancy) of grass seed can be determined by taking apparently normal seed that has not germinated at the end of a standard germination test and staining it with Tetrazolium (tri-phenyl tetrazolium chloride). Tetrazolium reacts with live cells in the embryo to form a bright red compound.

Low germination and high dormancy percentages in grasses often occur in fresh seed (e.g. Brachiaria *spp.). The simplest way to overcome this is to let the seed age in cool, dry conditions for 4–6 months or more.*

If the germination percentage of a seed lot is low but the viability of the ungerminated seed is high, then germination might be improved by treating the seed before sowing. Some procedures for this are on pages 41 and 42.

Treatment of dormant seed in grasses

1. Acid treatment

Acid treatment of grass seed is not often used unless immature seed is needed for sowing immediately. Brachiaria seed, for example, can be immersed in concentrated sulphuric acid (available from car batteries) for up to 10 minutes using the following procedure:

i. *Mix the seed in concentrated sulphuric acid for up to 10 minutes and stir frequently. BE CAREFUL NOT TO SPLASH ACID ONTO YOUR SKIN OR CLOTHES. IF THIS HAPPENS, WASH IT OFF QUICKLY WITH COLD WATER. The outer parts of the seeds (the 'glumes') will be removed by the acid.*

ii. *Drain the acid and rinse the seeds in water until free from acid. Rinse several times then spread the seeds out thinly to dry.*

iii. *Test the germination of the treated seed. If germination is still low and most of the seed is still hard and not swollen, you can soak the seeds in acid again. Do not soak seeds in acid for more than 30 minutes at any one time.*

2. Pre-drying

Seed is heated up to 7 or more days in hot air at 40°C–60°C.

Treatment of hardseededness in legumes

1. Soaking

Seed is soaked in hot water at 80°C for 2–10 minutes or 100°C for 3–5 seconds. This helps open the hard seed coat in some legumes (e.g. Leucaena).

2. Acid treatment (e.g. Stylosanthes hamata*)*

Mix the seed in sulphuric acid for up to 10 minutes and stir frequently (as for the acid treatment of grass seed).

3. Mechanically remove parts of the seed coat

With small seed lots, this can be done with a scalpel, nail clippers or sand paper. Caution should be used when cutting seeds to avoid damaging the embryo. With large seed lots, hammer mills can be used, but you will need special sieves for your seed type.

A WORD OF CAUTION: *Seed is alive. The methods described above can easily kill your seed if not used properly. Test each method on a small lot of seed first. Confirm that the treatment has been successful by comparing germination test results of both the treated and untreated seed.*

Useful reference

Harty, R.L. (1996). Seed testing. In: TROPICAL PASTURE SEED PRODUCTION — A TRAINING MANUAL. I.J. Partridge (ed.). Department of Primary Industries. Queensland, Australia. 110pp.

Inoculating legume seeds with rhizobia

If it is necessary to inoculate your legume seed, the inoculant can be applied to seeds, in a slurry or as a dry powder.

1. Slurry application

i. *Mix the inoculant and the seed with a little water to make a slurry.*

ii. *The seeds should be thoroughly wet and coated with the slurry, without being too wet. This is best done by swirling the seed around in a beaker, bucket or other container.*

iii. *Dry the seeds in a cool, shaded place before planting.*

iv. *Sow the inoculated seeds within 24 hours. You may choose to inoculate seeds in the evening and dry them overnight before planting the next morning.*

2. Dry application

Mix the dry inoculant with the seed immediately before planting.

IMPORTANT

INOCULANT SHOULD ALWAYS BE KEPT IN A COOL PLACE, NEVER IN SUNLIGHT AND NEVER FROZEN.

☑ Checklists

These checklists are designed to remind you of the practical suggestions mentioned in this guide. Make a copy these checklists to take with you to the field.

Planning the Experiment

- ☐ *Start a diary for the experiment.*
- ☐ *Explain the aims and procedures to everyone involved.*
- ☐ *Keep the experimental design as simple as possible.*
- ☐ *Allow enough time for the experiment to be successfully completed.*
- ☐ *Make sure everyone understands their responsibilities.*
- ☐ *Prepare a timetable for the experiment.*
- ☐ *Check that everything you need will be available on time.*
- ☐ *Store your seeds in a cool, dry place.*
- ☐ *Make sure that the site is typical of the area you are interested in.*
- ☐ *Find out how the site has been used before.*
- ☐ *Make sure that the site is as uniform as possible.*
- ☐ *Avoid sites prone to erosion.*
- ☐ *Make sure that the site will be available for as long as you need it.*
- ☐ *Check that fences around the site will keep unwanted animals out.*
- ☐ *Check that the site will not be affected by other farming activities or experiments.*
- ☐ *Make a description of the site.*

Preparations before starting the Experiment

- ☐ *Prepare a map of the experiment to show the location of the plots.*
- ☐ *Make extra copies of the experiment map.*
- ☐ *Test the germination of your seed. (Consider whether you need to treat your seed.)*
- ☐ *Carefully weigh seed or fertiliser for each plot.*
- ☐ *Choose the appropriate sowing rate for each species.*
- ☐ *Prepare and label as much as you can before going to the field.*
- ☐ *Place all the treatment materials in waterproof bags.*
- ☐ *Consider preparing some backup treatment materials.*
- ☐ *Check whether your legumes need inoculation.*
- ☐ *Calculate the size of the experiment carefully and double-check.*
- ☐ *Mark the experiment site clearly.*
- ☐ *Choose the appropriate plot size to match the aims of the experiment.*
- ☐ *Label the plots clearly and permanently.*
- ☐ *Minimise the risk of erosion.*

Managing the Experiment

- ☐ *Always carry a copy of the experiment map with you in the field.*
- ☐ *Lay all the treatments out on the plots before applying them.*
- ☐ *Check the label on each plot before applying treatments.*
- ☐ *Choose the appropriate sowing method.*
- ☐ *Choose the appropriate weed control measures.*

- ☐ *You may wish to establish a small nursery of seedlings for replanting.*
- ☐ *Apply treatments evenly within plots.*
- ☐ *Keep your methods consistent between plots.*
- ☐ *Apply treatments one block or replication at a time.*
- ☐ *Make sure that one treatment will not affect other treatments.*
- ☐ *Record any mistakes and problems.*

Collecting Data

- ☐ *Make the recording sheets clear and easy to use.*
- ☐ *Provide extra space on the recording sheets for notes and calculations.*
- ☐ *Collect data from one block at a time.*
- ☐ *Be consistent in your data collecting methods.*
- ☐ *Measure establishment success.*
- ☐ *Rate the relative performance of the treatments regularly.*
- ☐ *Measure relevant climatic information throughout the experiment.*
- ☐ *Make regular visits to the site.*

Harvesting

- ☐ *Know how to best treat and dry your harvest samples.*
- ☐ *Collect samples that are representative of the whole plot.*
- ☐ *Cut back the entire plot after harvesting samples.*
- ☐ *Account for weeds in harvested samples.*
- ☐ *Take unbiased subsamples (for example, use the 'quartering method')*
- ☐ *Weigh fresh samples and subsamples as soon as possible after harvest.*

After returning from the field

- ☐ *Dry your subsamples properly before storing.*
- ☐ *Make at least one copy of the collected data.*
- ☐ *Analyse your data soon after collection.*
- ☐ *Keep a systematic filing system for the data.*

Useful references

Ashby, J.A. (1990). EVALUATING TECHNOLOGY WITH FARMERS: A HANDBOOK. CIAT Publication No. 187. Cali, Colombia. 93pp.

Cameron, A. and Gibson, T. (1994). FIELD TECHNIQUES OF FORAGE EXPERIMENTATION AND EVALUATION. CSIRO Division of Tropical Crops and Pastures. Brisbane, Australia. 30pp.

Gomez K.A. and Gomez A.A. (1984). STATISTICAL PROCEDURES FOR AGRICULTURAL RESEARCH. International Rice Research Institute, Los Baños, Philippines. 680pp.

McIntyre, G.A. (1982). Statistical aspects of vegetation sampling. In MEASUREMENT OF GRASSLAND VEGETATION AND ANIMAL PRODUCTION. L. 't Mannetje, editor. CSIRO Division of Tropical Crops and Pastures. Brisbane, Australia, pp. 8-21.

Morton, J.R. (1994). HOW TO LAY OUT, MAINTAIN AND RECORD A RANDOMISED BLOCK TRIAL. Pacific Regional Agricultural Programme, European Union. Suva, Fiji.

Partridge, I.J. (1996). TROPICAL PASTURE SEED PRODUCTION — A TRAINING MANUAL. Department of Primary Industries. Queensland, Australia. 110 pp.

Tarawali, S.A., Tarawali, G., Larbi, A. and Hanson, J. (1995). METHODS FOR THE EVALUATION OF FORAGE LEGUMES, GRASSES AND FODDER TREES FOR USE AS LIVESTOCK FEED. International Livestock Research Institute, Nairobi, Kenya.