Conducting On-Farm Experiments

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by

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PREFACE AND ACKNOWLEDGEMENTS

The premise that on-farm experimental research is necessary has been widely accepted by those agricultural researchers in Africa who have been exposed to on-farm research philosophies. By teaching and reviewing on-farm research programs, I have become aware of the unique practical and conceptual problems involved in on-farm research. This manual, therefore, aims to address these problems through demonstrating techniques of on-farm experimentation.

I wish to thank Dr. Steven Franzel for drawing upon his experiences, particularly those of his last four years in Ethiopia's Institute of Agricultural Research, to comment on this work. Comments from Drs. O. T. Edje and C. Wortmann, agronomists from CIAT's African regional bean projects were most useful in orienting the publication. Dr. Roger Kirkby, Pan-Africa Coordinator for CIAT's Eastern Africa Bean Program, suggested ways of organising and presenting the material. Appreciation is also extended to Drs. Anandajayasekeram and Michael Collinson who involved me in regional and national training courses on on-farm research sponsored by CIMMYT's Economic Program in eastern and southern Africa. This experience formed the foundation of this manual.

Ann Stroud
Consultant on On-Farm Experimentation

OBJECTIVES

The manual aims to introduce techniques of on-farm experimentation and to answer common issues arising from the planning, design and implementation of such research. Diagnostic techniques, details of farmer participation, evaluation techniques and report writing are covered in other resource materials. Although emphasis is given to the conditions and problems faced by scientists conducting bean research in Africa, the principles involved are applicable to wherever on-farm research is conducted. The manual:

1. Describes the on-farm research process and its differences to on-station research practices.
2. Describes ways of involving the farmer in the research process.
3. Plans an effective on-farm research program, given the potential constraints of logistics and resources.
4. Describes ways in which extension workers can collaborate with researchers in on-farm experiments.
5. Analyses the criteria for selecting cooperative farmers, and field sites consistent with the experiment's objectives.
6. Gives examples of various types of on-farm trials, their management and the situations in which they are used.
7. Describes guidelines for treatment selection, including 'controls'.
8. Identifies test conditions, and describes methods and rationale for their management.
9. Discusses selection of plot size and number of replications, and their implications in trial layout.
10. Briefly describes procedures used for data collection in on-farm trials, and the type of information to be collected.

At the end of each part 'Study Questions' are given. These questions aim to assist readers and students to understand the issues involved.

INTRODUCTION

In many African countries, most agricultural research programs were first established in the 1940s and 1950s by colonial governments. Given optimal research station conditions, the programs emphasised cash or export crops produced by larger scale farmers. Resource-limited farmers were regarded as characterised by tradition-bound inefficiency, as needing education on the more efficient use of resources and as needing to adopt technology from developed countries (Caldwell, 1987).

Food crops were added to the research agenda in the 1960s, a change in orientation that was primarily related to national independence. Studies in India, the USA and elsewhere during the 1950s and 1960s documented obstacles to technology adoption by small farmers. The technology, however, was assumed appropriate and problems were blamed on the ineffectiveness of extension, credit and input supply systems, and the poorly understood characteristics of farmers. Redistributing existing resources by using improved farm management was shown to be ineffective. The resource-limited farms were not inefficient but were usually making the best use of resources, given the available technology (Caldwell, 1987). The relevancy of technology for small farmers was questioned. Evidence mounted up, showing that socio-economic circumstances influenced farmer adoption and should be analysed. Researcher evaluation techniques concentrated on statistical validity and excluded economics and farmer assessment.

By the mid-1970s, it was evident that the green revolution had limited impact, particularly where inputs necessary to complete technological packages were out of reach of poor farmers. Production systems in Africa were more complex than many Latin American or Asian systems so that full use of technological packages was difficult (Caldwell, 1987). The 'farming systems' perspective became relevant to research because '... a growing concern with the lack of success in transferring results from the research station to the farmer. ... Although the nature and the relative importance of the causes are not yet clear, some technologies developed by agricultural scientists in controlled environments clearly do not coincide with the farmer's objectives and do not fit into the physical, social, economic environment.' (Matlon et al., 1984, p. 93).

On-farm research emphasises the farmer as the primary client, and farmer circumstances as the basis for planning research. Researchers target potential solutions to specific conditions and users. Farmer participation in all aspects of the research process is now emphasised. Such emphases mean potentially faster selection and modification of technologies, and higher adoption rates by farmers.

Part 1

ON-FARM RESEARCH

This chapter defines on-farm research and discusses its role. Comparisons are made with station research to underline differences.

The primary objective of on-farm experimentation is, by consulting and collaborating with farmers, to design acceptable technologies that would provide a larger number of options for small farmers. The farmers would be more able to use existing resources more effectively to solve problems, relieve constraints, and exploit new opportunities at the local level without further stressing the environment.

On-farm research is characterised by its farmer orientation and interaction with the farmer. That is,

1. Small-farmer circumstances are analysed to find acceptable solutions;
2. Technological solutions are targeted to specific farmer groups who operate under similar socio-economic and agro-ecological conditions;
3. The farmers' indigenous knowledge is appreciated;
4. Farmers are understood to operate in systems where resources are limited and risks high, requiring multiple objectives for their management;
5. More emphasis is placed on farmer participation in all stages of the research process; and
6. Technologies are more rigorously tested in a more realistic human and environmental background.

Farmers as Experimenters: The Importance of Understanding Indigenous Knowledge

To emphasise the farmer and his/her local conditions is to appreciate the farmers' perceptions and knowledge of their own system. 'The farm family must live by the consequences of their decisions, not the scientists. Farmers live in both a technical and social world based on agriculture; researchers simply study these worlds.' Therefore a researcher must 'put oneself as much as possible in the farmer's shoes' (Rhoades, 1982).

Most farmers have evolved farming methods or 'traditions' based on their own experiences. They have learned by watching their fathers, mothers and neighbours, as well as through trial and error. Researchers will find that farmers have their own informal methods of experimenting, where their observations and intuition guide them in making technological choices and in developing production strategies. Their methods are not any less valid than the formal methodologies that the researcher uses.

Figure 1. The 'dungora', a traditional digging implement, is used during the dry season. Fields shown are infested by a 'hard-to-kill' perennial grass weed, Haraghe region, Ethiopia.

Figure 2. Farmer investing his labour in ploughing for teff, a high value crop, rather than in weeding beans, a low value crop, Ethiopia.

Figure 3. To solve a cattle-feed problem, the farmer over-sows his maize and then uses the thinnings for feed. Ethiopia.

Figure 4. The farmer uses banana stems to support climbing beans, Rwanda.

The researcher must develop, initially by survey and secondly through observation and questioning, an understanding of how the farmer perceives his/her situation, what indigenous environmental classifications are used, and how the farmer develops production strategies. Farmers develop strategies to deal with uncertainties in, for example, markets, weather conditions, labour unavailability and pest attacks. Often, their strategies for crop management will involve a sequence of decisions based on a sequence of events. The following examples show that farmers are indeed experimenters and usually have a sophisticated understanding of their environment.

1. *Variety selection*: a farmer in Kenya made his own collection of bean varieties from friends that visited Uganda and other areas of Kenya. He planted them and selected the ones that did well in his environment.

2. *Adoption of new crops*: a woman farmer in Kenya set aside an area to test citrus, a new crop for her. During the Ethiopian 1984-1985 drought, women developed new processing and cooking techniques to make meals from a new crop, sweet potato, which replaced the traditional sorghum. (Maize, beans, banana, sweet potato and Irish potato are examples of modern African staples which originated in Latin America.)

3. *Modification of cultivation implements*: farmers testing new implements adjusted them to their draught animals and soil conditions. In Kenya, farmers also developed alternative uses, for example, a furrow opener was successfully used to weed beans planted in narrow rows.

4. *Developing cultural practices for weed control*: in Ethiopia, whenever labour for weeding was not available, farmers grew beans with a spreading growth habit, planted densely to control weeds. In Uganda, they chose beans with an erect habit that do not form tendrils and planted them less densely so that the plants were easier to weed around.

5. *Soil classification*: in northern Zambia, researchers use the farmers' classification system and can recommend the amount of lime or other nutrients accordingly (O. T. Edje, 1990, personal communication).

6. *Land-use systems*: the farmer selects crops, varieties, and planting times according to their experience with, for example, different soil types and water-holding capacities, and slopes.

7. *Crop choice*: if rain is delayed in the Ethiopian Rift Valley, farmers will plant more teff (*Eragrostis tef*) and beans, which are relatively fast-maturing crops, rather than maize. If, however, rain is delayed only slightly and the market looks favourable, farmers will plant maize and beans, and use a more marketable bean variety, which, however, is less competitive with weeds. They will therefore invest more time in land preparation for the beans to avoid hand-weeding (Roger Kirkby, 1990, personal communication).

8. *Adjustment of a cropping system*: in Malawi, groundnut rosette is a common disease of groundnut, particularly if the population is low or if there is high seedling mortality. If this occurs, farmers will 'gap-fill' with beans or cowpeas which grow faster, cover the soil and so reduce rosette incidence (O. T. Edje, 1990, personal communication).

9. *Practices to spread labour*: teff, a fine-seeded crop in Ethiopia, requires considerable labour for land preparation and weeding. Farmers use high densities when planting other crops, such as beans, so that hand-weeding for these crops will be minimised, thus freeing labour for weeding teff. Note that labour is in short supply and herbicides are not available.

On-Farm Experimentation

As part of the research process

Although descriptions of farming systems research vary, the general consensus is that there are four major activities: diagnosis, planning and priority setting, experimentation and evaluation. When confronted with a new research area or when starting the process for the first time, more emphasis is given to diagnosis and planning with subsequent experimentation and evaluation. The process becomes reiterative: further diagnosis, planning, experimentation and evaluation are carried out until researchers are confident that recommendations can be extended to farmers (Diagram 1).

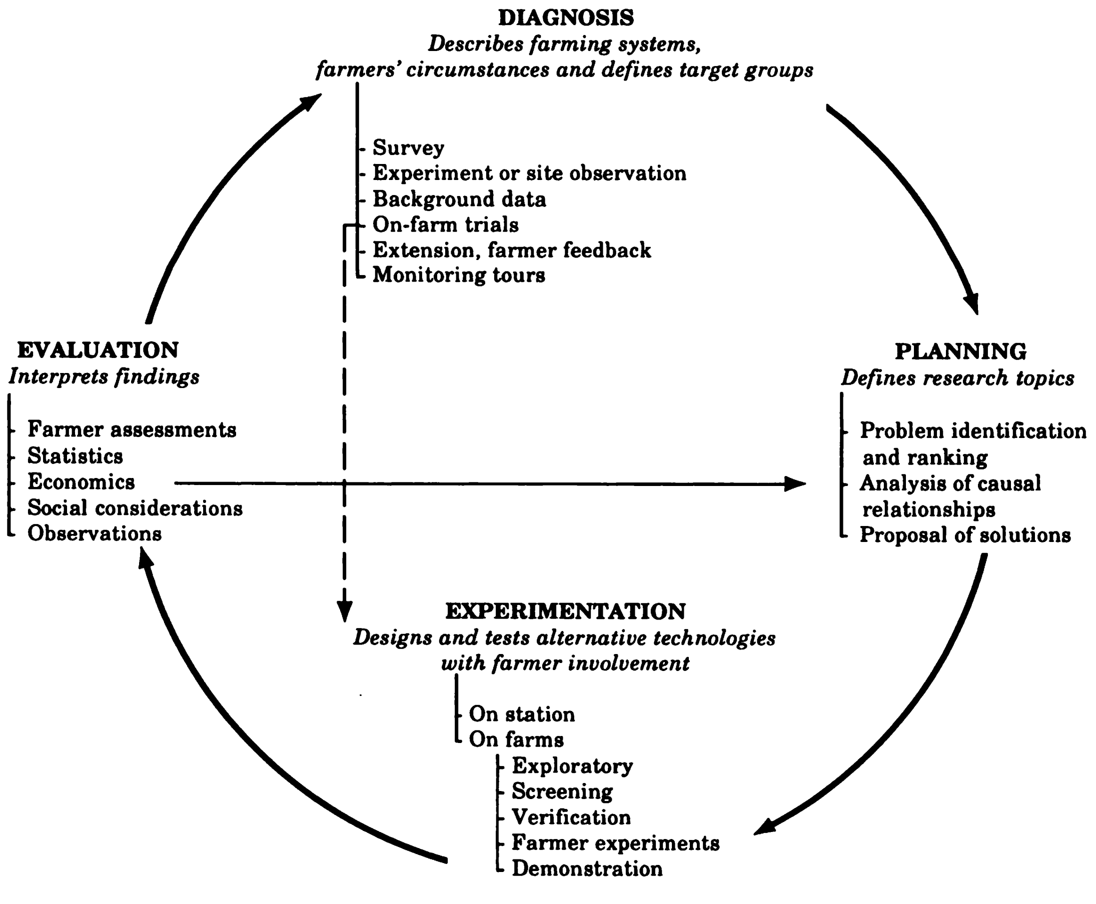


Diagram 1. Outline of on-farm research activities.

Diagnostic activities. Farmers are consulted concerning their situation through surveys, interviews and observation, including monitoring. The resulting data are combined with background information to understand the physical, social, economic and production features of the farming systems. A preliminary definition of recommendation domains or target groups can be identified and prioritised to develop appropriate technological solutions to the problems, constraints and missed opportunities found in each domain. Although this is a major exercise, diagnosis does not necessarily end here but may continue throughout experimentation as more specific, detailed data turn up and need collecting.

Planning and priority setting. The researcher uses the data collected during diagnosis to identify needs and thus decide on future activities: whether to plan experiments, make further diagnoses, or increase extension activities. Tripp and Woolley (1989) explain in detail the six steps of planning an experiment: (1) identify problems limiting the productivity of the farming system; (2) rank these problems; (3) identify the causes of the problems; (4) analyse the interrelationships among problems and causes; (5) identify possible solutions to the problems; and (6) evaluate the possible solutions. The farmer can collaborate in this process to ensure that problem identification, prioritisation and solutions coincide with their thinking. During the first year, diagnostic material is used extensively. Subsequently, experimental results and further observations contribute to the planning process, which, with new information, becomes reiterative.

Experimental design and implementation. Based on the decisions made during planning, objectives are set and experiments designed and implemented. Decisions must be made on, for example, type of experiment and management (including the degree and method of farmer involvement), its location, data to be collected and provision for farmer feedback. Experiments can have a diagnostic function. Merely interacting with the farmer in his/her situation can help the researcher to fine-tune his/her understanding of the farmer's point of view and circumstances.

Evaluation. This begins during the implementation of the experiment, when, for example, the researcher may be forced to evaluate the validity of a treatment when he/she sees the ease or difficulty of applying it. Farmer assessment occurs throughout and after the experiment. Evaluation must include a combination of statistical analyses, observations, farmer assessment, and economic analyses. The final interpretation will be used to redesign future experiments or research programs, or to finalise a recommendation.

Comparing on-farm research with station research

Figure 5. Note the orderliness of a research station, Kwanda, Uganda, compared with Figure 6.

Figure 6. Note random planting and mixed cropping in a farmer's field, compared with Figure 5.

Advantages of using on-farm research. These include:

1. Testing technologies on farmers' fields under variable environments and management, and perhaps under poorer physical and economic resource conditions compared with those of the research station. A technology's deviation from its potential and the causes of that deviation are of major interest.

Figure 7. Beans' response to fertiliser (at right) in an on-farm trial may be greater than on a research station.

2. Obtaining more direct input from farmers on technology design, testing and assessment.

3. Directly comparing research technologies or recommendations with farmers' practices under farmers' management to find systems interactions and/or social biases.
4. Exploiting more effectively farmers' indigenous knowledge.
5. Improving the understanding of the complexities of the farming system in order to develop longer term research strategies with broader implications for sustainability, long-term development, and potential future problems such as land shortage, increased use of marginal areas and exploitation of resources.
6. Encouraging interaction among multidisciplinary researchers, extension workers and farmers to facilitate a more holistic approach to problem solving.
7. Providing realistic data to affect or change policy.
8. Monitoring farmers' use of a new technology, as well as general adoption.
9. Providing feedback to station researchers in order to check orientation of research priorities.

Major differences in managing on-farm experiments. These include:

1. Farmers are involved in managing experimental and non-experimental variables, thereby causing some loss of control.
2. On-farm experiments *tend* to have fewer treatments, simpler and perhaps less conventional designs, fewer replications and larger plot sizes.
3. Data collection not only includes those parameters normally collected, but also farmer assessment and extensive information on site characteristics and management to help understand variation. Usually less detailed physiological data are collected.
4. Potential sources of bias may include subjective technology assessment by farmers, over- or undermanagement of trial and inaccurate reporting of events affecting treatments. If these biases exist, they must be managed by the researcher. The major bias of on-station research is that the researcher is obliged to test under only one set of circumstances.
5. Multidisciplinary involvement is encouraged, whereas station research tends to run separate projects.
6. Site selection and logistics take more time. Costs may be higher for transport and equipment, even if land and labour are provided by the farmer (which is usual).
7. The research emphasis is usually on step-wise modification to the existing system rather than on 'technology packages' because farmers tend to adopt technological components one by one.

Study Questions

1. What are the four major activities of on-farm research?

   a. ______________________________
   b. ______________________________
   c. ______________________________
   d. ______________________________

2. There are nine advantages of on-farm research over on-station research. List four:

   a. ______________________________
   b. ______________________________
   c. ______________________________
   d. ______________________________

3. Define the major objective of on-farm research:

   ____
   ____
   ____
   ____

4. There are seven major characteristics of managing on-farm experiments. Describe four:

   a. ______________________________
   b. ______________________________
   c. ______________________________
   d. ______________________________

The following sentences are either true or false. Indicate by writing T or F:

5. Farmers are researchers. ____
6. Farmers do not need strategies to farm because they know their environment very well. ____
7. On-farm experimentation is similar to on-station research in that the researchers try to control variability so that the treatments are under optimal conditions. ____
8. Multidisciplinary involvement in on-farm experimentation is good, but logistics must be planned well in advance. ____
9. Farmer participation is important in on-farm experimentation. ____
10. On-farm trials are easier to implement than on-station trials because they have fewer treatments. ____

For answers see p. 109.

Part 2

PLANNING AN ON-FARM EXPERIMENT PROGRAM

This chapter concentrates on aspects of planning that concern researchers: creative ways to use diagnostic material, how to identify problem-and-cause relationships, how to define target groups, how to decide research responsibilities, how to locate trials, resource allocation and program evaluation. For a discussion on priority setting and choice of solutions, see Dagg and Haworth, 1988; and Tripp and Woolley, 1989. Ways that researchers can involve farmers in the planning process are described in 'Farmer Participation' (beginning on p. 59).

Using Diagnostic Information

Maps, surveys and background information

Researchers can use survey and background information from literature and maps to visualise the size and diversity (ecologically and in terms of target groups) of the area. These sources of information can be used to:

1. Decide where any given technology would be potentially useful or transferable;
2. Locate potential trial sites;
3. Define and/or select target groups;
4. Prioritise regions for directing research efforts or results;
5. Monitor and analyse farmers' responses to various technological options, including adoption; and
6. Yield other information useful to researchers but which are not used in the mapping exercise.

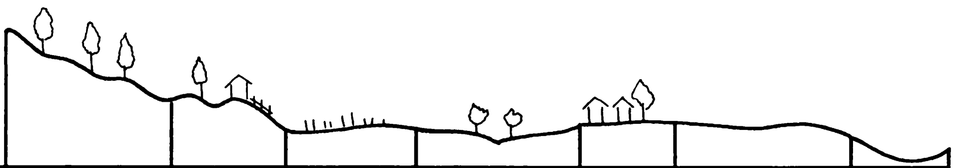
For example, Carter (1987) has described a method whereby researchers can overlay, on a map of the area, environmental characteristics gathered from background information, and farming systems information, including socio-economic factors. By using a regional commodity program as an example, the steps for the method are:

1. Map the region where the commodity is or can be grown.
2. Subdivide the region according to environmental features that influence crop adoption such as altitude, rainfall, temperature and soils. Each map can be overlaid to define agro-ecological zones or subregions. If sophisticated mapping facilities are not available, transparencies can be used, together with a map of the area, and a photocopying machine to make the overlays. All maps should be converted to the same scale. This technique alone is valuable but does not include other dimensions such as socio-economic factors, infrastructure and target group characteristics.

3. Choose areas for more intensive investigation by using farming-systems survey techniques to collect data on production practices, problems and constraints, land tenure and market and road distribution. A departure from the usual farming-systems survey is that, for mapping purposes, characteristics or variables of interest, used as stratification criteria, are chosen from results of an initial informal survey. Through the formal survey, sample points are selected according to the population's consensus on the chosen characteristics or issues.
4. To identify important factors to be mapped, microregions are drawn by establishing and combining distribution patterns of the important variables gathered from the formal survey in step 3.
5. Overlay characteristics found in step 4 on the environmental ones found in step 2.

Diagrams

Diagrams include simple maps, flow charts, seasonal calendars for different types of activities or events, and transects. (Transects spatially illustrate different areas and their major characteristics, problems and opportunities, Diagram 2.)



Land use	Woodland	Mixed	Grazing	Farmland	Town	Irrigated land	River
Soil	Rocks		Sandy loam	Sandy loam	Loam	Alluvial	
Crops and/or vegetation	Shrubs and newly planted trees	Shrubs and newly planted trees (e.g., coffee)	Grass	Sorghum, teff, legumes		Vegetables, fruit trees	
Livestock	Goats	<----------------Goats, sheep, camels, cattle and donkeys--------->					
Water	Springs	Springs			Water stations	Irrigation	
Problems	<--Erosion-->						
	Poor vegeta-tion; poor establishment; pests		Poor production	Drought, pests, diseases		Low pump capacity; unstable water intake	
Opportunities	Fuel, timber, honey, fodder	Prefer-able environ-ment	Silviculture	New crops, intercropping, agroforestry, water management		High potential	

Diagram 2. An example of a transect diagram, showing peasant farming association in Ethiopia, drawn after McCracken and Conway, 1989.

Diagrams are useful, for example, for understanding problem-and-cause interrelationships in the farming system, or identifying systems interactions before new technology is tested in the field. Diagrams can also help plan an experiment program by orienting researchers to the farmers' schedules for various activities. They can stimulate discussion with farmers about their situation (Conway, 1985; Conway, 1987).

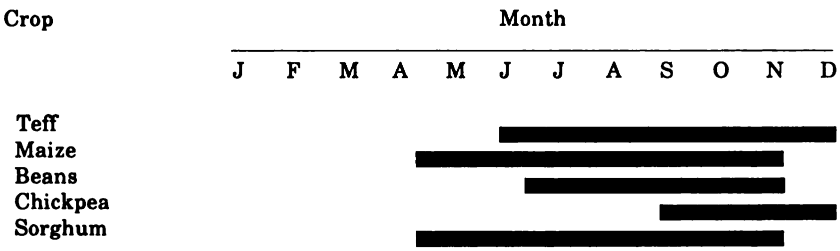
Seasonal calendars (Diagram 3) are particularly useful in illustrating, for example, labour bottlenecks, cropping sequences, weather patterns, animal-related activities, food deficits and health problems. Many farmer constraints in Africa are often related to lack of opportune labour for production activities. Seasonal calendars can help analyse labour-related problems and show ways of alleviating them.

A. Calendar for crop-related activities

Crop	J	F	M	A	M	J	J	A	S	O	N	D
Teff	httttt		llllllllllll		llllllllpppppppp				wwwwwwwwhhhhhh			
Maize	ttttt		llllllllllpppppp				ssssswssww				hhhhhhh	
Beans					llllllllllppppp				hhhhhhhhhhhttttttt			
Chickpea	ttttt								lllllllpppp		hhhhh	
Sorghum	tttttttt		llllllllll		ppppp		sswwssww				hhhh	

Legend: llll = Land preparation; pppp = Planting; wwww = Weeding; ssss = Shilshalo (cultivating); hhhh = Harvesting; tttt = Threshing

B. Cropping pattern calendar with one rainy season



C. Calendar of food availability

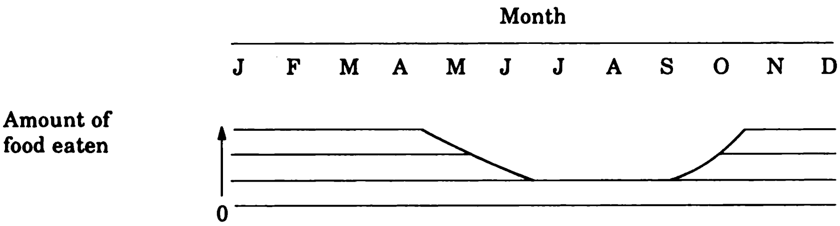


Diagram 3. Examples of calendars used in conjunction to help analyse problems within the farming system.

Identifying problem-and-cause relationships

Relationships between problems and causes must be understood in order to decide on research topics and experiment treatments. Farmer participation and/or more specific surveys may be necessary to establish details. A problem statement of 'poor management' or 'low yields' is not sufficient; rather, the problem causing low yields must be stated. Problems may have single or multiple causes, which can be easily illustrated by constructing a diagram showing the interrelationships. Major problems should be highlighted. Each may be thought of as a series of causes and effects where causes in themselves may be problems.

For example, in Diagram 4, the major problem is low bean yields, for which there are several contributing factors. One factor is bean-fly attack, for which there are two causes: a susceptible local variety and lack of control. Suggested actions are to introduce a resistant variety or provide better extension advice. Another factor is low plant stands, for which a number of causes are either known or hypothesised such as poor germination caused by poor seed storage; poor seed-bed preparation; soil capping; pests, such as cutworm, birds or rodents; and/or root rot. Hence, to improve low plant stands, extension work and research on improved storage procedures, improved tillage strategies and pest control are necessary.

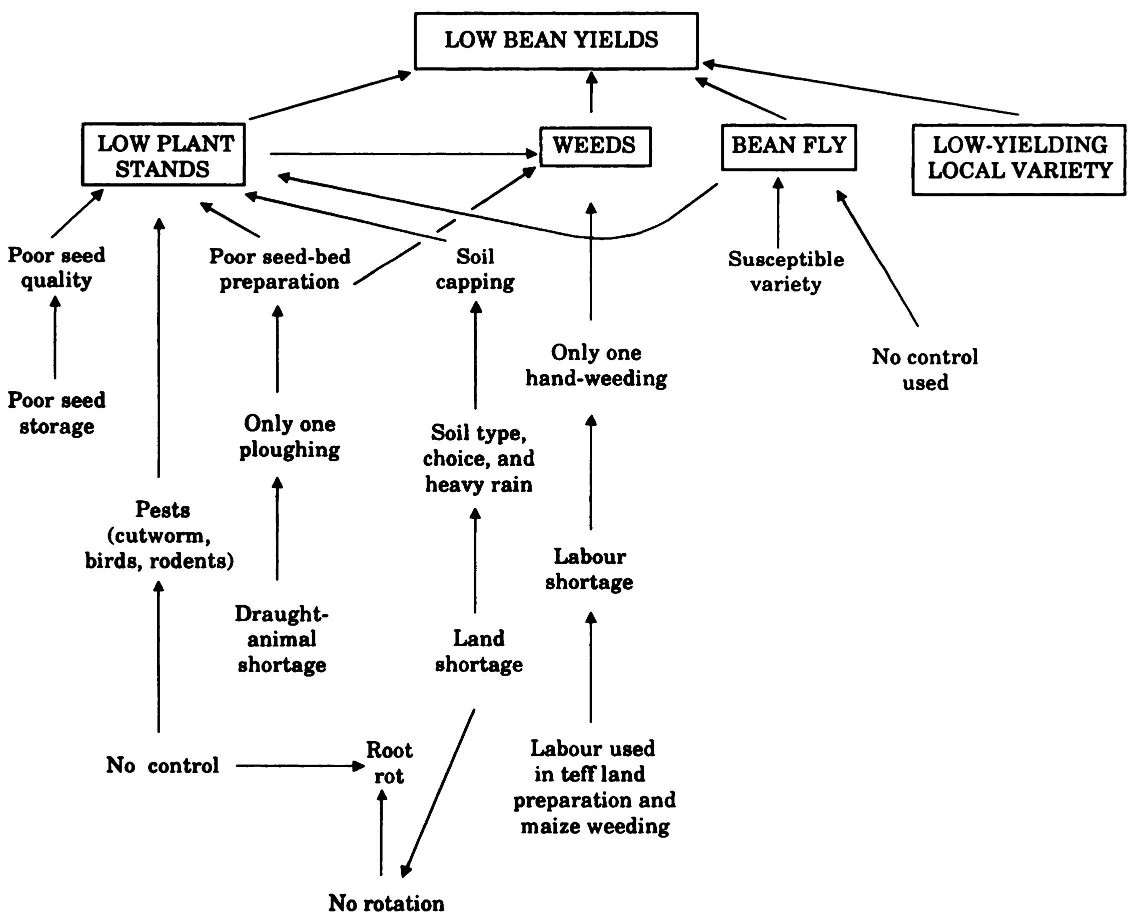


Diagram 4. Problem-and-cause relationships for bean production.

Defining target groups

Researchers should be able to identify one or more 'target groups' of farmers by using diagnostic survey and background information on an area. 'Target group' is a conceptual tool to help researchers plan. It is determined by stratifying or dividing a heterogeneous population into more homogeneous groups of *farmers* who would adopt the same recommendation because they have similar resources, problems and opportunities for development. Although the number of groups depends upon the variability of agro-ecological and socio-economic factors in the area, the farmers comprise target groups, not land types. Farmers make the decisions on new technologies, even though land type may influence their decisions. Researchers assume that farmers working under similar situations with similar problems have similar technology needs. Examples of target groups are resource-poor farmers in marginal areas; farmers located in particular agro-ecological zones; farmers growing

Figure 8. A target group may be households headed by females.

Figure 9. The African family is typically extended. Target grouping must therefore consider family size, as well as available resources.

Figure 10. Target grouping should consider farm size, as in this example near Kitale, Kenya. Note the large-scale farms (top) versus small-scale farms (bottom).

Figure 11. Target grouping considers such socio-economic factors as market access and infrastructure, Rwanda.

different types of food crops; farmers having a particular farm type (e.g., size); farmers having a certain type of production system (e.g., hoe versus animal tillage); and farmers in a recommendation domain (e.g., where short-season maize would meet a need) (Ewell, 1988).

Target groups must be defined before planning an on-farm experiment program because this will help:

1. Set research priorities;
2. Site experiments and demonstrations;
3. Allocate resources;
4. Avoid designing the same recommendations for the whole farm population;
5. Note differences in circumstances and farming practices; and
6. Choose appropriate treatments.

There is no precise formula for defining a target group; researchers must use their judgement and common sense. Box 1 gives a suggested list of variables for target grouping, but the researcher must decide which variables are relevant as stratifying criteria, as he/she did for steps 3 and 4 in obtaining mapping, survey and background information (p. 12). Target groups can be redefined as the researcher learns more about the situation.

Box 1. List of variables to consider when forming target groups for on-farm research.

Agro-ecological variables	Socio-economic variables
Climate	Farm size
Temperature	Land tenure
Rainfall intensity, duration, distribution	Access to:
Frost incidence	markets
Risk of drought	inputs
Risk of flooding	labour
	credit
	cash
Land form	Power source type and availability
Altitude	Access to irrigation
Topography	Off-farm employment
	Food preferences
Soils	Diet
Texture and structure	Community customs
Drainage	Customary obligations
Slope	Membership in local institutions
Depth	Infrastructure
Cation-exchange capacity	Head of household
pH	Gender issues
Organic matter content	Administrative structure
Salinity	Health problems
Nutrient content	
Production elements	
Disease incidence	
Pest incidence	
Weed incidence	
Crops grown (combinations)	

SOURCE: Anandajayasekeram, 1985.

Planning the Program

Number of trials

Experiments should be located on farmers' fields for the following reasons:

1. Technology requires evaluation under farm conditions;
2. Technology requires assessment by target farmers, e.g., in the case of mechanisation or varieties;
3. To demonstrate results in order to influence policy decisions or researcher's ideas concerning a previously made recommendation; and
4. To learn more about farmers' situation and their indigenous knowledge.

Once the decision has been made to locate the experiment on farmers' fields, the researcher must decide how many trials he/she needs by considering:

1. The need to capture important aspects of variability hypothesised to affect the performance of the technology;
2. The subject matter of the trial;
3. The degree of farmer and/or extension involvement;
4. The amount of supervision required of the researcher;
5. Environmental or management risks; and
6. The trial's objectives.

In a pest control trial, a larger number of trials may be necessary where pest incidence is unpredictable. For variety, fertiliser and cultural practice trials, the number of necessary sites will depend upon such factors as variability of soils and environment, and upon the extent to which the researcher sees them as likely to affect treatment response. For example, if fertiliser response of beans is being studied, then the researcher will need to sample areas having different soil types and rainfall regimes, and where farmer practice differs in terms of weed control, planting arrangement and fertiliser application method.

The researcher must (1) understand the various factors present which may affect the functioning of the technology; (2) decide which of these must be sampled by locating the trial in the area containing the factor or combination of factors; and (3) site the experiments accordingly.

Some general guidelines are:

1. If a large number of trials are located at many sites, then:
   a. trials tend to be small and simple;
   b. farmers or extension workers are more involved;
   c. less researcher supervision is needed;
   d. distances may not be too far between sites (distance is not a deterrent if supervision is assumed on site);
   e. objectives are usually validation and demonstration;

f. there is greater risk of data loss; and
g. an area is sampled with a higher degree of variability, which will affect technology performance.

2. If a small number of trials are located at a few sites, then:
   a. trials tend to be larger and more complicated;
   b. farmers or extension workers are less involved;
   c. extensive researcher supervision may be required;
   d. long distances may adversely affect necessary researcher supervision;
   e. objectives are usually exploratory and for technology refinement (p. 30-31);
   f. if researcher managed, less risk of data loss; and
   g. relative to (1), variability has less effect on technology response.

Locating trials

Thoughtful siting of experiments within a target area will greatly assist the researcher to:

1. Understand the variability of the area in terms of the farmers themselves and their environment;
2. Test specific hypotheses concerning the variable factors that may affect the functioning of the technology; and
3. Analyse the data by being able to stratify them across the variable factors.

Researchers should use a map to help them visualise in advance feasible sites for experiments. If logistics (personnel, transport, budget) limit the number of sites that can be monitored, sites can be located strategically within the sampling regime to minimise problems; for example, in clusters (Diagram 5) near roads and near staff (extension) locations.

Location, considering one variable factor. Example A shows the research area as having four different soil types. Although recommended, the fertiliser rate for beans has never been tested under small-farm conditions. The researcher has hypothesised that the varieties being tested will differ in their fertiliser requirements according to soil type. Therefore, the variety x fertiliser experiment is sited so that there are six trials on each soil type. The sites are clustered as much as possible to ease implementation and monitoring of the 24 trials.

Location, considering two variable factors. In example B, the researcher has decided that both soil type and previous crop are important variables for a tillage implement experiment. The previous crop is important because where maize is planted the farmer ploughs several times, uses good weed control practices and leaves a large quantity of crop residue. Where beans are sown, the farmer uses fewer ploughings, poorer weed control and leaves no residues. For comparison purposes, the researcher wants to sample both maize and bean fields on each of the three soil types in the area. The researcher will try to locate the trials on farms where both crops are grown and the soil type is uniform throughout. The researcher decides to limit the number of sites to two per soil type because he/she is testing implements with farmers for the first time. There are two trials at each site (farm), sampling each of the two field histories, and two sites (farms) located on each of the three soil types, making a total of 12 trials.

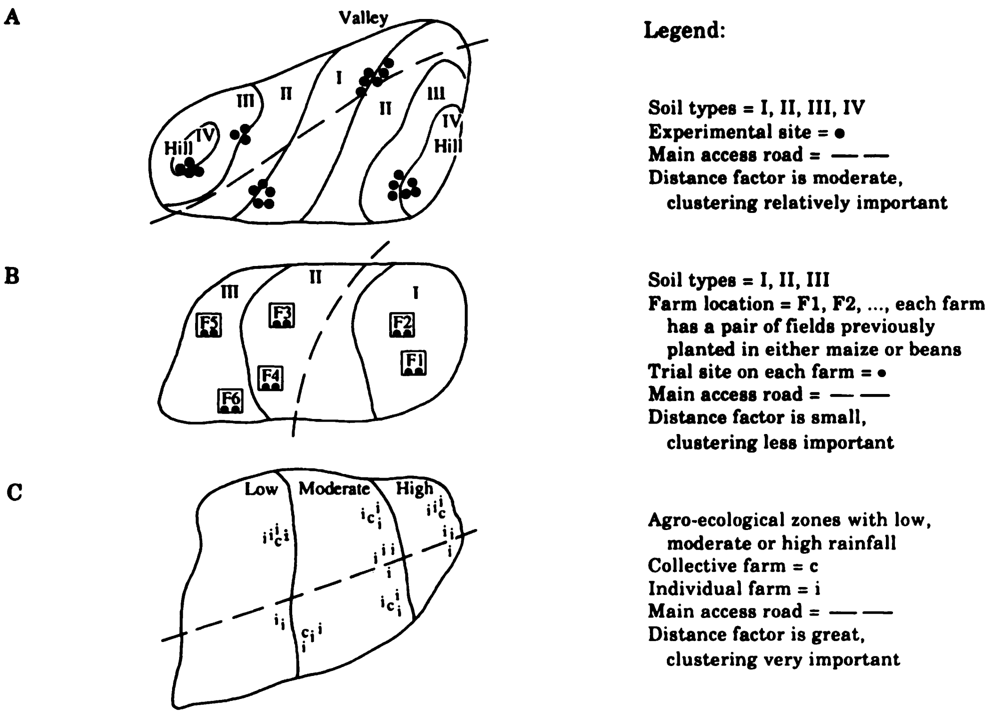


Diagram 5. Examples of how to locate trials: A = where one variable factor, and B and C = where two variable factors are considered for sampling target areas.

Location, considering target groups and agro-ecological factors. In example C, farmers work either on small individual holdings or on larger collective farms. The research area covers three agro-ecological zones (low, moderate and high rainfall), each having both types of farms. While individual farmers do not use fertiliser, they plough with oxen and have sufficient labour to weed on time. The collective farms have access to fertiliser, tractors, but have a problem of weeding on time. Although different, the two types of farms have the same technology need: a higher yielding bean variety. Variety trials need to be sited to sample both farm types in each of the three agro-ecological zones. The major area for bean production is in the moderate rainfall zone; however, they are grown to a lesser extent in the other zones. Although the varieties performed well in station trials, they had not yet been tested on farms; the researchers decided on a large number of trial sites. Because there are few collective farms relative to individual holdings, more individual farmer trial sites are clustered near the collective sites in the moderate rainfall area.

Research responsibilities

After diagnosis, what next? After completing a diagnosis, and identifying problems, causes and the target group, a number of issues will have arisen. Researchers must then decide whether to (Diagram 6):

1. Carry out further diagnosis?

2. Organise better extension advice?

3. Try to facilitate policy and/or infrastructure change? or

4. Design an experiment or series of experiments?

If further diagnosis is needed because the problem and its causes are not well understood, a formal or informal survey, an exploratory experiment, monitoring farmer practices or a combination of these can be used. Perhaps a greater degree of farmer participation in the diagnostic process is needed.

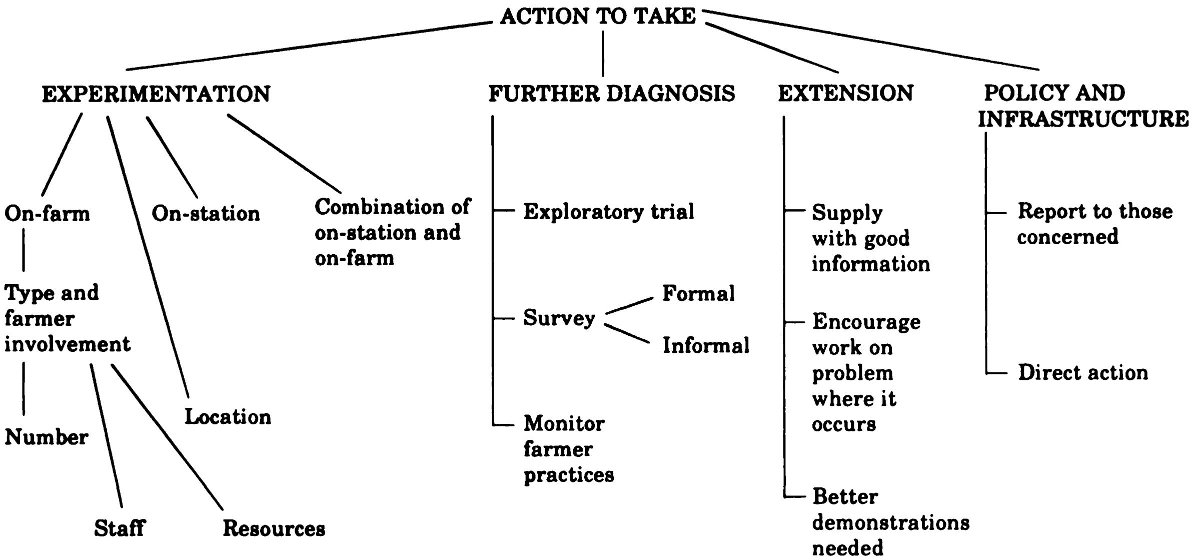


Diagram 6. Following problem identification, researchers must decide what actions to take.

If the solution to the problem is well known and assuming that the solution is appropriate, the reason farmers are not practising it may be because extension is not working with farmers on that problem; the solution has not been convincingly demonstrated; or extension does not have needed information from research. Better linkages between extension, research and the farmer are, therefore, needed to improve the situation.

A policy or infrastructure change may be needed to solve the problem, in which case the action needed is usually outside the research institution's control. If there is an available forum for suggestions and supporting evidence, the researchers can pass their information to this forum in the hope of effecting positive change. In simpler cases, researchers can take it upon themselves to facilitate change more directly. For example, in Kenya, researchers discovered that a major problem in one area was poor input supply. They contacted the merchants and organised timely delivery. In Malawi, beans sold as mixtures received a lower price compared with single varieties. Farmers normally grow in mixtures and had to separate the varieties in order to get a better price. Researchers approached the national produce agency and persuaded them to remove the price differential.

If experimentation is warranted, researchers must decide how the research will be organised: where it will be done, how it will be done and who will do it. On-farm research has often been the responsibility of a team that usually involved an economist and at least one agronomist. The team may conduct surveys and oversee experiments on farmers' fields, while other researchers work on station, perhaps using survey information to identify experiment themes and treatments. However, the farming systems approach can be used by all researchers, regardless of their discipline. For example, they may use the general survey information to identify a problem but conduct further surveys to uncover details. They may then design a series of experiments, some done on the station and some on farms, with varying degrees of farmer involvement, to suit their objectives. In some situations, particularly where research resources are limited, the number of researchers interacting with farmers may, of necessity, be few.

Needed research actions. Often several different research actions may be needed to solve a problem. For example, the problem of low bean plant stand may be tackled in the following ways:

1. Bean fly: controls known from previous research are referred to extension, work carried out on pesticide supply scheme; collaboration with extension on ways to introduce pesticide use to farmers.
2. Poor seed-bed preparation: experimentation on implements needs to be carried out on-station and on-farm; further diagnosis is needed through farmer monitoring.
3. Poor seed storage: further diagnosis would include monitoring present farmer storage conditions; and identifying insect pest species.
4. Soil capping and land choice: on-farm experiments to intensify production by intercropping beans on better soils.

If the problem has only one cause, it can be assigned to the appropriate researcher. However, problems often have multiple causes and can involve a number of scientists from different disciplines (multidisciplinary). For example, the low plant stand problem (Diagram 4) can involve a soil scientist, agronomist, entomologist and pathologist, each overseeing an experiment or series of experiments. A team approach should ensure coordination.

There may be similar causes to different problems, for example, in Diagram 4, both low plant stands and poor weed control problems have poor seed-bed preparation as a common cause. The researcher working on tillage-related solutions can consider researching both problems simultaneously, perhaps within the same experiment.

The solution to a problem may be in manipulating the system. For example, in the case of labour competition between bean weeding, ploughing for teff and weeding maize, labour may be made available for bean weeding by the researcher testing herbicides for maize or reduced tillage for teff. Or the cause may be livestock related, as in the case of draught-animal shortage causing weed problems. As these examples illustrate, multidisciplinary teams cannot work with one commodity alone but must also involve other commodities of the farming system.

These examples show the need to have a holistic picture of the system before embarking upon designing a research program and experiments. Decisions concerning who does which experiments cannot be made until after potential solutions have been prioritised. Whether research is organised by commodity or by discipline, inter-unit coordination is necessary, best ensured by annual reviews and planning meetings at each research station or zone.

Resource allocation

This is perhaps the most difficult step in implementing an on-farm experiment program. The tendency is for researchers to plan a much larger program than they can handle, both in time and resources. The series of steps illustrated in Diagram 7 and described below indicate how a program can be limited.

USING DIAGNOSIS
- Diagrams
- Background information
- Maps
- Surveys

DEFINE
- Problems
- Causes
- Target groups

ASSIGN
- Solutions
- Priorities
- Responsibilities

PLAN AND DESIGN
- Research and extension linkages
- Location and number of trials
- Resource allocation

Diagram 7. Stages in planning on-farm trial programs.

When planning a program, researchers should:

1. Tentatively decide on such aspects as the type and complexity of the experiment, its location (on-farm or on-station), the number of sites and their distribution, the type of management required and data collection required.
2. Carefully consider costs (Table 1), logistics and number of personnel required:
   a. Travel
      i. distances to be covered,
      ii. mode of transport,
      iii. availability of transport, and
      iv. ease of travel during the rainy season.

   b. Communication, difficulties and implications.

   c. Staffing
      i. number of research staff visits required,
      ii. involvement of other institutions (extension),
      iii. location of staff,
      iv. amount of supervision or in-the-field training needed,
      v. number of field staff needed, depending upon the number of farmers and frequency of visits required, and
      vi. composition of the research group for each visit.

Table 1. Factors affecting costs of on-farm experimentation.

Activity	Cost
Farmer identification	
by researcher	High
by extension agent	Low
Site identification	
by researcher	High
by extension agent	Low
Trial management	
by researcher	High
by extension agent	Medium
by farmer	Low
Data collection	
by researcher	High
by extension	Medium to low
Complexity of the trial	
complete factorial with several levels	High
variety trial	Medium
validation trial	Low
Level of inputs	
many	High
few	Low

SOURCE: Charles Wortmann, 1990, personal communication.

3. Prepare a 'scope of work', and a proposal that includes:
    a. the objectives of the work;
    b. a brief outline of the situation, particularly with respect to client conditions;
    c. the plan of work, defining responsibilities, including a list of experiments with number and timing of visits required and their purpose; list of farmer and extension or non-governmental organisation (NGO) meetings and their purpose; reporting schedule;
    d. cost estimates, including research and support staff time, facilities and recurrent funding required and the program's estimated duration.
4. Review resources, such as personnel, budget, time, transport available, including logistics; match available resources with tentative plans; eliminate the program's lesser priorities to make it more realistic.
5. Map and schedule activities; designate inputs and materials needed; organise training schedules of staff or farmers; schedule activities; and outline personnel responsibilities according to the plan developed.

Program Evaluation

It is important that on-farm research programs be dynamic and flexible enough to incorporate, at the least, minor changes in direction; otherwise the systems approach becomes static and unrealistic. Modes of operation and results must be evaluated before each growing season. Researchers must decide whether the experiment should continue as it was, be modified or discontinued. Reasons for changing the experiment's status would include poor design, evidence that the problem was not important or had solved itself, or the technology can be recommended without further trial.

Researchers must also decide on operational changes. Any modifications made should be designated; for example, change the location and/or go back to the station; move to different farmers; adjust treatments; change non-experimental variable management; change the amount or method of farmer involvement; or modify objectives. If new problems have been identified, new experiments must be designed. If more information is needed on particular points, surveys must be conducted or farmer meetings held. These points are discussed in detail in the following chapters.

Several methods can be used to help researchers evaluate their programs:

1. Keeping records of problems or questions encountered during the season;
2. Noting farmer and extension feedback;
3. Conducting small, informal surveys concerning the experiment program to give insight into how it is working in terms of:
    a. successful relationship with farmer;
    b. farmers' understanding of the trial and treatments;
    c. monitoring adoption, even before the experiment is finished;
    d. relationships between field staff and farmer;
    e. problems in implementation; and
    f. identification of environmental interactions with experiment performance that were not previously hypothesised.

Study Questions

For some questions you need to fill in the blanks:

1. Mapping is a useful technique for planning because ______________________________

____

____

2. Seasonal labour calendars are useful in planning because ____________________

____

____

3. It is helpful, for planning purposes, to see the systems problems in terms of ____________________ and ____________________

4. A target group is ____

____

____

5. List four potential actions that may lead to solving a problem:

   a. ____

   b. ____

   c. ____

   d. ____

The following sentences are either true or false. Indicate by writing T or F:

6. Target groups can be redefined. ____
7. It is better to have only one scientist working on a problem when doing on-farm research, even if the the problem is complex. ____
8. A scientist can do an experiment on maize to solve a problem for beans. ____
9. When trials are located at many sites they are usually larger and more complicated, and need more supervision by researchers. ____
10. Pest control trials may need to be located at numerous sites to ensure adequate infestation. ____

For some questions you need to fill in the blanks:

11. ____________________ sites can help in the logistics to implement and monitor trials.

12. ______________________ sites according to variable situations will help the researcher to logically sample how the technology will perform in variable situations.

13. When planning logistics consider ______________, ______________, and ______________ as three broad categories.

14. A research proposal should include:

    a. ____

    b. ____

    c. ____

    d. ____

15. In what ways can an experiment evolve?

    a. ____

    b. ____

    c. ____

    d. ____

16. List two ways to evaluate an experiment program:

    a. ____

    b. ____

For answers see p. 109-110.

Part 3

DESIGNING ON-FARM EXPERIMENTS

This chapter covers major decisions on designing on-farm experiments, including setting objectives, types of trials, management of experimental variables and test conditions, selecting treatments, replication number, randomisation, plot size, and choosing a statistical design.

Traditionally, an experiment is designed to ensure a valid, unbiased estimation of the differences between treatments; estimate standard errors for treatment differences to achieve a desired level of confidence in the results; and maximise the precision with which differences are estimated by controlling test condition variation through randomisation, replication and careful management.

In on-farm experiments, although variation within one site or farm is minimised, as with an on-station experiment, variation between farms or sites is usually not controlled, but sampled. Data on treatment performance in a variable background are therefore collected and analysed.

Far from being a 'lesser' form of research, compared with station research, on-farm research actually takes more skill to design and analyse. Inferences may be more important than 'power of proof' under variable circumstances. Because the qualification of treatment differences where other factors are highly variable can be difficult, more analytical skill is required.

Setting Objectives

Objectives should concisely state the hypotheses that indicate the experiment's intention and reflect the potential solutions to the identified problems of one or more target groups. The objectives are closely tied to the treatment selection and data collection, so they should be reviewed after treatment selection. Farmers can help set experiment objectives (see p. 59-60).

To set objectives:

1. To improve efficiency, an experiment can aim to answer several questions, unless it becomes too unwieldy to be conducted on-farm with farmer participation. If one experiment cannot answer all aspects of a complex problem, then the problem is broken into manageable segments, and several smaller and simpler experiments designed. Eventually the results from the different investigations can be combined.
2. The statement on objectives should be entered in field notebooks to remind research assistants, visitors, and the researchers themselves the goals of their plan.
3. The statement on objectives will help the researcher make the following decisions on the experiment:

a. level of expertise, disciplines and number of people to be involved;

b. the location, nature and number of sites;

c. statistical design, including number of replications;

d. type and number of treatments;

e. layout and plot size;

f. data requirements and sampling methods;

g. management aspects; and

h. evaluation methods.

Types of Trials

The type of on-farm trial the researcher chooses is based on its function. The major categories of trial types (exploratory, refinement, verification, farmer experiments and demonstration) and their functions are discussed below in detail.

In the literature, trial types are often discussed as being synonymous with research stages or with a sequence that technology must pass through before it is recommended (FSSP, 1986; Hildebrand and Poey, 1985; Steiner, 1987). However, developing rules on the time required for testing technology within a given experiment is difficult. Too much depends upon, for example, the time it takes to develop confidence in the technology, its complexity, and the degree of interaction with variability in the environment. A technology may have previously been developed in other countries and can be easily transferred. Another technology may be unique to a specific situation and has to be developed from the beginning.

Thus, the researcher must be aware of the types of experiments that can be used and to choose that which fits the situation. The work should always be evaluated after each season to see what changes would be needed (see p. 24).

Exploratory trials

This type of trial is used when further information about the farming system is needed. Perhaps there has been a tentative diagnosis of a problem but the causes or relative importance of the causes are unknown. Or the researcher may be searching for an innovation and needs to 'explore' the situation further by using experimental treatments. The trial sites are usually few in number, relatively area specific, and have a relatively large amount of researcher management. However, the 'add-on' type (see p. 29-30) can be superimposed and largely managed by the farmer. The types of exploratory trials are:

Investigative or diagnostic. These are simple trials where the researcher investigates a problem. While conducting an experiment, the researcher may uncover a new problem, such as poor bean-plant vigour. He/she uses an array of fungicides to see if the problem will be solved. While observing fungicide effects he/she discovers that poor vigour is caused by nematodes.

Factorial (2^n). This type of trial is used when the researcher wants to find the factors and interactions that are the most important for improving yields or giving higher returns. As is usual, he/she selects and compares two levels of each factor, for instance, two levels of fertiliser, two varieties and two pest management control measures. If he/she found a large response to fertiliser, the researcher may next do an experiment with different levels of fertiliser.

Figure 12. Researchers in Rwanda are carrying out a diagnostic factorial 2^n trial on the farmer's field.

This type of trial can give the researcher more confidence in choosing a particular type of technology for future experiments and how to phase the development of a series of component technologies. As farmers rarely adopt complete packages of technology, the researcher must sequence the introduction of components and discuss with farmers their priorities.

'Add-on' or 'take-off'. The researcher may decide to test one factor in addition to the farmer's practice ('add-on') or he/she takes a package of recommendations and removes one or more factors ('take-off'). This technique helps sort out those factors important to the farmer. In this type of trial, the farmer may manage all aspects except for those variables that are 'added'.

An example of an 'add-on' experiment would include a series of treatments such as disease control plus farmers' practice (FP), insect pest control plus FP, fertiliser plus FP, and FP alone as a control. This type of trial shows the potential effect of any single factor but will not demonstrate the importance of interactions or other factors.

A 'take-off' trial tests a combination of factors in any given treatment, minus one factor. For example:

Treatment 1 = FP plus fertiliser and disease control;

Treatment 2 = FP plus fertiliser and pest control;

Treatment 3 = with all factors (FP plus fertiliser, disease control and pest control);

Treatment 4 = FP alone.

The contribution of one factor can be calculated by subtracting the treatment where the factor is not present from the treatment which has all factors. (Treatment 3 – Treatment 1 = effect of pest control). In this way, one can see the interaction effects, and can have information concerning the potential yield increase if all factors are present (useful in policy making).

The 'take-off' design is more complex than the 'add-on' design but can give more information and is less complex than a complete factorial (Graf and Trutmann, 1987). A modified minus-one design (see example above) can also be used to quantify factors that limit yield and to detect interactions among them.

Yield loss trials. When the diagnostic survey uncovers several problems that are reducing yield, the researcher does not necessarily know the magnitude of each in order to set priorities. For a small number of factors, a yield loss trial is useful for determining magnitude. This type of trial can also be augmented by monitoring farmers' fields for damage and using multiple regression to sort out cause and effect.

Refinement trials

These trials are conducted when the researcher has an idea of the type of technology to concentrate on, but needs more details on performance in the farmer's environment; thus, 'refining' the possibilities.

This type of trial has been traditionally done on research stations, but experience has shown that information generated on research stations for environmentally or management sensitive technology may not be relevant for problems such as weed control or implement testing.

These trials are usually larger, more complicated and require more researcher supervision than other types of on-farm trials because more treatments and replications are used at any given site. They may range from being located at a few, specifically chosen, sites to being located at many sites, depending upon the objectives of the research and the variability of environment and socio-economic conditions. A factorial treatment arrangement can be used where the researcher is interested in main effects and interactions.

This type of trial may be repeated on the research station to compare results with those from farmers' fields. For example, a station site may be necessary to ensure that there is one site where there is adequate control or where the researcher may have problems visiting on-farm sites regularly. Two types of trials are:

Levels. This type of trial is used to determine a response curve, as with fertiliser, and/or economics of a certain technology that can be applied at different rates under given circumstances. For example, an exploratory trial has indicated that fertiliser application can improve yields and is potentially economic. Farmers are interested in this technology but want more site-specific information for their two major crops. A 'levels' experiment may then be designed to see which nutrients in what amounts are the most promising.

Screening. A 'screening' experiment is used to determine which are the 'best bet' treatments to select from a relatively large array of choices. It is used with, for example, chemicals, varieties, timing of operations and alleviation of a stress (drought, P, K). An example would be that researchers and farmers have decided that minimal tillage would help alleviate a labour shortage problem. Four herbicides will be tested in combination with three different types of land preparation (ploughing, disking and strip ploughing).

Figure 13. A weed control screening trial for beans is carried out on a farmer's cooperative in Ethiopia.

Verification trials

These trials are used when the researcher has strong evidence that the technology is more or less successful, that is, at a limited number of sites it has performed well, is economic, and farmers like it. However, the technology needs to be tested over a wider range of farmer conditions and modified according to circumstances before it can be recommended.

Figure 14. A soil erosion control verification trial, using sugar-cane contour strips, is performed in Tanzania.

These trials are usually simple and have few treatments. The farmer's practice is always a treatment for comparison purposes. Verification trials are performed at many, carefully selected sites. Usually, there is considerable farmer participation in the experiment and farmers usually manage the 'farmer practice' treatment. Economic evaluation, farmer assessment and systems interactions are important factors to measure. Because of the nature of these trials, they have more demonstration value than the two previous trial types.

Farmer experiments

Technology, such as varieties, forage shrubs and implements, can be given directly to the farmer. The farmers 'design' the trial themselves. The researchers monitor how the technology is used and collect extensive site data to help explain results. This type of experiment is useful to verify technology or to explore how it would work under farmer conditions. For comparison purposes, it can also be used simultaneously with trials of the same technology that are more formally managed with researcher input. For example, a new short-season maize variety was given to farmers, to whom its capabilities were explained. Researchers also conducted their own trials in the same area. Farmers used the maize variety by mixing it with longer maturing varieties to avoid wild-pig damage, whereas researchers planted it unmixed and sustained considerable losses. Sumberg and Okali (1988) discuss how useful this technique was for testing alley-cropping options and Ashby (1987) discusses this technique as a means for testing fertiliser.

There are several reasons to give the farmer the technology to experiment with:

1. The farmer may know how to best use the new technology; and
2. Having the technology completely under the farmer's management may be the best way of conducting farmer assessments.

Figure 15. A farmer is experimenting with peas, a new crop (centre), during the dry season, Ecuador.

The disadvantage of this type of direct experimentation is that it may not be possible to collect quantifiable data for statistical analysis. If the technology is complex, the farmer may have problems in understanding how to use it, even after training. There is always a learning curve associated with new ideas in that after the farmer gains experience, implementation will improve. Given this, it may be necessary to repeat the trial several times. It may be feasible to simultaneously use the complete farmer participation approach, along with a more formal, researcher-managed approach and compare the results.

Demonstrations

Demonstrations usually have only one new treatment in a relatively large plot. There is direct comparison with the farmer's practice and farmer assessment is still crucial at this stage. Demonstrations are often organised by extension agents but implemented by the farmer. Technology testing is now nearly finished. Although the major purpose is to inform a large group of farmers on how to use a new and potentially useful technology, observations and data can still be taken on the treatment's performance.

Figure 16. A demonstration plot showing the use of agroforestry species: *Leucaena* (right), Guatemala grass (centre) and *Calliandra* (left), Tanzania.

Figure 17. A Kenyan farmer appreciates the advantages of this improved plough, with its lighter weight and greater durability.

Treatment Selection

General criteria

Selecting treatments is probably the most difficult but potentially interesting decision a researcher has to make. When selecting treatments, the researcher must consider the farmer's situation:

1. The degree of probability that the technology will work, make sense to the farmer and be acceptable;
2. Potential benefits in terms of profitability, reduced risks, equitability, reduced drudgery and sensitivity to gender issues;
3. Ease of adoption, that is, compatibility with the farming system and local culture; availability of institutional support to sustain it; degree of simplicity; and how obvious the advantages are;

4. Ease of investigation in terms of testing with farmers, costs, complexity and duration; and
5. Sustainability of the solution, that is, its effect on the environment and self-sufficiency.

Checklist

When choosing treatments and deciding on non-experimental variable management, the researcher may use a checklist similar to the following:

1. Farmer practices and preferences
   a. current management practices affecting the aspect being investigated;
   b. current levels of inputs being used and their availability;
   c. important crop-livestock interactions;
   d. labour availability for the new technology and other activities competing for labour;
   e. farmer decision-making criteria that may affect the use of the technology.
   f. gender sensitivity of the technology.

Figure 18. Farmers in semi-arid areas of Kenya use different land preparation strategies to avoid risk of crop failure from uncertain rainfall and labour shortage. This practice may affect fertiliser and/or weeding trial design.

2. Economic performance
   a. minimal amount of crop needed for sale, storage or consumption;
   b. maximal level of inputs allowable, considering production costs, including labour;
   c. degree of risk reduction;

d. demand and marketability of the product; and

e. availability of inputs and support services.

3. Agronomic performance

a. response of crop or animal to different types and levels of inputs, pests and environments;

b. expected interactions between various factors for crop (including intercropping) or animal production, such as fertiliser, spacing and weeding; and

c. expected performance of the treatment compared with local practice.

Information concerning points (1) and (2) above can be ascertained by diagnosis and farmer interviews. Should agronomic performance be already known from previous research the treatment choice can be made with some confidence. However, if the response is not well known, the choice of treatment will have to be made either as an educated guess or through a refinement trial. Farmer feedback and research experience should establish whether the technology is acceptable.

Treatment combinations

Selecting package components. Adoption studies show that farmers usually adopt one or two components of a recommendation 'package' at a time (Byerlee and Hesse de Polanco, 1986). A package may include improvements, e.g., a new variety, spacing, fertiliser and weeding, that together give the greatest yield increase. The farmer, however, is most likely to adopt only one component at a time. Eventually, he/she may adopt them all. His/her reasons for doing this include risk avoidance, labour conflicts and/or a poor input supply system.

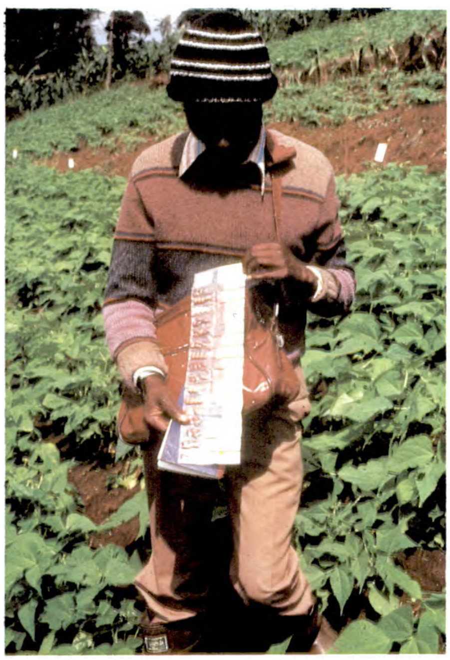


Figure 19. A Tanzanian research assistant holds packets of bean seeds of various varieties which will be evaluated in multilocational tests.

To decide which components of a package to include as treatments, a researcher first needs to know the relative response of each component under farmer conditions by using a factorial, add-on, take-off type trial. The researcher should also interview farmers to discover which components within a package would be the most readily adopted.

For example, researchers have a high-yielding package that includes a variety, fertiliser, insecticide, and a row planting method to facilitate weeding. Most farmers interviewed were interested in the new variety, and secondly in using the fertiliser. The planting technique was less attractive because of additional labour requirements. The insecticide was difficult because most farmers did not have sprayers. Target group farmers currently do not use fertilisers or insecticides and use a traditional broadcast planting method. Based on this example, an exploratory trial was designed with the following treatment combinations selected from the package:

Treatment 1 = farmer's practice: farmer's variety, no fertiliser;

Treatment 2 = new variety, no fertiliser;

Treatment 3 = new variety plus fertiliser;

Treatment 4 = farmer's variety plus fertiliser; and

Treatment 5 = whole package.

Choosing options. Farmers should be offered a series of technology options to solve a problem. No two farmers manage alike and the greater the number of technological options they have to choose from, the greater their flexibility in dealing with environmental, market and resource management variability. Therefore, when choosing a series of treatments, a researcher should consider a number of solutions for a problem. For example, to solve a weed problem, a farmer can use an increased number of land preparations, herbicide, hand-weeding, or animal-drawn cultivators, depending upon the problem's severity, the resources available to the farmer and the economic situation. By testing a number of options, the researcher can recommend a choice, qualifying it according to the circumstances under which it works best.

Figure 20. In Somalia, several hand-weeding implements were tested with farmers, providing them with options.

Once a treatment combination is selected, for analytical purposes, a researcher should check the statistical validity to avoid unwanted confounding.

Research should not have a predetermined focus. When deciding on treatments, the researcher should ask the following questions about the average farm:

Who makes the decisions?

Who does the labour?

Who controls the land and capital resources?

Who uses the products produced?

Who controls the outputs?

Who knows about current farming practices?

Once the researcher knows the answers to these questions he/she should be able to consider whether the proposed technology is gender sensitive (i.e., it affects one sex more than another) or gender neutral. If it is gender sensitive, the researcher must find out, for example, if the proposed technology is oriented to the users' goals, will meet all needs, if the beneficiary has to pay costs and if the beneficiary controls the necessary resources.

Treatment levels

Interviewing farmers. The treatment levels selected should be economic and acceptable to farmers, and the researcher should know which differences in treatments would cause adoption or rejection by farmers. The response to this question should guide the researcher in making treatment choices. Options should be included for various categories of farmers.

Figure 21. It is important to discuss proposed treatments with groups of farmers.

Figure 22. In Burundi, a researcher discusses proposed treatments with interested farmers.

Determine response curve. To define a biological response (e.g., to fertiliser or pesticide) or an economic response, a series of rates or levels must be selected. Usually only three points are needed to determine a response curve: a control or zero level; low level (linear portion of a curve); and high level (plateau portion of the curve). The 'high' level must be chosen carefully because if it is set too low, the response to the input will not indicate the plateau portion of the curve, where the input ceases to increase yield. Once the response curve is known for a number of situations, it can be used to choose the optimal rate and/or calculate the most economic rate, given local prices for inputs and produce.

Labour requirements. Labour requirements are particularly important for cultural practice treatments which often require a change in labour input patterns. Cropping pattern and labour use calendars are useful for predicting potential conflicts with other activities and finding ways to remove those conflicts. For example, can a farmer realistically accomplish the number of weedings proposed? Does increased plant density mean that more or less weeding time will be required?

Low input level. Although a low input level would not be considered optimal according to previous research results, it may be necessary to include it in a treatment regime. A low level may be an 'optimum' for farmers who cannot afford higher levels of input or management. The inherent risk of adopting only one technology component can be determined by including low levels. This point is especially relevant when verifying variety performance because an improved variety may yield less than local varieties at low input levels.

Examples. Many pesticides are notoriously expensive. Therefore, economics and effectiveness must be used as criteria to decide which pesticide to use and at what rate. Farmers may prefer a cheaper, less effective chemical to a more expensive, effective one. Product manufacturers usually suggest optimal rates for use, which can then be used as a guide. However, it is a good idea to test the product at lower rates than recommended and at double the optimal rate. Thus, the researcher can discover effective but more economic rates than recommended and possible side effects of overdosing caused by inaccurate spraying (see p. 41).

To choose fertiliser levels, the researcher must know the nutrient requirements of the crop at different growth stages, what nutrients the soils in the study area can supply, and what potential carry-over effects there are from various other production practices, such as crop residues, manure and legumes. By determining and stratifying the diversity of the study area, the researcher can determine treatments suitable for different types of soils and cropping patterns, and can choose trial locations. The researcher should answer such questions as: Will fertilisers be subsidised and for how long? What prices can farmers afford, given the marketing and yield conditions? (economic questions); How specific should a fertiliser recommendation be for the conditions? (questions on utility); and How does the farmer classify and use soil types? (questions on resource access and use).

Number of treatments

The number of treatments is dependent upon the objectives, type of trial and type of management employed.

Trial type. An exploratory trial may have a variable number of treatments, that is, an investigative trial may have a moderate number (four to six), whereas an 'add-on' or 'take-off' type may have only two or three. A refinement trial usually has a larger number to better define a biological response or factor, and a demonstration trial may have only one or, at the most, two.

Management. Usually, the more the farmer is involved in evaluation and management aspects, the fewer the treatments in order to make the trial easier for the farmer to understand and manage. There are statistical designs that can be used so that a larger number of treatments can be included but not at each site, thus keeping the size at any given site at a manageable level (see p. 45-46). If a larger number of treatments are used when the researcher is managing, land availability must be considered.

The resources available to manage the trial, either by the farmer or the researcher, may limit the treatment number and trial size. Where land is in short supply, the number of treatments will need to be reduced at each site to limit the size. This will encourage farmer cooperation. Risk to the farmer and the need for compensation will also be reduced by having a smaller trial with fewer treatments.

Figure 23. Trial size and treatment number has been limited in this on-farm trial in accordance with the farmer's resources.

Figure 24. Treatment number and plot size in this sugar cane-bean intercropping trial is determined primarily by sugar cane mechanisation requirements, Mauritius.

Figure 25. This potato-bean intercropping trial in Uganda is testing several bean spacings. The trial must be kept to a reasonable size for the farmer to manage and understand it.

Type of technology. Intercropping, rotation, machinery, and some pest control trials tend to need larger plots; thus, if land is a limiting factor, fewer treatments are used or a statistical design developed to accommodate more treatments overall. Conversely, variety or fertility trials often require small plots, therefore allowing for a larger choice of treatments if trial size is the only consideration.

Intercropping trials. Treatment design may be more complex because, for each crop, several factors can be varied, such as variety, population, spacing and time of planting. The number of treatments can escalate quickly; therefore, for on-farm trials, where the space and complexity is usually limited, the design must be altered to keep the treatment number to a reasonable level. This can be done by limiting the number of variables to be tested, by using an incomplete factorial design, or by using superimposed trials. If the objective is to compare intercrops, the number of monocrop plots can be kept to a minimum or can be grown alongside the intercrop plots in fewer but larger plots. Monocrop plots can be used to standardise yields of intercrops (Mead, 1989).

Fertiliser trials. It may be difficult to have a reproducible fertiliser response over a large area because of field differences, which must be recognised in advance. It may be that the number of fields sampled may have to be increased and several years' data collected in order to broaden the results and inferences.

Risky technologies

The researcher must use his/her judgement to weigh the risks in taking technology directly to the farmer. What amount of confidence is there that the technology will work under local conditions without too much modification? What amount of time would be lost if tested first on the station? Such aspects as possible danger to the farmer (pesticides), danger to the environment (increase in potential soil erosion) and risk of crop failure (ineffective control of insects) must be considered.

Figure 26. Herbicide injury to beans (left) occurred in this verification trial because the recommendation, which was derived from station conditions was not suitable for a different soil type, Ethiopia.

Imported technology. There may be technology which has been reliably tested in other countries or locations that can solve a problem, but has not yet been tested in the research area. The question may arise as to whether it needs to be tested at the station first before being tried on the farmer's field. How this question is answered depends upon the technology and the problem it is to solve. For example,

1. If a series of new varieties are imported, it is wise to test them at the station first to discard those that are not adapted or are susceptible to local diseases, thereby decreasing risk to farmers.
2. Some risky technology needs to be tested first in the farmers' environment; for example, testing new herbicides on *representative* weed flora. The researcher can assume full management of the trial to reduce risk to the farmer.
3. A seed dressing treatment widely tested elsewhere proved to be an excellent control measure for bean fly and was successfully tested directly on-farm, by-passing the research station.

Pesticides. The researcher must make an intelligent decision when introducing pesticides. Although pesticides can effectively control many pests, the conditions present in many developing countries may not warrant the introduction. Factors to consider include:

1. The toxicity of the compound;
2. The hazard posed to the farmer and environment, considering local conditions; for example, availability of good storage facilities, availability and use of protective clothing, and functioning, well-maintained equipment;
3. Know-how in safe application techniques;
4. Presence or absence of regulatory procedures;
5. Extension expertise to assist in pest identification, pesticide choice and application training.

After these and other considerations are taken into account, the researcher may decide that it is irresponsible under prevailing conditions to introduce pesticides.

Control treatments

The purpose of a control treatment is to provide a standard for comparison with other treatments. However, for investigative or exploratory trials, a control treatment may not be needed.

Various types of controls can be used, depending upon the experiment's objectives:

1. Optimal level (may be unrealistic but will demonstrate the full potential);
2. Standard variety or practice (average practice);
3. Farmer's practice (individual's practice);
4. Current recommendation; and
5. 'Untreated', in which case the actual levels of pest attack, fertility, weed infestation must be recorded.

More than one control can be used: for example, comparison of the currently recommended variety, the farmer's local variety and a to-be-released variety. In some cases, the recommended practice may be the same as the optimal level.

Farmer's practice. A major objective in conducting on-farm research with farmers' participation is to compare the new technology with the farmer's practice. Often researchers, when comparing the new technology with the 'local' check, find out after the fact that there were three *different* local checks. The local practice, whatever it is, needs to be described in detail at each site: How was the 'local' or 'conventional' weeding practice done? When, with how many people and how long did it take? What was the 'local' variety like, e.g., its colour, growth habit, the way it was planted and maturity time? What are the traditional pest control practices? What effects do such factors as rotation and residue handling have on pest incidence and control?

In most situations it is desirable to have the same local check across sites. If this is not feasible, then the local checks can be grouped into categories for analysis purposes, e.g., climbing versus bush types, early maturing versus late maturing. Post-stratification, that is, the grouping of the same local checks together, can also be done, provided there are enough samples from each type.

Researchers should avoid simulating or copying a farmer's practice instead of letting the farmer implement it, because, unless researchers are very perceptive, they may not fully understand the details of implementing the practice.

Untreated treatments. The 'untreated' treatment, if used, must be selected carefully. The untreated treatment may give such different results from other treatments that special analysis techniques must be used (e.g., orthogonal comparisons). Researchers tend to use untreated plots for academic interest, but in on-farm trials this is not realistic, creates unnecessary work, and takes up more space. The untreated plots in a pest control trial will probably become a source of unwanted pests, and a treatment such as 'no weeding' is unrealistic if the farmers never do it themselves. In some cases, the untreated plot is the same as the farmer's practice. The researcher must use his/her common sense and refer to the original trial objectives.

Special cases. Often farmers grow many varieties. Not every local variety needs be a check as the researcher probably aims to replace only one.

When a new crop is being tested, there may not be any local control of the same crop. If, for example, the nutritional aspects of a new crop is being compared with those of an existing crop, this local crop should be used as the control.

A control *group*, the mean of 3 to 4 standard varieties, can be used as a standard in variety testing trials. This would increase precision, especially where a single control, used for comparison, gives wider fluctuations in yield under differing environments or management practices.

How to Manage Test Conditions

Test conditions, or non-experimental variables, refer to both controllable and uncontrollable factors. Controllable factors include all management and cultural practices that are applied to the trial area other than treatments. For example, in a weeding trial, treatments would be different weeding regimes and test conditions would be land preparation, fertiliser application, planting time and variety choice. The controllable factors are also termed non-experimental variables. Uncontrollable factors are the environmental conditions, e.g., rainfall, frost and temperature.

In on-station experiments, experimental error is, in part, controlled by using proper plot techniques to minimise variability from controllable test condition factors and is under the direct control of the researcher. Thus, by minimising test condition variability, treatment differences will not be masked. In on-farm experiments, it is usually more difficult, and not necessarily desirable, depending upon the objectives, to control test conditions because there is often less direct researcher control and greater farmer involvement.

Uncontrollable factors

Uncontrollable environmental conditions change with season and site (e.g., rainfall), and within a site (e.g., soil heterogeneity). The effect of these uncontrolled conditions is important and should be quantified and evaluated. The variability associated with these site-related factors are important in on-farm research, whereas in station research they are generally of less concern to researchers.

Controllable factors

When designing on-farm experiments, controllable factors should be identified and decisions made on their management. The identity of controllable factors depends upon the type of treatments to be tested and which management factors are hypothesised to interact with treatment performance. Controllable factors would include land preparation and planting times and methods; crop density and thinning or transplanting practices; weeding methods and timings; supplementary irrigation; pest and disease control measures (when, what and how applied); and variety selection.

It is also necessary to know the farmers' practices in detail to anticipate non-experimental variable management needs. For example, if a researcher is planning to test varieties with farmer participation, the methods farmers use for fertility and weed management are two factors, among others, that would affect variety performance. When a number of farmers are involved, their management practices may differ from one another. The researcher has therefore to decide whether a uniform management should be imposed or to let each farmer manage as usual, record the different management systems and post-stratify for analysis.

Optimal level versus farmers' level

Researchers often debate what level of non-experimental variable management should be used: the optimal level or the farmer's level, which is usually not considered optimal by the researcher. Researchers argue that they do not want to demonstrate poor management to the farmer by having less than optimal test condition management. Researchers also fear that the treatments will not perform well under management levels used by the farmer. However, the decision should be determined by the experiment's objectives.

For example, in a fertiliser refinement trial, researchers impose a weeding practice. In this case, they are more interested in the performance of the treatments in a uniform background than what the fertiliser response is under varying weeding regimes. Whereas if it were a fertiliser verification trial, the researcher would be more interested in what the response was under varying weeding practices as found in farmer-managed conditions. The creation of a superior environment in a verification trial, by using recommended levels of inputs not normally used by the farmer, defeats the purpose of this type of experiment.

It is usually not wise to have all the non-experimental variables managed at the optimal level if this is not the farmer's level. Farmers rarely adopt full packages, as discussed in the previous section on treatment selection (p. 33-42). A compromise would be to compare the technology under farmer's management with both the fully recommended management and farmer's practice. For example, a new variety is tested with all non-experimental variables managed at the farmer's level and compared with the new variety under improved management, and with the farmer's variety and management.

Special concerns in farmer-managed trials

Seeding rate in variety trials. Farmers may use different seeding rates for local varieties, for cultivars having different-sized seeds and for varietal mixtures, and again different from what is recommended for new varieties. The researcher needs to understand the logic behind the farmer's practice: Is a low seed rate related to environmental or soil conditions, to the growth habit of the variety, to weeding practices or to intercropping plans? Is a higher seeding rate related to weed or pest control, poor germination, environmental conditions or variety growth habit? Once the farmer's logic is understood, the researcher may wish to adjust the new variety's seeding rate to match the farmer's practice or to impose a new seeding rate, depending upon the condition. If a new rate is imposed, planting may need supervision.

Sowing practices. The farmer's sowing practice and rationale must be understood before planting. The researcher's planting time may be related to factors such as availability of funds or labour, or perhaps the research station is located in a different agro-ecological zone, and the farmer's practice is locale specific. Some farmers may prepare the land several times well in advance of sowing, others may prepare and sow on the same day directly after ploughing in order to conserve soil moisture. Sowing depth and the covering practice should be considered. Many on-farm trials have failed where the researcher used his/her planting method next to the farmer's method which succeeds, merely because the farmer has locale-specific experience.

Fertility trials. The management of other test conditions, such as seeding rate, level and time of weeding and planting depth, may influence the crop's fertiliser response. It should be noted if higher levels of fertiliser stimulate more weed growth, thereby requiring more weeding in those plots. This, in turn, would influence labour use and availability, in which case labour use must be monitored.

Statistical Design

Blocking techniques

Blocking is used by the researcher when variation is expected within the field because of factors such as soil type and drainage patterns. When experimenting, the ability to detect treatment differences increases as the size of the experimental error decreases. A good experiment incorporates all possible means of minimising experimental error. Three commonly used techniques to do this are blocking, proper plot technique and data analysis (Gomez and Gomez, 1984). Blocking is used in on-farm experiments to maximise variability between blocks and minimise variability within blocks. Only the variation within a block becomes part of the experimental error.

Identifying sources of variability. Examples of variable gradients are soil heterogeneity, direction of insect migration, moisture gradient created by a slope or depression and nearness of a tree.

Shape and size of blocks. If the gradient of the land is in one direction, use long and narrow blocks oriented so the length is perpendicular to the gradient. If there are two gradients, equally strong, or if the gradients are unpredictable, use square blocks. For the former case, there are other techniques as well (see Gomez and Gomez, 1984).

Replications within and between fields

Replication gives a measure of experimental error and must occur at random by using blocks (randomised complete blocks) or merely by repeating the treatment within the experiment (completely randomised design). The greater the expected experimental error, the more replications will be needed; however, increasing the number of replications does not decrease experimental error.

Replications at each farm deal with variability within the site, and replications across sites (that is, using several test farms) are used to cope with variation between farms. Variation is expected to be smaller within a farm than between farms (Gomez and Gomez, 1984). When replicating across sites, the information generated is useful only if the factors causing the variability can be described and any interaction of these factors with the treatments explained. The researcher should be able to identify most of the factors that cause variability before the experiment is designed, and selectively place the trials to sample the variability (see p. 71-75).

Number of replications

The number of replications to include depends upon objectives, experimental design, type of trial, number of treatments to be tested, type of management, space available, variability in experimental material, amount of precision required and labour available.

Exploratory and refinement trials are normally conducted at a limited number of sites (<10). At each site, between 2 and 4 replications would be used, usually placed in blocks, depending upon the complexity of the trial (number of treatments and design) and available space. More replications are needed within a site when precise data are collected and when there is considerable variability in the field. Normally, the farmer is not fully involved in these trials, which means that the researcher can afford to use a greater number of replications per farm site without confusing the farmer or causing him/her undue risk or labour inputs. This will allow the researcher to analyse each experiment on its own, and to combine the data for analysis across sites.

Two replications and blocks, as described above, are more useful in situations where the within-field variability is not well understood; there is considerable within field variability; management is unpredictable; and land is available. If land is available, two replications are better because extra labour is minimal as one side is already laid out; there is more surety that the researcher will receive some return for the time invested in such activities as site selection and explanations to the farmer; and risk of loss is reduced. The fewer the treatments (4 to 5), the more likely it is that two replications can be used.

Where several treatments are used, one replication should be used in order to keep the trial to a manageable size.

Investigative (diagnostic) and verification trials can have 1 to 2 replications per field. As these trials tend to have greater farmer involvement, they should be kept small, simple, manageable and understandable. Plot size and number of total plots, determined by the number of treatments and replications, can be adjusted to satisfy these four conditions (see p. 49-50 and p. 77-80).

Where only one replication is used, replications between farms can satisfy requirements in controlling variability, particularly where the researcher is interested in understanding the variability of the area. The researcher can achieve internal replication by taking subsamples from each plot area; however, the analysis of these results must be treated appropriately. In demonstrations, the plot size is usually large and only one replication is necessary.

Plot size and shape

Plot size. Practical considerations, ease of management and variability resulting from field irregularities are the three main considerations in deciding on plot size. The larger the plot size, the smaller the variability, but precision decreases (Gomez and Gomez, 1984). In on-farm experiments, the amount of farmer management, risk, labour requirements, and available space are considerations for determining plot size in addition to normal concerns, i.e., the crop or intercrop, type of treatment (including technical concerns for implementation and measurements needed) and soil homogeneity. With agroforestry, experimental plot size determines the sampling procedure, precision of evaluation and visual importance for demonstration value (Rao, 1990).

Figure 27. Plot size for tillage operations must take into account the size of the machinery, Kenya.

Figure 28. Testing animal-drawn tillage equipment requires the researcher to consider the amount of room needed for turning between plots, Kenya.

Figure 29. Distance between the farmer's bananas (3 x 3 m) determined the plot size in this bean density on-farm trial. There were no pathways between plots, Tanzania.

Smaller plots are used when a range of treatments (investigative or refinement trials) are tested, or where the farm size is small, or, particularly, when the researcher manages the trial.

Larger plot sizes are used for demonstrations, insect trials, measuring labour, tillage operations, large crops or large agroforestry species, and promoting farmers' understanding. Larger plots permit farmer management levels to be realistically implemented and can help the researcher and farmer identify resource conflicts. Many management problems do not manifest themselves on small plots. Large plots in verification trials can be used to make improved variety seed available more quickly. Nevertheless, the plots should not be too large, as they would impose an unreasonable burden or risk on the farmer or distort normal farm operations.

Some plot size estimates from the literature may give guidance: exploratory trial — 20-50 m^2; a refinement trial — 30-100 m^2; a verification trial — 200-500 m^2; a variety trial — 100 m^2; an agronomy trial — 250 m^2; 500-1000 m^2 for monitoring labour (Rao, 1990, after ICRISAT). These estimates are dependent upon the type of crop being used. Others say that a researcher-managed trial should be between 15-40 m^2; a jointly managed trial 15-80 m^2, and a farmer-managed trial 70-100 m^2. Generally, the experimental area should not exceed 20% of the farmer's cropped land. Plot size is only one consideration in adjusting the experiment's size.

Should plot sizes at all trial sites be the same? There may be valid reasons for choosing to reduce the size of a plot at one site and increase it at another. It is important to note the plot size for each site in the field notebook and indicate the harvest area. The advantage of having same-sized plots is to standardise data collection and avoid mistakes.

Plot shape. To reduce experimental error, the general rule is to use long narrow plots for areas with distinct fertility gradients, with the length of the plot parallel to the fertility (or other field) gradient. Plots should be as square as possible whenever the fertility (or other pattern) is spotty or unknown, or when border effects are large.

Nevertheless, in on-farm experiments, plot shape may have to be adjusted to fit the situation because fields may be irregular in shape or unevenly levelled as in rice production. The researcher may have to remain flexible, making a decision at the last minute once the condition of the field is seen (Gomez and Gomez, 1984).

Border rows

Border or guard rows should be used in on-farm experiments for the same reasons as for station experiments: plants near the edge of the plot can be affected by conditions in the neighbouring plot or area and may not be representative in, for example, yield or growth parameters. To avoid such bias, a strip around each plot is discarded and measurements from the central area only are used.

A number of rows or an area in crops sown by broadcast should be designated as a border area, and included in the plot size measurement. The area of the border depends upon the type of crop and treatment, or on the amount of competition or interference that is likely to be encountered from the neighbouring area. Competition is expected to be greater for small-seeded grain crops in closely spaced rows (e.g., wheat and rice), so that two rows on each side of the plot should be discarded. For larger seeded, wider spaced (>50 cm) crops (e.g., maize and sorghum), only one row on each side is discarded. To decrease the amount of space devoted to border areas, plots can share a border row or area. Intercrops and agroforestry plots generally require a larger border than monocrops.

In farmer-managed, on-farm trials, the farmer may not readily understand the concept of border rows and may reject border plants in the harvest. If possible, the borders should be harvested ahead of time. If the borders are included in the harvest sample, a correction to the harvest needs to be made.

Pathways

In on-farm trials, the area devoted to pathways should be reduced as much as possible to help keep the size of the experiment small and to reduce additional, unnecessary management requirements for the farmer or during layout. Paths between replications or plots can also serve as pest or weed infestation sources. Nevertheless, a path between blocks may be a compromise. If paths are not used, stakes at the plot edges would help differentiate between treatments. If the experiment involves mechanical treatments, pathways will probably be necessary for implementation purposes. A buffer area around the experimental area will help deter animals or thieves.

Statistical design considerations

Statistical designs are used to help the researcher understand the nature of differences among treatments and the certainty or probability of that variability. Probability indicates whether the differences were real or due to chance, and whether results can be repeated. Replication and randomisation within the experiment are two techniques that help the researcher obtain a more accurate measure of treatment differences. In on-farm research, statistical analysis is only one method of trial analysis; others being economic and risk analyses, and acceptability determined by farmer assessment.

Mead (1989) gives helpful design guidelines on degrees of freedom (df), which can help the researcher make decisions on block and treatment number, while maintaining an efficient experiment. Degrees of freedom are used in three ways:

1. Blocking or control of variation (including covariance);
2. Estimating error (o^2); and
3. Answering treatment questions.

Mead suggests keeping the number of degrees of freedom for error between 10 and 20. Furthermore, he states that an experiment is inefficient if the following conditions exist: (1) not enough df for blocking; (2) not enough or too many df for error estimation; (3) insufficient number of treatments to use df available for answering treatment questions; and (4) other methods to control error are not being used, such as good experiment management and replication.

There are many excellent texts dealing with statistical tests and computations. However, the on-farm researcher should be aware of the following useful tests, which are not always employed in station research:

Paired comparison. The planned, paired comparison test involves a given pair of treatments that are to be compared and that must be identified before the experiment starts. This simple test is useful for comparing, on a number of farms, the farmer's practice with a new technology. It is useful in any trial type, such as exploratory, verification or demonstration, where a single factor is compared with another. In the unplanned, paired comparison test, pairs of treatments are not selected in advance but are compared after the experiment is run. Commonly used tests for this are Duncan's Multiple Range Test (DMRT) or Least Significant Difference Test (LSD).

Fractional factorial. This design is used when a factorial experiment is too large to place on a farmer's field. To reduce the size, subsets of treatments are tested on different sites but are selected in such a way to make final analysis possible. This is often used in exploratory trials.

Strip plot design. This design is suited for a two-factor experiment where the desired precision for measuring the interaction effect between the two factors is higher than measuring the main effect of either factor. A vertical strip is established for the first factor and a horizontal strip imposed on the vertical strip for the second factor. The strips are always perpendicular to each other. This is useful for experiments testing mechanical or timing interventions as it makes treatment application easier to do and understand.

Incomplete blocks. This design is used when there are many treatments. Each block is small, it does not contain all the treatments, is homogeneous, and gives a higher degree of precision. There are ways, however, of selecting which treatments appear in which block so that the number of treatments and replications is inflexible. Analysis is complex. It is a useful technique for maintaining small experimental sizes where land or labour is a constraint in on-farm experiments (Gomez and Gomez, 1984).

Study Questions

For some questions you need to fill in the blanks:

1. An objective should be a concise statement of the hypotheses indicating the intention of the experiment. It should help the researcher make a number of decisions concerning the experiment. List five likely decisions relating to objectives:

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

   e. ______________________________

2. Briefly state the function of each of the *five* major types of trial:

   a. ____

   b. ____

   c. ____

   d. ____

   e. ____

3. Name the four categories of exploratory trials and briefly explain their function:

   a. ____

   b. ____

   c. ____

   d. ____

   e. ____

4. Why is there usually a larger degree of researcher management when conducting levels or screening experiments?

   ____

5. For verification experiments, the researcher tests the technology under ____________________ conditions. Why?

   ____

6. __________________________ and __________________________ are important factors to measure when doing verification testing.

The following sentences are either true or false. Indicate by writing T or F:

7. Farmers usually adopt whole packages of technology. ____

8. Farmers need a series of technological options to solve problems, therefore researchers should consider this when choosing treatments. ____

9. Treatment selections are always statistically valid, therefore there is no need to check this aspect. ____

10. When choosing levels of treatments, it is not necessary to consider economics. ____

11. When choosing fertiliser levels, a minimum of three levels will give a response curve. To choose these levels it is important to know about the crop, soils and other farmer practices concerning nutrients. ____

12. It is important to include a lower level of input as treatment even though it may not be an optimal level. ____

For some questions you need to fill in the blanks:

13. List several reasons why on-farm trials have relatively few treatments:

    a. ______________________________

    b. ______________________________

    c. ______________________________

    d. ______________________________

    e. ______________________________

14. What types of technology need to be tested on larger plots?

    a. ______________________________

    b. ______________________________

    c. ______________________________

    d. ______________________________

    e. ______________________________

15. Two techniques can be used to help limit the number of treatments. These are _______________ trials and an __________________________ design.

16. Briefly discuss whether imported technology should be tested directly on farmers' fields?

____

____

17. Name five types of control treatments:

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

18. Why must a 'local' control treatment be fully described?

____

____

19. State two reasons why an 'untreated' plot would not be used as a control treatment in an on-farm trial?

a. ____

b. ____

20. Briefly describe what are controllable and uncontrollable test conditions:

Controllable: ____

____

Uncontrollable: ____

____

21. Name four controllable test conditions that would need managing in a variety trial:

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

The following sentences are either true or false. Indicate by writing T or F:

22. More than one control treatment can be used in an experiment. ____

23. It is necessary to always manage test conditions at an optimum. ____

24. Test conditions may significantly interact with treatments. ____

25. In on-farm trials, replications can be used in space and time, as well as within one experimental site. ____

26. The more precise the information needed from the experiment, the fewer the replications needed. ____

27. All plots for a given experiment must be the same size at all experiment sites. ____

For some questions you need to fill in the blanks:

28. Plots should be ________________ and ______________ when there are gradients and __________________ when there are none.

29. Name at least four ways to decrease the size of an experiment.

   a. ____

   b. ____

   c. ____

   d. ____

For answers see p. 110-111.

Part 4

TRIAL MANAGEMENT DECISIONS

Trial Management

Farmer involvement is a major feature of on-farm research. How the farmer will be involved, and to what extent, must be determined once the type of trial is decided upon. Trial type and management type are usually closely related. Farmers and researchers can make complementary contributions (C. Wortmann, 1990, personal communication):

Farmers	Researchers
Know the priorities of their problems	Can identify technical constraints less obvious to farmers
Know the local situation	Know outside history
Can assess their own possibilities and capabilities	
Have good observational powers	Have formal analytical tools
Know local diversity	Know outside diversity

Both farmers and researchers

Are sources of ideas for solutions
Can assess feasibility
Are experimenters

The following list of points can be considered when deciding on farmer involvement:

Points to consider (These should not be considered as inflexible)	Management type	
	More researcher involvement	More farmer involvement
Type of precision desired	Detailed measurements; Control on-site variability	Measure and understand target group variability; Identification of resource conflicts
Confidence in the technology	Less	High
Risk to farmer (economic and others)	High	Low
Type of experiment	Refinement; Exploratory	Validation; Demonstration
Trial objectives	Require tighter control of the experiment	Farmer conditions are needed for implementation and assessment
Trial complexity and size	Greater	Less
Number of sites	Smaller	Larger

The degree of farmer involvement should be considered as a gradient rather than as a 'yes or no' situation. The more the farmer is involved in the trial's management, the more the researcher will learn about the farmer's perception and use of the technology. There are management issues concerning both experimental and non-experimental variables (see p. 59-66 for further discussion on farmer participation).

Researcher management

The researcher both plans and implements the trial, controlling the application of treatments and management of non-experimental variables. He/she may seek farmers' advice on treatment selection and/or assessment. The researcher enters a contractual arrangement with the farmer for land and services.

This type of management is used where:

1. A more realistic environment for a station-type trial is provided by the farmer's situation;
2. The researcher needs to have control over experimental variables and test conditions;
3. The trials are large and complicated; and
4. The trials pose undue risk for the farmer.

Researcher management is most common for exploratory and refinement trials. Inputs and labour are usually supplied by the researcher and the site by the farmer.

Figure 30. A researcher-managed trial. Note the small plot size and layout are similar to those used on a research station trial, Rwanda.

Shared researcher and farmer management

The simplest form of shared management is where the researcher uses the farmer's production practices but adds or changes the system slightly. The researcher usually manages some or all of the experimental variable(s), whereas the farmer usually manages non-experimental variables (test conditions). Sometimes a researcher manages one or two test conditions if they are difficult or risky to implement, such as pesticide application; time-consuming to accomplish, such as additional labour for weeding; or are new and critical to the technology's functioning, such as a new plough. Shared management is useful when evaluating the response of one or two factors in direct comparison with the farmer's practice, and where the new technology must be exposed to the farmer's level of management.

The trials done in this manner are usually simple and of the exploratory or verification type. More data may have to be collected on the farmer's management inputs for both experimental and test conditions in order to make comparisons across many sites. The more traditional the farmer's management, the more pronounced is the tendency to introduce researcher bias in management when a consultation mode is being followed, that is, when the trial is researcher designed and farmer implemented (Ashby, 1987).

An example of shared management is in the 'superimposed trial', where the intervention, such as a new variety, a fertiliser treatment or pest control measure, is applied to the farmer's field by the researcher. The other treatment, 'farmer's practice', and all non-experimental variables are managed by the farmer. Another example is where the researcher plants the trial area with a different plant population but leaves the rest of the management to the farmer. Or the researchers may apply a chemical or fertiliser treatment to an area of the farmer's crop and leave all other management to the farmer.

Figure 31. A jointly managed trial, with the farmer and researcher discussing the results, Tanzania.

Figure 32. Organising a jointly managed trial requires the researcher to discuss all aspects with the farmer, Rwanda.

Farmer management

The farmer uses his/her own resources and completely manages the trial, both the experimental variables and test conditions. The farmer may even design the trial. The researcher consults the farmer, giving instructions on how to lay out the trial and when and how to manage non-experimental variables. Or, in other cases, the farmer is left to make all decisions. The outcome will most likely be different for these two different modes. Ashby (1987) showed that, when farmers made all the decisions, yields were usually lower than in trials where researchers consulted the farmer, particularly concerning management of non-experimental variables.

Reasons for using this approach are:

1. The technology is in its developmental stages, and the researcher can monitor how the farmer uses and assesses it (exploratory);
2. The technology is near the final stages of development and testing, and the researcher can monitor how the technology performs at many sites in a realistic environment (verification); and
3. The technology comes from another country or area so that only verification is needed.

Farmer-managed trials are usually simple and carried out over a large number of sites. As with shared management, farmer-managed trials require more data to be collected so that researchers can explain variable performance by relating the data to site or management parameters. For example, a new bean variety was given to farmers and they were told to plant it next to their local variety. Farmers employed three different spacings, two different weeding regimes and planted on two different soil types. The results can be stratified by spacings, weeding and soils in order to test for significant interactions and to explain potential yield differences. The results would indicate that a particular spacing and weeding regime for one soil is best, whereas a different spacing is required for the other soil. A researcher-managed trial may not uncover this type of useful information (Table 2).

Table 2. Type of trials and management.

Trial type	Function	Size	Site number	Management
Exploratory: investigative; simple factorial; add-on/take-off; yield loss	Find causes to problem; Prioritise problems	Small	Few, precisely located	More researcher control; Shared
Refinement: levels; screening	To select best level or types of technology	Potentially large	Few, precisely located, or more if a wider environment is required	Researcher; Shared
Verification	To test technology on a larger and in a wider range of circumstances	Few treatments	Many	Farmer; Shared
Farmer experiments	To take full advantage of farmer participation; To understand ITK[a]	Small	Many	Farmer
Demonstration	Direct comparison with farmer practice; Demonstrate use of technology	One new treatment	Many	Farmer; Extension

a. Indigenous technical knowledge.

Figure 33. A farmer-managed weeding trial in Ethiopia.

Farmer Participation

Role of farmers in research

'On-farm research is not of much value if farmers do not consider themselves part of it ... . Building rapport is the best way to gain farmer cooperation, and this requires that scientists spend much time in the field' (Rhoades, 1982).

Farmers can help researchers to:

1. Understand the farming system;
2. Choose trial sites;
3. Provide technology;
4. Choose or evaluate treatments;
5. Anticipate problems in treatment application and modify the treatments if need be;
6. Manage, or help manage, the experiment;
7. Assess the technology by their own criteria and so put results into perspective; and
8. Evaluate the technology's adoptability.

Many recent publications deal with farmer participation. The examples they describe include village brainstorming to identify local problems (participatory diagnosis); studying farmers' informal trials to learn how farmers carry out and evaluate their own research; conducting farmer assessments by using various ranking and quantifying systems; group experimentation for testing technology according to the farmers' design; and innovator workshops to enlighten researchers about farmers' perceptions of the technology (Ashby, 1986; Farrington and Martin, 1987).

Advantages of involving farmers. Farmer involvement is important if *farmer-technology interactions* are to be understood. Data will be more reliable, which reliability is especially useful during early stages of testing, particularly of cultural practices. Farmers usually intervene in an experiment because either it creates conflict or they do not understand what is wanted. *Farmer feedback saves time*: the researcher can make needed adjustments to the technology to fit farmers' criteria for acceptability. An example from Kenya illustrates an experiment to optimise the yield of intercropped maize and beans by finding the ideal plant population combination and configuration. The 'final' recommendation was demonstrated to farmers, most of whom rejected it because the beans were spaced too closely to the maize, causing extra labour in weeding. Had the researchers involved the farmers earlier they would have either developed a new smaller hoe or adjusted the spacing to accommodate the weeding constraint.

Figure 34. Interviewing farmers about their farming system, Ethiopia.

Figure 35. A researcher discusses variety treatments with a cooperating farmer, Ethiopia.

Why researchers do not involve farmers. Although researchers in theory understand that farmers should be involved in on-farm research, they tend to be reluctant to involve farmers and do so only in a controlled and limited way. Perhaps, by limiting the farmer's role, the researcher feels more secure that results will not be 'spoiled' by mismanagement or factors out of their control, thus leading to 'unacceptable' results.

Researchers also argue that if their technology fails on the farmer's field then this would be a 'demonstration' to farmers of their inadequacies. They prefer to have the technology ready for farmer acceptance, more like a demonstration, before the farmer can 'view' their work. Researchers also may be afraid of exposing farmers to too much uncertainty. With these attitudes, the researcher is missing the point of on-farm research where the client should be intimately involved in the research process.

For example, the researcher and farmer decide to compare broadcasting (farmer's practice) and row planting of beans with the farmer managing treatment application. The researcher explains the trial to the farmer who has had no experience with row planting. The farmer does not plant well and ends up with a poor stand of beans and uneven rows. Of course, the farmer is not impressed with row planting.

There are several solutions to this problem: (1) during the first year the researcher could plant and the farmer watch; (2) the researcher demonstrates the technique more fully, and the farmer copies it. The researcher or technician should be present so they can comment on the farmer's technique; and (3) the researcher reviews the technology with the farmer. By watching the farmer implement row planting, the researcher can anticipate what problems other farmers would have during the extension phase, and can respond by changing how the technique is taught or changing the technique itself. By watching the farmer, the researcher may even learn a better method of performing row planting.

In this example, the farmer was not familiar with the new technology, so more interaction is necessary. If the farmer is more familiar with, for example, variety introductions, or the technology is easy to use, then fewer problems can be anticipated. The researcher should also be aware of the 'learning' curve, in that the second or third attempt is usually implemented better than the first.

Communicating with farmers

Effective communication is the most important part of farmer involvement. If this is not done successfully, then the trial, assessment, and overall farmer-researcher relationship will not yield positive results.

The researcher must try to establish 'neutrality' by adjusting expectations that farmers may have, such as:

1. The researcher will solve problems for them;
2. The researcher will teach a new practice or recommendation;
3. The researcher will penalise farmers for something they say or do;
4. The researchers will reward them in some way; or
5. The researchers will inform government officials about their assets.

Farmers need to know how the information and the opinions they share with the researcher will be used. It is important to talk *with* the farmer, not down to him or her. The researcher must express willingness to learn from the farmer, who would then give important insights and information. The researcher must maintain flexibility and have a sense of humour at all times when dealing with farmers.

Relationships with farmers. Biggs (1989) discusses ways of participating with farmers. Particularly pertinent for on-farm researchers are contract, consultation and collaboration.

A contract-type relationship, most used during exploratory or refinement testing, is one where the researcher hires or borrows land, labour or other services from the farmer. The consultative mode, usually on-going throughout the whole on-farm experiment, is one where researchers consult farmers about their farming system, problems and possible solutions. A collaborative relationship occurs when researchers and farmers are partners in the research process and continually collaborate in activities. This mode is used particularly for verification and farmer-designed trials; however, it can also be used where the trial is researcher managed and where the researcher wants to maintain close rapport.

Figure 36. Improved livestock, an introduced technology, are raised under farmer conditions to understand problems related to adoption.

Figure 39. Farm children threshing harvest of a treatment.

Figure 37. Farmers preparing land for an experiment, Ethiopia.

Figure 38. Farmer plants a variety trial, Ethiopia.

Figure 40. A researcher discusses with a Tanzanian farmer the outcome of a trial on yield loss from bean fly.

Who to talk to. The researcher should communicate with all members of the farmer's family or group involved with the farm's activities and decision-making. The husband may be head of household and the major decision maker, but the wife may do most of the farm work and influence the husband's decisions. Or, the women may make all the decisions and do all the work as well. The researcher should make a point of understanding how family relationships affect farm management. On a broader level, the researcher should understand the communication links within the community and between the community and individual or groups. The researcher should also communicate with neighbours to help forestall any negative social pressures on the cooperating farmer.

Figure 41. To avoid misunderstandings, the researcher should discuss on-farm research with community leaders, such as this headman in West Africa.

Figure 42. A group meeting of neighbouring farmers, Uganda. Such meetings help explain various aspects of on-farm research and clear up misunderstandings.

The researcher needs to be aware of gender issues. In some situations, women, who are important contributors to the production system, may not be open with, or be permitted to talk with, male researchers or extension workers. In this case, female researchers or technicians must assist if full understanding and cooperation are to be achieved.

The farmer may be illiterate, and so cannot use written instructions or write down data. Use of local expressions and units of measure will help facilitate communication, and, if necessary, someone who speaks the local language should be brought along.

The researcher who decides to hold certain management factors constant, must devise, in advance, a way to do this. He/she must communicate to both the farm owner and labourers what is to be done so that the appropriate management can be carried out.

What to discuss. The farmer must understand the *purpose of the trial*. The researcher should discuss the objectives of the trial and farmer assessment each time he/she meets the farmer during implementation. A visit to the research station by a group of collaborating farmers will help them better understand the whole research process. Such a visit is also a useful technique for obtaining farmers' assessment of technology in early stages of testing. The researchers can also arrange for the farmers involved in the trials to visit one another to discuss differences or similarities occurring among treatments throughout the area.

A second major point to discuss is the *nature of the farmer's involvement*. The farmer should understand exactly what must be contributed, particularly for non-experimental variable management, such as land preparation before planting; planting; fertiliser or manure application; and when and how weeding and pest control should be done. If farmer management is not to be used, then the researcher has to consider whether the farmer should be trained to manage the trial according to instructions. Meeting dates should be arranged in advance and/or a method of sending messages to avoid wasting time.

Duration

A policy is needed concerning how long researchers should continue to work with a farmer. The advantages of staying with the same farmer for a number of seasons are communication improves, thus easing operation and so increasing efficiency. Disadvantages are that the farmer's 'new' practices may not reflect a representative situation, it restricts sampling of the variation, and the farmer becomes a 'trained' cooperator. A compromise would be to change after two seasons. Whatever arrangement is chosen, it must be discussed at the onset to avoid disappointment or misunderstandings.

The trial objective and context must be considered. Is the objective to sample variability? If so, it may be better to change cooperators every year. Is the trial concerned with trees or animals, where results will take several years to show? If so, then cooperation must continue longer. Did the farmer appear uncooperative or was he absent for most of the planned meetings? If so, it may be better to change. The situation after each season should be evaluated, and adjustments made to ways of relating to farmers, to choice of farmers and to aspects of experimental management so that researcher-farmer-extension relationships continue improving.

Problems

Compensation. Farmer cooperation should be solicited on the basis of interest rather than payment or expectation of receiving compensation. However, some circumstances arise where compensation may be necessary and in the following cases: large hidden costs such as for entertainment; the technology poses abnormal risks; and large yield losses outside the farmer's control and related to the treatments. Problems may arise when other organisations have set a precedent by compensating cooperative farmers. In this case, researchers may have to find other farmers to work with.

It is inevitable that some technologies will fail, thereby exposing the farmer to loss in yields, time and/or inputs. The researcher has to decide why the treatment failed, such as the farmer's deliberate inaction, the nature of the treatment, or the overall environmental conditions which interacted negatively with the treatment. There should be a policy of action based on the cause and seriousness of the loss. The conditions for which compensation is granted and what sort of compensation is given should be discussed with cooperating farmers before embarking on the trial.

Types of compensation are:

1. Return in yields, considering the amount of actual versus expected.
2. Return in seed or in kind;
3. Return in cash, especially in the case of land rental; and
4. Insurance or credit.

Unwillingness to participate. Farmers may be unwilling to participate because they fear that the experiment will take too much of their time; they may be punished if the trial fails; they had no intention of planting a crop which they consider new or minor; they fear government intervention. In most of these cases, the researcher can overcome the fears through good communication concerning expectations and objectives.

The farmer's rejection may be related to past experiences: when less sensitive researchers demanded too much from them; a bad experience with pesticides; or, other programs supplied everything so that the farmer has high expectations which cannot be met. In these cases, other farmers should be contacted (Gemechu Gedeno, 1986).

It may be difficult to convince the farmer to provide land or labour for a trial of a crop which is new or of minor importance. A strategy must be thought out, in advance, for convincing the farmer of the crop's utility, be it teaching farmers how to use the crop, encouraging more consumption of the crop, or developing markets for the crop.

For example, in some areas of Ethiopia, diets are low in protein. Beans, which are not traditionally grown, do well in these areas, and would offer a solution if farmers could be convinced of their utility and taught how to incorporate them in their diet. Extension or nutrition workers could be sent, in advance, to teach about the use and utility of this new crop. The researchers' task of testing varieties would then be easier.

If farmers are still highly resistant to the idea, it is best to involve them in intensive discussion during the diagnostic phase, educating them in part to their problem if they have not understood it, in order to seek a mutually agreeable solution.

It is important to involve women, especially those who either singly or jointly head households. However, there may be cultural resistance to women becoming involved in the research process. The nature of the resistance must be understood in order to develop a strategy for overcoming it.

Figure 43. Women, who are often the household head and/or the main farm workers, should be involved in discussions concerning on-farm trials.

Incentives, such as a research station visit, a field day with food and drinks or certificates for participating farmers, may improve cooperation.

Extension Involvement

Preconditions for cooperation

Although both research and extension work towards improving the farmer's life, traditionally, they have been separated, both functionally and institutionally. Because activities are performed with the farmer rather than on an isolated research station, on-farm research can provide a forum between research and extension, and so diminishing their traditional divisions. Cooperation will more likely occur if the following preconditions exist:

1. Interdependence between extension and research so to develop appropriate technological alternatives from research and appropriate demonstration methodologies from extension;
2. Agreement on the area and farmers' conditions and problems;
3. Well-trained and committed professionals;
4. The capacity to fulfil agreements, accompanied by a clear definition of responsibilities;
5. Effective linkage mechanisms with the necessary administrative and budgetary support (Ewell, 1989; Kaimowitz et al., 1989).

Extension and researcher attributes

Usually, extension workers provide considerable information because they have good farmer contacts and extensive knowledge about the farming system, particularly if they have worked in the area for many years. Occasionally, however, extension agents do not visit farmers often and have a poor knowledge of the system, particularly if they receive frequent transfers and lack transport.

From the extension worker's point of view, research systems may not adequately deliver pertinent information. Thus, extension workers may not feel confident in research results. On-farm research may help encourage communication.

Extension contributions

A relationship can start during the diagnostic process. The extension agent may be able to guide the researcher towards useful informants or areas and can act, with extra training, as an enumerator for formal surveys. The researcher helps the agent to become more informed about his/her own work area and clients; to become exposed to important, useful concepts not usually expected of extension workers such as economics; to improve farmer contact by using transport provided by research.

Extension workers are also useful in assisting with trial management, such as site selection, design, implementation and monitoring, data collection, evaluation and general follow-up. When the researcher wants to carry out trials at numerous sites and/or when the station is far from the on-farm experiments, making it difficult to implement and monitor trials in a timely fashion, extension agents can be invaluable. The researcher will soon learn that, by involving the extension agent, there will be a much better understanding of the technology and therefore a potentially more thorough demonstration when the time comes.

Figure 44. A farmer's field day when extension workers and farmers can discuss concerns about the trial, Ethiopia.

Figure 45. Extension agents can assist in collecting data or scoring plots, Rwanda.

Figure 46. Extension agents can help collect data on farmers' evaluations of technology, Ethiopia.

Figure 47. Extension agents can demonstrate technology to farmers more effectively if they have been involved in the technology testing process, Rwanda.

Extension involvement has many potential benefits but researchers should be aware of biases which may occur through extension contact and adjust their program accordingly. The farmer may be mistrustful or associate extension with unwanted interference, particularly where the extension agent is involved in other governmental activities. The extension agent may also contact only progressive farmers rather than representative farmers. To impress visitors and researchers of their knowledge, extension may direct 'farmer-managed' trials to such an extent that they do not actually represent farmer management.

Formalising linkages

Whenever possible, research-extension linkages should be formally institutionalised. Personal efforts and contacts can be successful, but, in the long term, there is greater success when the relationship is more formally established, in which the mandates are accommodating, longer lasting, and where there is a planned working schedule.

Appointment of liaison positions can be very useful as long as the appointees are treated as equals. Training extension staff in on-farm research increases the level of understanding and communication, and helps extension workers to be more effective trial assistants, thus minimising researcher supervision. Joint projects can become more efficient in producing results. Other ideas for cooperation include a directory of experiments so that duplication is avoided; joint monitoring tours; joint discussion of research proposals, extension activities and recommendations; and joint workshops on special topics (Ewell, 1989).

Study Questions

For some questions you need to fill in the blanks:

1. List three preconditions for research-extension cooperation:

   a. ____________________

   b. ____________________

   c. ____________________

2. List several ways by which extension agents can be involved in on-farm research:

   a. ____________________

   b. ____________________

   c. ____________________

   d. ____________________

3. Name three management types:

   a. ____________________

   b. ____________________

   c. ____________________

4. When a trial is primarily researcher managed, name three ways in which a farmer can still participate:

   a. ____________________

   b. ____________________

   c. ____________________

5. A ____________________ trial can be jointly managed by the farmer and researcher. Give an example of this: ____________________

   ____

   ____

6. List two advantages and two disadvantages in using complete farmer management when testing technology:

   Advantages: a. ____________________

   b. ____________________

   Disadvantages: a. ____________________

   b. ____________________

7. List seven ways in which farmers can participate in on-farm research:

   a. ______________________________
   b. ______________________________
   c. ______________________________
   d. ______________________________
   e. ______________________________
   f. ______________________________
   g. ______________________________

8. What is a hidden cost? ____

   ____

   ____

The following sentences are either true or false. Indicate by writing T or F:

9. Technology should be well proven before involving the farmer so that it will not fail. ____
10. Farmers are unsophisticated and do not know anything about modern methods so that the researcher must tell them everything. ____
11. People performing the production tasks and making decisions should be involved in discussions concerning the trial, even though they be women. ____

For some questions you need to fill in the blanks:

12. List four ways of compensating the farmer:

    a. ____
    b. ____
    c. ____
    d. ____

13. If the researcher is testing a new crop, how can the farmer be convinced to become involved in the on-farm trial?

    a. ____

       ____

    b. ____

       ____

For answers see p. 111-112.

Part 5

IMPLEMENTING EXPERIMENTS

This chapter covers aspects of implementation that are unique to on-farm experiments. Emphasis is given to trial site and farmer selection, farmer participation, extension involvement, planning and preparation, treatment application and data collection.

Site and Farmer Selection

This section deals with aspects of selecting a farmer and a trial site on the farm. See p. 17-19, for the number of trials and their location within a research area.

Site choice criteria will depend upon the objectives and subject matter of the trial. If the trial is to test alternative weed control measures for beans, then the farmer chosen must grow beans and the site chosen must have a representative weed flora. The key is to choose a representative farmer and a representative trial site.

Once a field site is identified, the farmer should be interviewed once again about the field's history, the specific practices the farmer uses and any yield differences occurring within the field. The problem under investigation should be discussed and the farmer's attitude towards the proposed solutions ascertained. To stimulate discussion with the farmer, the researcher should refer to features on the farm.

Figure 48. A researcher interviews a farmer about a field's history, Ethiopia.

Representativeness

On-farm trials are more meaningful if conducted with representative farmers on representative sites. Criteria for site selection must be developed, based on background and survey data. The sites may be stratified; for example, for a fertility trial, and before setting out the trial, sites representing different soil types or cropping patterns should be chosen. Another criterion is logistics. Constraints of time and finances may force the positioning of trial sites as clusters or located along roads (see p. 18-19). For example, it makes little sense, in a fertility trial, to choose merely the farmers, set up the trial, and then do a soil test after the fact, because the choice of sites may not represent the variability the researcher wants to sample.

A representative farmer should be one of a target population of farmers who have similar circumstances and could use similar recommendations. Specific criteria should be developed, related to the objectives of the trial:

1. Is the farmer male or female?
2. Are the farmer's income level and resources representative?
3. Are the farmer's management practices representative and suitable for the type of trial in mind?
4. Is the farm size typical?
5. Does the farmer work full-time? Is he/she resident on the farm?
6. Is the farmer in a representative ethnic group?
7. Is the farmer interested in participating? Does he/she have confidence and the ability to communicate and be analytical?

The selected farmer should be cooperative and willing to partake in the on-farm experiment, even if it is only to lend or rent some of his/her land. Non-representative farmers can give misleading results and make the extrapolation of results difficult. Variation in the group should be sampled and subgroups designated, provided they are within the target group for the experiment.

A representative field or trial site has similar soils, terrain, previous cropping history to other farms or plots belonging to farmers in the same target group. A trial concerning a crop should be planted in a farmer's field containing the same crop.

Knowing the variability in farmer's management will help site experiments when it is important to sample the 'background' in which the technology will perform. For example, some farmers use fertiliser on their beans and some do not. The trial can be sited by selecting representatives from both management groups. The treatment responses can be grouped according to fertiliser practice for analytical purposes to check for site and/or management interaction with variety performance. Here the test condition is treated as a variable and can interact with test factors. This must be specified in the design.

Specific considerations when choosing a trial site are:

1. *Uniformity*. Such features such as fertility and drainage gradients; pests or weed species distribution; crop and weed residue distribution; erosion or gully formation; presence of trees, stumps or termite mounds; and previous cropping history should be noted. Counter checks can be made by looking at soil texture and colour, slope, stoniness, the previous year's crop, weed growth, erosion marks and by discussing with farmers.

2. *Hazards*. Areas to avoid are those likely to be damaged by wildlife and livestock, such as near major pathways, roadways, pasture lands, and houses or trees; and where a pathway would be created as a short cut. Field edges should also be avoided because they are not representative and encourage outside encroachment.

3. *Accessibility*. An accessible field should be chosen, especially during the rainy season when the farmer's residence may be accessible but the field not.

4. *Size of the available trial area*. A field should be able to accommodate the trial. See p. 77 for areas that are too small.

Figure 49. To investigate the control of the troublesome weed, *Cyperus esculentus*, a sugar cane field is chosen where the weed is uniformly distributed, Mauritius.

Figure 50. This potential on-farm trial location in Rwanda is a good choice because most farmers' fields are steep.

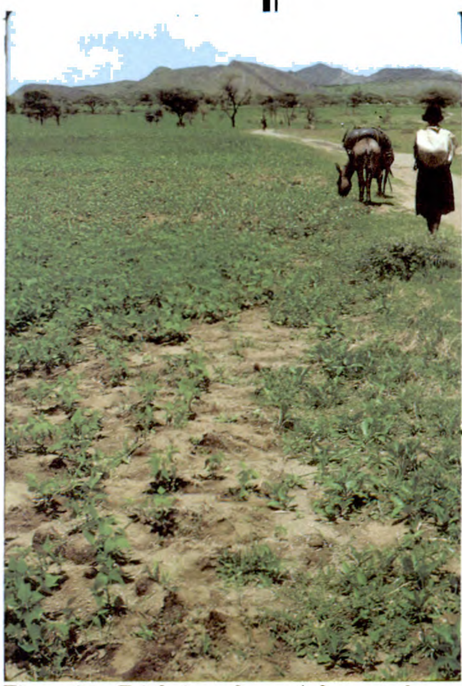


Figure 51. Trial sites along roads are to be avoided because of grazing animals and other hazards.

Figure 52. 'Rugos' (farms) in Burundi are very small, thereby reducing the available area for on-farm trials.

Selection procedures

A suitable procedure must be established to identify sites and farmers. The local situation and attitudes must be well understood before selecting farmers. Selection depends on the objectives: farmers with experience, farmers who will be potential users of the technology, or interest groups.

Researchers may face dilemmas when trying to select farmers in that not all characteristics may correspond with what is desired. For example, representative farmers may not be willing to accept the risk; the location is not convenient, given the logistics available; the farmer may not be skilful in management; or the trial size is too big for the area.

Three types of selection procedures are:

1. *Extension*. The most common procedure is to contact the extension service, who will help the researcher locate sites and farmers. However, they may choose more progressive farmers.
2. *Community leaders*. Another fairly common procedure is to be introduced to farmers through local administrators or village leaders. However, they may choose relatives or people they favour.
3. *Random selection*. Some researchers use a random selection process which may not be as biased as the previous two methods for meeting farmers. However, this may be more time consuming, depending upon how well the researcher knows the area (see 'Multistage sampling techniques' in Anandajayasekeram, 1985).

Biases. There are three major sources of bias: local community bias, research team bias and logistical bias. In the first type, when using extension or community leaders, the researcher should be aware of potential biases, such as being introduced only to the more advanced, and not necessarily 'representative' or resource-poor farmers. This is often the case with extension workers who want to impress researchers and visitors. If extension workers or leaders are male, they may not introduce the researcher to female farmers. Nevertheless, researchers may prefer to work with dynamic farmers for the first year to gain their neighbours' confidence. The researcher must be aware that farmers dislike or mistrust government representatives, an attitude which may hamper cooperation because the farmer sees the researcher as 'one of them'.

Local contacts should be visited a number of times to discuss objectives and explain the reasons for selecting a given farmer and site. Once experienced, the researcher should be able to identify biases, decide how important they are, and whether and how they can be avoided.

Research team bias may include, for example, only male members, limited backgrounds, preferring wealthier farmers for their hospitality or preferring articulate farmers. Logistical bias includes, for example, choosing only those farmers who are easily accessible (Sperling, 1990).

Number of trials to a farmer. A different set of farmers should be chosen for each type of trial (or demonstration) when working in an area. If the same farmer is chosen, he/she may confuse the objectives of the different activities. No more than one trial should be put on a given farm because the objectives of on-farm trials is to expose the technology to variable conditions.

Contacting different types of target groups. Different procedures may be used for contacting farmers for different target groups. For example, resource-poor farmers may best be contacted through a 'farm trek', where farmers are met *en route*. More sophisticated farmers may be selected through community meetings.

Specific steps in farmer selection: First make a selection by using random selection or otherwise as described above. Then either make orientation visits to individuals or have a group meeting to discuss purpose, objectives and requirements. The fields to be used should then be identified and agreements finalised between the people participating in the trial.

Planning and Preparation

Planning a trial

The following points should be considered by the researcher and/or the program's technical assistants:

Checklist of activities and timing. Because of the nature of on-farm experiments, for example, dispersed locations, different managers and data collectors, it is necessary to plan as much of the trial implementation in advance as is possible, for example, to determine the number of visits required per site to carry out the various activities, including preseason planning visits and postseason follow-up visits (Table 3); and to define the tasks, including management aspects and who is to do them. Once these plans are decided, a tentative work plan should be made and distributed to all those involved. If the farmer is literate, he/she should receive a work plan as well; if he/she is not, then the work plan must be communicated clearly.

Table 3. Planning a time schedule for an on-farm trial.

Activity	Timing	Visits (no.)
Discussion and formulation of trial program	3-4 months before season starts	2-3
Explaining the trial program to field staff and farmers	2-3 months before season starts	1-2
Selection of villages	6-8 weeks before season starts	2-3
Selection of farmers and trial sites	5-6 weeks before season starts	2-3
Distribution of materials to field staff and farmers	4-5 weeks before season starts	1
Demarcation of plots	3-4 weeks before season starts	1
Planting	Beginning the season	1-2
Monitoring the trial and farmer assessment	Throughout the season	4-5
Harvesting the trial	End of the season	1-2
Follow-up of farmer's assessment	4-6 weeks after harvest	1-2

Contingency plans. Extra visits may be needed or, if a visit cannot be made, alternative actions to solve unforeseen problems should be decided in advance. For example, What should be done if the rains are late or deficient; if there is a pest attack; if there is a delay in operations; if there are no weeds in a weeding trial? The researcher must decide whether to impose the farmer's level of management to solve the problems or to bring in additional inputs; whether he/she can delegate the responsibility of decision making.

Supplying materials and inputs. After deciding upon treatments and data collection, the necessary equipment, inputs and other materials should be organised and well in advance, particularly inputs that are to be supplied to farmers.

Seed and transplant multiplication for variety, agroforestry and other trials must be planned at least a season in advance, depending upon the multiplication conditions, so that enough seed is available. A germination test may be necessary ahead of time to ensure that viability is not a problem. Seed should be checked for quality and purity. If chemical injury in storage is suspected, seedlings should grow an additional 2 weeks to check for vigour. If cuttings or transplants are used, these must be started well in advance so that they are available at the right stage at planting time. Uniformity (size, quality, vigour) of planting materials is also important, whether for grass splits, tree transplants, potato tubers or seed, if treatments are not to be affected. *Note*: If planting material is not uniform, the last block is usually planted with the poorer stock.

Seed and fertiliser should be packaged in double plastic bags to avoid potential breakage. Inputs, particularly those applied on an area basis, should be measured correctly, and delivered to the farmer on time. Colour-coding and marking packets and corresponding stakes can help avoid confusion and mistakes in application.

The farmer's measurements should be compared with those of the researcher. The farmer may apply higher or lower rates of fertiliser or seeds than the researcher. The researcher must decide which method is to be used and adjust the amount of inputs supplied accordingly. Extra supplies should be carried in case of unforeseen changes in the layout plan or application rates. Fertiliser mixes can be prepared ahead of time in plastic bags and should be well mixed before they are distributed.

Figure 53. Researchers and their assistants prepare inputs for on-farm trials, Ethiopia.

Figure 54. Materials ready for a spacing and fertiliser trial, Tanzania.

Training observers. Extension agents and technicians may be the researcher's 'eyes and ears', so they need to be sensitised to making useful observations and being good communicators. Written skills are important for recording observations. Training may be necessary to develop some of these skills, including an intensive follow-up, particularly in the first year. Many researchers have found it advantageous to have regular meetings with their cooperators to discuss implementation problems, observations and ideas for future work (see Part 6, p. 89).

Farmer training may be necessary if the technology is completely new and the farmers must apply the treatment as the researcher wishes; for example, adjusting a new type of plough or equipment, or banding fertiliser in a way that the plants will benefit and not be damaged (see p. 60-61).

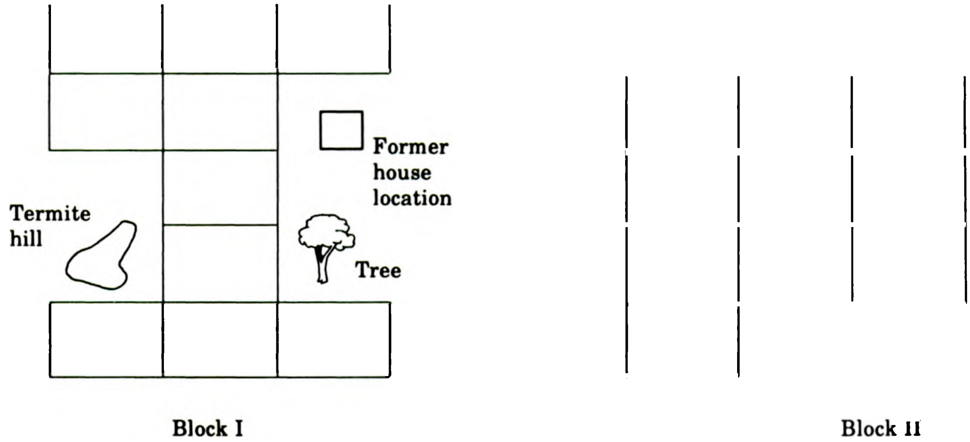
Planning the trial layout

Available area too small. If an area is too small, the researcher can change the design, e.g., use a fractional factorial (see p. 50); or decrease the size by reducing the number of blocks (replications), the number of treatments, the plot size or pathways. If there is a 'farmer's practice' treatment, the researcher can eliminate this within the trial area, and take a representative sample from the surrounding farmer's field. If none of these is feasible, then another site should be sought.

Figure 55. In trial areas that are too small, care must be taken to avoid field edges because of possible competition and shading.

Placement of blocks and plots. Blocks do not necessarily have to be square or rectangular or, for that matter, contiguous. They must each cover an area that is judged to be uniform. For example, for a weed control trial, locate the blocks where there is an even infestation rather than placing them right next to each other where the infestation is uneven. Be prepared to arrange both the blocks and plots on site to fit the field situation, avoiding problem areas such as drainage ditches, trees and large rocks. The blocks and plots may have to fit into a field that is irregular in shape (Diagram 8, A). A rule of thumb is to use 'unfolded blocks' where the gradient is severe (all the plots in a line) and 'folded blocks' when the gradient is less severe (plots in two or three rows). The blocks do not have to be parallel with the sides of the field.

A. Layout around obstacles in an otherwise uniform area



B. Layout where fields are ploughed by oxen

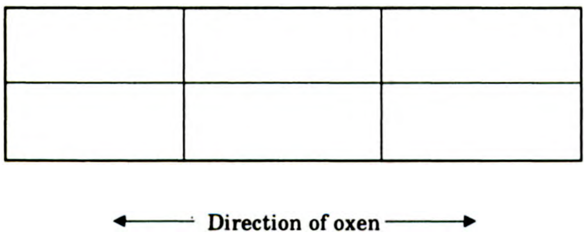
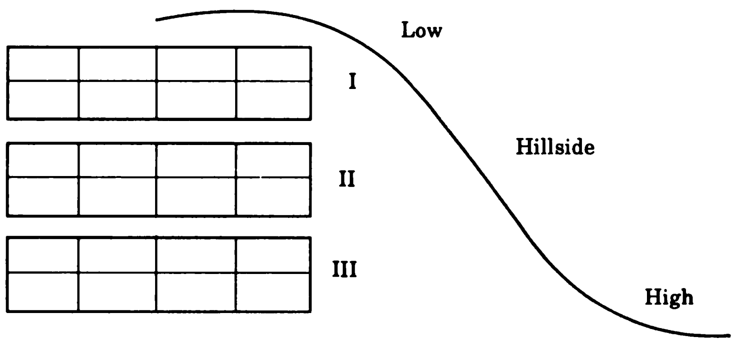


Diagram 8. Plot layout.

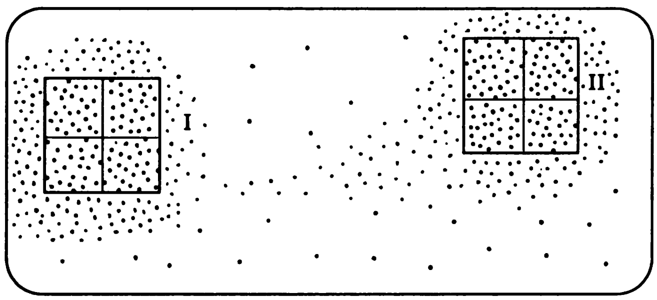
Figure 56. Although a tree is growing in the trial area, it can be avoided by laying out the plots around it.

The plots which make up the block can be located in a non-contiguous fashion, as long as the area chosen is uniform (homogeneous) for the plots assigned to that block (Diagram 9). If strips across the field are used for plots, the researcher has to remember that as the strips become wider, the experimental error increases.

Fertility gradient



Uneven weed infestation



Non-contiguous blocks

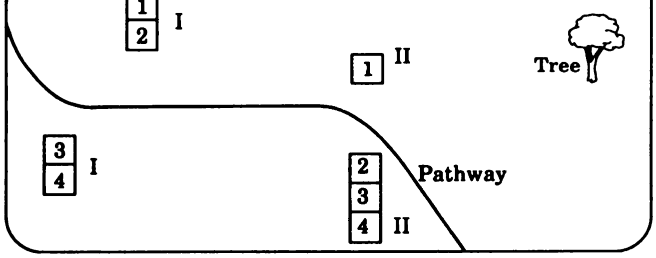


Diagram 9. Arranging trial blocks in the field.

Randomisation. Whenever possible, the plots should be randomised in advance to facilitate the layout and application of treatments. However, if the trial layout has to be readjusted, the plots can be randomised again on the spot. Plots should be randomised differently at each trial site by using different randomisation plans throughout.

Treatment Application

This aspect of on-farm experiment management is challenging because it requires many decisions that will ultimately affect the outcome and interpretation of the trial. The art of involving farmers in the implementation process is to make reasonable decisions on how much supervision is needed versus how much to leave to the farmer. At all times, the original objectives of the trial need to be kept in mind.

Timeliness

It is often difficult, particularly in jointly managed trials, to be present at crucial times. To compare the new technology with farmer's practice, the trial and farmer's field should be planted on the same day. Although the researcher may want to be present during planting, the farmer's schedule may be determined by other priorities and unpredictable rainfall. Because communication is often difficult, the researcher can waste time visiting when the farmer is not ready, or after he/she has already planted. The researcher can do one, or all, of the following:

1. Give the inputs and instructions to the farmer to complete the task, as with a superimposed trial.
2. Organise logistics so that a technician or extension worker living nearby can be in charge.
3. When planting a number of trials within an area, provide a car to carry a group of overseers and drop a few off at each site. A larger number of trials can therefore be handled in a single day.
4. Measure the plot area in advance, so that even if the farmer plants the surrounding area, the trial area is still under the researcher's control.
5. If the type of trial permits, use a superimposed model (treatment applied to an already planted area), e.g., as with pest control or fertiliser application.
6. For simple trials, locate farmers already planting and ask them to participate.

Biases in management

Farmers may adjust their management contributions slightly, spending more or less time than normal when performing a task. Farmer feedback can also over- or underestimate their management time. Nevertheless, it is important to involve farmers and solicit their opinions because there are various ways of identifying and handling such biases; for example,

1. Comparing the trial with adjacent fields;
2. Monitoring the farm frequently, to understand what the farmer normally does compared with what he/she is doing in the trial; and
3. Checking the farmer's subjective reports against results from objective analyses.

Marking and pegging

Although the same techniques for marking plots on the research station can be used, on-farm trials can be much less formal, particularly when laying out a superimposed trial, where a reasonably sized area can be treated and accurate pegging is not usually necessary. When short for time during peak planting, accurate layout techniques may have to be to sacrificed in order to plant a larger number of trials.

A uniform plot size is necessary when the treatment is applied on an area basis, e.g., a standard fertiliser rate is used throughout a fertiliser trial. This is not so crucial for a less sensitive treatment. If the plot size varies, particularly in farmer-implemented trials, the researcher should collect data such as plant density (see Part 6). If possible, a uniform sample area should be taken at harvest.

Figure 57. A research assistant in Ethiopia lays out a fertiliser trial as if on a research station because of the importance of applying a given amount of fertiliser to a given area.

Mapping the trial. If possible, plot stakes should be placed in each corner and the trial area mapped so that it can be relocated again in the following year or when plot stakes are inadvertently removed. One or more stationary reference points, such as a tree, large rock, house or road, are found and measurements recorded from these reference points to the stakes in the trial. Where the crop is very thick and tall, taller plot stakes can be used.

Handling varieties

Seeds should be packaged separately for each variety. The varieties should be discussed with the farmer before planting. In some cases, the seeds of different varieties may look the same. Colour-coding the packets will help minimise confusion. Variety names instead of numbers should be used where possible.

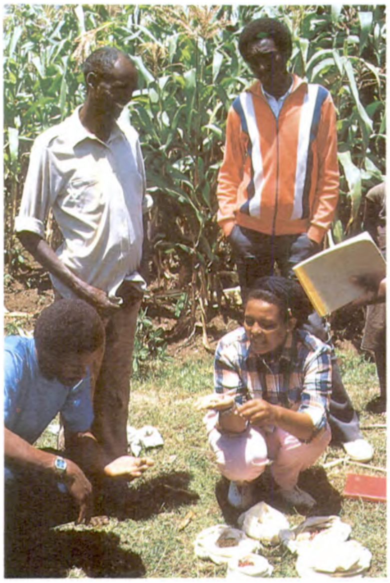


Figure 58. In a variety trial, it is good policy to discuss the varieties with the farmer before planting.

Row-by-row planting. When laying out superimposed trials the researcher should note whether the farmer plants row by row. If so, he/she may need to insert the treatments along the row, following the farmer, so that the test treatment receives

Figure 59. A farmer has used an ox-drawn plough to furrow for a variety-fertiliser trial. The plots will be laid out to follow the ridges.

the same sampling conditions as the farmer's practice. For example, in dry areas, seed is sown immediately into the furrow and covered, to ensure germination.

In the farmer uses oxen to cover seed, plots (rows) should be laid out in the direction to oxen will be moving. This avoids extra turning (Diagram 8, B).

Furrow planting. Farmers may plant in furrows. Plot lines should therefore follow the ridges, with demarcation stakes on ridges rather than in furrows. The rows (i.e., furrows) in each plot should be counted to ensure that each plot has the same number of rows. Plot areas may differ slightly; for example, the farmer may not be accurate in making furrows or the field is irregular in shape and, hence, some furrows are not continuous across the field. To avoid this situation, the researcher must discuss accuracy with the farmer in advance. However, if inaccuracy is unavoidable, this must be taken into account when the rows are counted and the plot area assigned. A correction factor to adjust yields will have to be used (Gomez and Gomez, 1984).

Weeding methods

When weeding is a treatment variable, appropriate labour and tools should be arranged well in advance. If the trial is sizeable and a number of labourers are used for hand weeding, the trial should be monitored. Each block should be weeded by only one farmer or labourer to avoid treatment bias because different weeders have different techniques and standards. Or the same group of people weed block by block if weeding is likely to be interrupted or is too much to finish in one day. The overseer should inspect the plots to ensure that a more or less even treatment has been applied across replications. The weeds removed from each plot should be weighed to indicate the degree of competition in the various plots. This may help give a relative indication of the quality of weeding and so help explain treatment results. If the weed species being removed re-root easily, the pulled roots should be completely removed from the

Figure 60. One method of implementing a weeding trial is to have a group of farmers weed together block by block, Ethiopia.

Figure 61. After weeding, the farmers should be encouraged to assess the work and discuss the various weeds and treatments.

plot area to prevent their reinfesting the plot. The farmers should assess the job, e.g., commenting on the types of weeds they consider to be most troublesome, and on the treatments themselves, e.g., the ease or difficulty of implementation.

Applying fertilisers

Previous field history is very important for locating trials in the research area and within the farmer's field. The farmer's local practice should be known ahead of time so that a management decision and strategic location of the trial can be made in advance.

When the farmer is directly involved in the trial, local measurements for such inputs as fertiliser and manure should be used to avoid confusion. Local measurements can be converted later to researcher's measurements for analytical purposes. However, if two or more types of N, P and K are to be applied as treatments, it is easier to weigh and package them in plastic bags in advance. They should be mixed well just before applying because finer grained components sift through the larger grained components, to settle on the bottom.

The amount of fertiliser that cooperating farmers use may vary, that is, the farmer's local practice may not be uniform because of differences in such factors as field history, soils and ability to purchase the fertiliser. The researcher must decide whether to monitor and record the local practice or to have the farmers standardise the rate to an average level. This choice depends on trial objectives and variability of soil types in the area.

Figure 62. An Ethiopian farmer applies fertiliser near the seed during planting. A measured amount is given per bag for each plot and the farmer has been instructed to apply, as evenly as possible, one bag a plot.

Cultural practices

The types of trials included in this category are varied, for example, tillage; mulching; plant population and planting patterns; cropping patterns; planting times; secondary cultivations, such as ridging; maintenance operations, such as pruning, staking, leaf stripping; and water management. These types of trials are usually more complicated to implement than variety or fertility trials. They require more supervision, and perhaps the farmers or technicians need to be trained in their implementation. System interactions can be expected, particularly in terms of risk, resource use and labour, so it is important to have the farmer involved at an early stage.

Figure 63. A screening trial in Uganda is being planted by farmers under the supervision of the researcher to ensure that the more complicated spacing treatments are applied correctly.

Agroforestry

Agroforestry poses several challenges to on-farm researchers because most trees and shrubs are perennial; time to realise productive output is longer; often there is more than one product; more space and commitment are required from the farmer; considerable changes may have to be made to traditional systems; and it is more complex ecologically (in structure and function) and economically than monocropping systems. Because of their complex nature, agroforestry experiments need extensive planning, often involving a number of people representing different disciplines.

Factors to consider in the design and implementation of agroforestry trials are:

1. Tree arrangements may be difficult to duplicate at various sites, especially in farmer-managed trials;
2. Trees, by having a longer life cycle, impose a higher risk of losses over time;
3. Production is sometimes difficult to synchronise and may vary among sites and seasons;
4. As there may be several final products, such as fuel, mulch and staking material, the researcher has to consider how to measure them and their economic value over time;

5. A relatively large experimental area is needed;
6. Objectives may change over time because of the long-term nature of the experiment;
7. Competition arises and may increase between trees and arable crops over time;
8. Effects on the soil's physical and chemical properties and/or pathogens;
9. Management of tree species.

Rao (1990) suggested using 'core' treatments, which are the same across all sites and to allow other treatments to differ if necessary. Core treatments will give a basis for comparison. He also suggested including contingency plots which are later used for testing the farmer's augmented treatments. By being added later, they can serve as a basis for estimating within-farm error or variation.

Disease and pest control

The interrelationships of the pest's life cycle, farmer practices influencing pest incidence, and past field history must be fully understood when planning the trial. Areas where the pest is present and relatively evenly distributed should be chosen. These issues should be discussed with the farmer well in advance. Trials can become complicated when dealing with cultural control methods such as crop rotation, residue handling, and control of alternate hosts. Similar precautions for cultural practice trials must be taken regarding systems interactions.

Some pests are wide-ranging, thus where farm sizes are small, the pest incidence may be influenced by the neighbouring farmer's practices. If so, the trial may have to include a group of farmers rather than individuals.

If risky practices, such as pesticides, are being tested, the researcher or a well-trained technician should administer the treatment, depending upon the sophistication of the farmer and the potential hazards and toxicity of the pesticides being tested (see p. 41). Local measures, which are understandable and achievable by farmers, should be used.

Order of treatment application

As with station trials, treatments should be applied block by block (i.e., replication by replication), particularly if the trial is large and complicated or if there is a risk of the treatment application being interrupted by such factors as rain, lack of labour and machinery breakdown.

The order in which treatment components are applied should be planned; for example, in a weeding and fertiliser trial, when should the fertiliser be applied, before or after weeding?

Study Questions

For some questions you need to fill in the blanks:

1. Five major considerations when choosing a site are:

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

   e. ______________________________

2. Any method of choosing farmers will give you a __________________ sample.

3. If you were planning a variety trial on beans at 20 sites, with 2 replications at each site, using a seeding rate of 70 kg/ha and a plot size of 10 x 10 m, how much seed would you need for each variety being tested?

   ____

   ____

The following sentences are either true or false. Indicate by writing T or F:

4. Blocks should be placed perpendicular to a gradient. ____
5. Blocks must be rectangular in shape and contiguous. ____
6. Plots within a block do not have to be next to each other as long as the block is uniform where they are located. ____
7. It is important to have the block lines straight, regardless of furrow direction. ____
8. Plots should be randomised differently at each trial site. ____
9. All on-farm trials must be accurately measured and marked. ____

For some questions you need to fill in the blanks:

10. How can a researcher relocate the trial if all the stakes were removed?

    ____

    ____

    ____

11. Name four ways in which researchers can manage a trial if they cannot be there at crucial times:

    a. ____

    b. ____

    c. ____

    d. ____

12. Name two ways in which a researcher can identify and handle management biases:

    a. ______________________________

    b. ______________________________

13. List three important points to remember when implementing a weeding treatment:

    a. ______________________________

    b. ______________________________

    c. ______________________________

14. Researchers should use ______________ measurements to ensure farmer understanding, but later convert them to ______________ measurements.

15. Why is it advisable to have farmers involved at an early stage for cultural practice trials? ______________________________

    ____

    ____

    ____

16. How do agroforestry trials differ from other crop experiments?

    a. ______________________________

    b. ______________________________

    c. ______________________________

17. If pests are wide-ranging, how should the location of trials be handled?

    ____

    ____

    ____

    ____

For answers see p. 112-113.

Part 6

DATA COLLECTION

Data collection for on-farm experiments is more comprehensive than that for on-station experiments. Much more information is needed about the varied environments, management practices (including labour inputs), economics and farmer's decision-making processes. It is only within this context that the final interpretation of the experimental results can be made.

Data collection is a continuous process: the gathering of information on the farming system and specific farming practices starts during the diagnosis; continues with observations and discussions with the farmer during the planning stage; and during experimentation with further farmer assessment and collection of experimental data, and ends with general observations and postharvest assessments.

Data Organisation

A well-designed, easy-to-use field notebook is essential. It must be well-laid out with extra space left to allow for unforeseen but important entries.

A standard format includes the title of the experiment, followed by a clear statement of the objectives and an organised way of recording a selection of information previously mentioned. In addition, it is useful to design periodic visit sheets where observations concerning the trial, farmer's activities and hazards can be recorded. Notes should be taken in an abbreviated but understandable form to save time during interviewing. Box 2 shows a trial instruction sheet for field staff.

Field workers may need training in how to use the field notebook so that the researcher, if unable to be present on all occasions, can be confident that the job will be well done. The people collecting the data should be supplied with the necessary tools, such as balances, writing materials and measuring devices. The field workers' performance during the season should be monitored to ensure that the work is done on time and properly. A schedule for data collection should be set up ahead of time.

Data should be directly recorded into the field notebooks as, obviously, data loss and errors occur if data have to be recopied, or if bits of paper are misplaced and observations forgotten.

Any new aspects of management must be recorded in the field notebook to adequately interpret trial results, particularly if an important interaction occurs among the treatments. If the farmer changes the management pattern on his/her own, the changes should be monitored, as these may indicate resource conflicts that may be important for interpreting the acceptability of the technology, or merely an adjustment of the technology to farmers' conditions.

Box 2. A trial instruction sheet for field staff.

Intercropping maize and beans: Verification trial

Objectives

1. Compare effects of improved planting pattern with and without improved bean variety.
2. Examine returns to labour and systems interactions with changed planting patterns.
3. Compare traditional and improved bean varieties in both planting systems.

Treatments

1. Local maize, local beans, farmer's planting pattern.
2. Local maize, improved bean variety, farmer's planting pattern.
3. Local maize, local beans, improved planting pattern.
4. Local maize, improved bean variety, improved planting pattern.

Site selection

Farmer qualification: intercrops maize and beans.

Agro-ecological zones:

a. altitude 900-1200 m, rainfall 850 mm.
b. altitude 1200-1500 m, rainfall 1100 mm.

Choose 20 farmers in each agro-ecological zone.

Maize variety: in each agro-ecological zone, a maize variety with the same maturity time.

Instructions

1. Give each farmer 2 packets of improved bean seed.
2. Plant maize first, using farmer's practice.
3. After maize has emerged, mark plot areas, choosing, with the farmer, a uniform maize stand in such a way that markers are not disturbed by first weeding. Plot size = 8 x 10 m.
4. After first maize weeding, instruct farmer to plant beans: 2 plots with farmer's planting method (broadcast), i.e., 1 with farmer's variety and 1 with the improved variety; and 2 plots planted with new planting method, i.e., 1 with farmer's variety and 1 with new variety.

   New planting pattern ('x' for maize and 'o' for beans):

   ```
   x o o x o o x o o x o o x o o x o o x o o x o o x
   x     x     x     x     x     x     x     x     x
   x o o x o o x o o x o o x o o x o o x o o x o o x
   ```

5. Instruct farmer to keep track of his/her labour for planting but try to be present when bean planting takes place. Explain that new variety is a semi-climbing type and needs to be planted next to maize in maize row, every other row.

6. Data to take (refer to field notebook) in relation to treatment application:

   a. maize stand counts and spacings at bean planting time; average maize size;
   b. soil condition (wetness, friability, overall suitability for planting, weed infestation) at bean planting time;
   c. describe farmer's methods of planting both patterns;
   d. labour requirement for both planting methods;
   e. normal monitoring and harvest data;
   f. name and take small sample of local varieties of maize and beans;
   g. planting data;
   h. farmer's comments about planting methods and new variety;

7. Visit each farmer once every 2 weeks for monitoring.

Types of Data

General

The usual tendency is to collect too much data, which is time consuming and often irrelevant. However, if data are too scarce, crucial information may be left out, making the interpretation of trial results difficult. By referring to the experiment's objectives and methods of analysis, and imagining how the data collected will be used, a better coverage will be obtained. The researcher should ask questions such as: Is it relevant? Will it help interpret the results? It is not enough merely to say that one treatment was significantly better than another, but the reasons and conditions present must be understood to explain the performance. Supportive data are therefore necessary. The more experience a researcher has, the more easily he/she can make these decisions. The following list of items serves as guide, and the researcher must use his/her discretion to choose the important items.

1. *General trial information*. Data would include title; trial and management type; design; number of blocks; plot measurements and path locations; treatment list; a detailed map of the site's layout, including location, specific markers and their distance to the plots; slope indicated by arrow with percentage estimate; illustrated fertility differences, trees or other noticeable inclusions; the names of the place, cooperating farmer(s) and extension agents; and farmer's income rating (low, medium or high).

2. *Materials and methods selection*. The researcher should detail methods of trial management and crops used. Data on trial management would chronologically present land preparation, planting, seeding rate, fertiliser rate and type and method, replanting, weeding and pest control. Data on crops should include seed sources, varieties and detailed descriptions of local materials used.

Figure 64. An Ethiopian farmer has planted a new variety in his field. By measuring the area that was planted and by weighing the remaining seed in the bag, researchers can determine the seeding rate the farmer used.

Information on site characteristics and performance aspects is very useful in interpreting experiments that are performed at a number of sites. It also helps the researcher to explain interactions between site factors and treatment performance by using yield function analysis to understand variability.

3. *Environmental information*. Such data would include soils (type, fertility, texture, drainage, pH, organic matter content and conservation structures); rainfall, both historical and collected on site, its periodicity and duration; diseases and pests; temperatures; altitudes; slopes; and if mountainous, the direction in which the field is exposed to the elements.

4. *Management factors*. Records and descriptions are obtained of field history in advance of trial establishment. They should include details on the previous crop and its management, residue handling, manure or fertiliser placement and previous weeding regimes. Data on present season's operations, including methods and timings, would comprise land preparation, thinning, mulching, planting and seeding rates and spacings; water management; power sources; and labour.

5. *Performance aspects*. Stand counts. Information should include normal as well as barren, stunted or small plants; germination dates and percentages; and losses from pests or other factors and whether potentially related to the treatments.

Figure 65. A rain gauge is useful for collecting site-specific rainfall data in on-farm trials.

Figure 66. Researchers take notes on differences found in plant vigour in this on-farm fertiliser verification trial in Ethiopia.

6. *Harvest data*. These data must be related to a harvest area and can indicate yield, yield components (harvest index), number of plants, and percentage of moisture.

7. *Periodic observations* are made to rate the performance of each treatment, including growth stages; to note plant densities and any effects after treatment or management application; to check plant colour (related to disease, fertility, drought or treatment injury); to check for pests, diseases or weeds; and to note any problems or unusual occurrences. During these periodic visits, farmer assessments should be obtained. The date and weather should always be noted.

8. *Socio-economic aspects*. Data should be obtained on farmers' opinions and experiences of the treatment application and performance (see p. 97-104); prices of produce; costs of inputs, including labour for particular jobs at particular times during the year; decision and management behaviour; and system interactions (changes in management of other enterprises resulting from introduced technology).

Figure 67. Selling bean varieties in a Ugandan market. A small marketing survey can help researchers understand the relative value of different varieties.

Harvest data

Various points to consider include:

1. At least two yield samples should be taken from the farmer's field for comparison purposes. This can help identify trial management biases.
2. Harvest should be carried out block by block.
3. Adjustments should be made for significant grain moisture differences.
4. When treatments affect maturity, the handling of sequential ripening should be considered, e.g., Should each plot be harvested when it reaches the same maturity? The harvest date should be noted.
5. For the farmer's benefit, harvest measurements should be translated into local terms.
6. The researcher should be aware that the extrapolation of small-plot yields to a hectare basis will usually overestimate yields.
7. The size of the harvest area should always be indicated on the data sheets.

Although farmers can be instructed on harvesting, the researcher, trained technician or extension worker should be present to prevent mistakes. For example, the farmer may want to use the vegetative portion of the plant for animal feed, erosion control or other purpose before the researcher can measure it. Both farmer and researcher should agree in advance on a harvest method. Various ways of handling harvesting are:

1. Threshing and weighing the harvest on the spot;
2. Bagging the harvest, taking it to the research station for measuring and then returning it to the farmer;
3. Using subsamples to handle the bulk of the harvest, taking the smaller representative samples back to the station for specific measurements, and extrapolating what the total yield would be. If this method is used, several subsamples should be tested first to see how much a subsample over- or underestimates plot yield.

Figure 68. A researcher weighs the harvest from various treatments and will put it into the farmer's container so that she can see the difference in her own terms, Rwanda.

Figure 69. The harvest area has been indicated by string to assist the farmers in eliminating border areas, Tanzania.

Weeding data

A simple, subjective rating scale or weed weights can be used to substantiate or explain results and indicate variability in infestation. Before implementing weeding treatments, the uniformity (or variability) of the infestation within the experimental area should be compared with the surrounding area. Reasons for variable infestation should be found, e.g., Does it result from fertility differences, variety or crop growth habits (competitiveness), land preparation or sowing differences, differences in crop densities, field history? The infestation levels will determine the amount of weed competition in each treatment, as well as the amount of labour and success of removal treatments.

Weed species present should be identified because they have varying abilities to compete and varying difficulty in removal. For example, grasses spreading by rhizomes are difficult to remove. Annual broad-leaved plants, such as *Amaranthus* sp., are relatively easy to remove, as long as they are removed early. Some weeds emerge once during the growing season, while others emerge each time there is soil disturbance or rainfall. Some species take root again easily. Therefore, understanding the biological nature of the weed species helps interpret the final treatment effects. Farmers also help by pointing out why certain weeds are particularly problematic.

Weeding efficiency can be estimated by comparing the percentage of weeds removed with the total amount of weeds present. A subjective scoring system can be used or a subsample of 1 m^2 weighed. There will be differences in calculation, depending upon how the weeds are removed, e.g., pulled, cut or cultivated by hoe or cultivator. The researcher can record the time it takes to weed either a measured area (a subsampling method) *or* the whole plot area.

Agroforestry data

The researcher must determine at what stage to take measurements for the various products, such as mulch, fuel and staking materials. Such factors as harvest dates, growth measurements, and pest infestations must be considered. Special tools may need to be designed or procured for fast and accurate measuring. Necessary economic data, including farmer assessment, should be collected throughout.

Counting plants to make plant population adjustments

A quadrat can be used to count plants; the quadrat size is determined by crop size and density. However, if the crop is row planted, a faster method would be to measure the width of the trial, count the number of rows, divide the number of rows by the trial area and multiply by 10,000 to calculate the number of rows per hectare. To estimate the number of plants per hectare, obtain the average number of plants in a trial row from a sample of 3 to 6 rows and multiply by the number of rows/ha in the trial. If the subsample shows that plant spacing is variable, then use quadrat counts.

In a plant population trial, data should be collected on how management factors, such as weeding, and environmental conditions affect the stand.

Looking for and explaining the unexpected

Occasionally, results are not related to the original trial objectives. These should be noted. For example, a weeding trial was conducted where different weed control treatments were imposed on the farmer's field. When making observations, the researchers noted that the farmers who ploughed 2 to 3 times had no weeds, whereas the farmers who ploughed only once had numerous weeds. Although the number of ploughings was not part of the objectives or in the treatment plan, it appeared to be a suitable weed control option to be confirmed by further experimentation.

A second example was in a fertility trial where farmers commented that the researcher's variety required more fertiliser than their own local variety to attain the same yields. Although the objective of the trial was to look at fertiliser response, the interaction reported by the farmer could not be ignored.

In a third trial, researchers noted that the recommended seeding rates gave the lowest yields. When asked, farmers explained that the seeds had not been planted deep enough for their field conditions, thus causing poor germination. Greater farmer involvement would have avoided this.

Labour Data

The major reasons for measuring labour inputs are:

1. For estimating labour costs to compare treatments; and
2. To help identify positive or negative system interactions concerning labour patterns.

Measuring labour data can be very time consuming and costly, involving numerous visits to the farmer. The decision to measure labour may, therefore, depend upon the relative importance of the task; the need to use the information for analysis; whether the estimate is for a new or traditionally performed task; and the adequacy of estimates from other trials or interviews.

If the task is new, labour data collection will probably have to be done on site, whereas if it is a normally performed task, interview estimates may suffice. The method chosen for estimation also depends upon the variability of the task across farmers (sites) and years, e.g., the estimate for threshing time per unit of harvest for a given crop is usually fairly constant so that previous estimates can be used, provided the threshing method is the same. If plot sizes are too small, a reasonable labour estimate will not be made.

Labour estimates from interviews

The researcher should collect labour estimates by interviewing farmers him/herself rather than relying on enumerators. The researcher should not randomly select farmers for interview, but choose a selective sample with definite criteria in mind, e.g., farmers who are representative and perform the task in an average manner. The time estimate for task completion should always be related to the number of people performing the task and the area covered. Because the farmer may use local time to tell when a task was completed, such as two days before the last market day, data should be collected during or just after the task has been completed. The greater the variation in answers, the greater the number of farmers who should be interviewed to obtain an adequate estimate of average. Usually a large sample is not needed.

Questions should be meaningful to the farmer. By understanding how a task is accomplished, the researcher will obtain better information on that task from the farmer. Some sample questions follow:

1. How long does it usually take to harvest (or perform any particular task) a certain area and with how many people? How long is the working day? At what times does it start and finish? Were all workers present during the entire task? (*Note*: The farmer may use local measures for land.)
2. Or, How long did the farmer take to harvest (or perform another task) on a particular field (having an estimate of the field size)?
3. If labourers are hired, how much are they paid for a given operation? Do men, women and children receive different amounts?

Labour estimates from on-farm trials

Getting an *accurate* estimate of labour from on-farm trials is difficult because the situation is 'simulated', with small plots. Nevertheless, labour estimates are *relative*; for example, the researcher can report that a certain weeding treatment took three times as long as the traditional practice to complete.

Estimates will be biased if station, hired daily labour, or even farmer labour is used. They may work faster or slower than is normal. A method to calculate labour estimates in on-farm trials is to use estimates from surveys of the traditional practice. Then, for estimating the labour for treatments, a percentage change in the new treatment can be compared with the traditional treatment. For example, for the new treatment, the estimated farmer labour is multiplied by the percentage increase of labour in the new treatment over the traditional treatment:

Where: Traditional practice = 22 man-days/ha

Percentage change = 81% or 17.82 days more/ha

New practice = 22 man-days/ha + 17.82 = 40 man-days/ha

With a wage of 10 East African shillings per day, the extra cost of weeding the new practice was 40 man-days/ha - 22 man-days/ha = 18 days x 10 shillings/day = 180 shillings/ha (S. Franzel, 1989, personal communication).

Farmers' Assessment of Technology

As mentioned on p. 59-66, an important way of involving farmers in research is to encourage their assessment of the treatments. If the farmers cannot detect any differences between treatments, they will most probably be reluctant to change their practices. With input from social scientists and economists, researchers are becoming more adept at soliciting farmer opinion and including this factor in their evaluations. Farmer assessment should be done every time the researcher visits the farmer, not just at the end of the season.

Why use farmers to evaluate?

1. To identify their criteria and priorities, which may differ from those of researchers;
2. To understand farmers' practical knowledge;
3. To understand farmers' decision-making processes;
4. To involve 'users' in decisions on recommendations;
5. To identify technology that farmers may want to test in future trials, and why;
6. To help put new technology into context; and
7. To understand farmers' expectations (Sperling, 1990).

Evaluations should be used to compare alternatives; to validate developed technology; and to encourage early development of technology.

Several techniques can be used: an open-ended evaluation where free expression is invited. This is used where qualitative insights and ideas about farmer reasoning are needed. Structured evaluations such as questionnaires, preference rating and focused group interviews are used when criteria are known already but the researcher wants to quantify opinions (Sperling, 1990).

When taking notes or collecting data, inconsistencies, unanswered questions, insights into concepts and methods should be noted.

General information to include

1. Differences in the performance of treatments at key times throughout the season, e.g., after emergence and after weeding.
2. Differences in performance between experimental treatments and farmer's practice.
3. Causes of problems, such as pest infestation or low population densities.
4. Interactions, e.g., if a fertility x variety test was done, how do responses to the fertiliser differ between local and introduced varieties?
5. Timing and ease of treatment application.
6. Harvest and postharvest criteria, e.g., How well does the variety store? What is the cooking time? Is the taste satisfactory?
7. Timing of the harvest for marketing or consumption.
8. Did the technology interact negatively or positively with resource use (e.g., inputs, labour and time) or other production activities?
9. Modifications that farmers made to treatments, their reasons, and outcome.
10. Farmers' observations on environmental factors, peculiar to their situation, which interacted positively or negatively with the treatment(s).
11. Farmers' opinions and understanding of the problem, proposed solutions, and the trial itself.

Figure 70. Postharvest data collection may uncover previously unknown information. For example, this Ethiopian farmer likes to harvest dry beans when they are immature.

12. Necessary steps to take if farmers are to adopt. Are conditions conducive or not, and why? Does the farmer see long-term benefits, such as marketing, erosion control and soil fertility maintenance, even though short-term benefits are not apparent?
13. What returns does the farmer associate with different treatments, compared with other activities?
14. What risks does the farmer perceive as related to the treatments and how serious are they?

A checklist of specific data to collect on a variety's characteristics would include the following (S. Franzel, 1990, personal communication):

Stand, germination and vigour
Ease of weeding
Yields
Ease of threshing
Cooking time
Appearance and size of seed
Handling seed
Residue palatability for animals
Where it grows best
Sensitivity to fertility
Storability, with or without chemicals
Susceptibility to weeds
Tolerance of pests
Shattering
Taste
Ease of preparation
Marketability and profitability
How seed was used
Seed colour
Drought or frost resistance
Maturity length

Organising assessment sessions

The two major assessment tools are (1) open-ended questions, which promote free expression and are used to collect qualitative information; and (2) structured questions, which include preference ratings, questionnaires and focused group interviews and are used to collect and analyse quantitative data. A combination of the two tools can also be used.

Based on the two tools, assessment sessions can be structured according to the objectives and information needed.

Individual farmer assessments are common and easy to organise. They have the advantage that answers are not biased or affected by group opinion. Individual assessments can be compared to determine variability, its causes and clustering. The analysis of the performance across site subgroups (by management practices, agro-ecological zones, yield level of the site) can help determine why yield or other differences occurred.

Group interviews can be organised, using a field day-type situation. Farmers can jointly look at the technology and be asked either separately and/or jointly for their opinions. Group discussion can help uncover reasons for disagreement or consensus. Farmers can visit several sites, which were chosen, for example, for different types of performance. Farmers can also be brought to the research station for assessment of on-station trials, which may help researchers understand farmers' criteria early in the research process. Farmers can also help select technology entering on-farm trials in which they will participate, e.g., varieties or components of intercropping.

Figure 71. This Rwandan farmer is assessing bean varieties in their vegetative stage in an on-station variety trial.

Figure 72. Technology can be assessed by interviewing a group of farmers who cooperated in the respective trial.

Figure 73. Farmers, who are considered by their peers to be bean seed experts, have been invited to the research station to help assess varieties during the screening stage, before release to on-farm trials. Researchers expect to learn what characteristics farmers wish to see in their bean varieties, and accordingly adjust selection criteria in the early stages of research, Rwanda.

On collective farms, where labour is organised so that no one farmer is involved in the whole production process, it may be difficult to get an accurate treatment assessment. The users of the end-products may not be the farmers themselves, who then become indirect beneficiaries through wage payments, unless they are paid in the produce in accordance with the labour they put in. The researcher must therefore clearly understand such components as inputs, products and users, to appreciate user assessment. Different groups may need to be interviewed for different contributions, for example, collective managers, or the labourers involved in implementing the treatments.

Timing of assessments

Farmer assessments can form part of the routine monitoring exercise throughout the season, concentrating on questions pertinent to the timing of the visit and stage of the trial. For example, after emergence, plant stands among varieties can be compared; or, after weeding, the ease or difficulty of performing different treatments or of removing different types of weeds can be compared; or pest attacks can be discussed.

Furthermore, not only should farmer opinion be assessed during the trial, but the researcher should also return the following year to see if the farmers or their neighbours are using the technology. The percentage of area under the new practice should be determined, together with the percentage of farmers adopting. Any modifications made by farmers to the technology should be examined.

Soliciting assessment through interviews

This open-ended evaluation is conducted by following a relatively unstructured method of eliciting information from the farmer. Box 3 provides an example of a check-list of questions for an interview on a wheel-hoe.

Box 3. A checklist for an open-ended farmer assessment of a wheel-hoe cultivator.

1. General information and how used?
   Useful?
   If useful, under what conditions?
   Any suggested modifications?
   Used by self? If so, how many times? On what sized area? What work hours per area?

2. Effectiveness was determined by (give farmer's opinion in detail):
   Soil type
   Weed density and height
   Seed-bed quality
   Crop
   Other (farmer's suggestions)

3. Compare traditional weeding practice and wheel-hoe for (give farmer's opinion):
   Speed
   Efficiency in removal
   Energy required
   Usability by women and children
   Effect on moisture conservation
   Effect on rainfall percolation
   Other

4. Modifications to examine:
   Angle of handle
   Width of blade
   Angle of blade
   Handle grasp
   Length of axle
   Other

SOURCE: S. Franzel and Tilahun, 1988, personal communication.

The following conversation gives an example of a farmer commenting on climbing bean varieties:

1. Let's begin with variety 4, which I like a lot. I like to come here often too. Sometimes I come when it rains, or when it is very sunny, and do you know something, this variety never has any problems. It is always the same, especially when it rains.

2. You can see that this variety flowered evenly and rapidly. I think that with a little more fertiliser it would even be quicker. Once I tried to apply Nitrofoska to some cassava I planted in that spot down there, but it didn't do any good.

3. Now this other variety doesn't do well at all. What I mean is that it doesn't produce much. It gets a lot of pods, but they're empty. I think that that is because the soil is no good. That's why I don't like it. It's large, red and round. It gets the best price. If I had enough money, I would plant 3 ha of my best land to this one, and I would wake up rich, don't you think?

4. I don't know about this variety. My neighbour says that it's cash in the hand, that it's the best one for selling dry and that it's good eating, but I find that it climbs a bit too high. You know, staking material isn't cheap these days: a bundle might cost 1 birr[1] here and the same bundle 3 birr there. And the longer the stake, the more costly.

5. Let's see here. Ah! My neighbour said that when he planted this variety, it was the one he liked best because it had a lot of pods. I didn't find it that way; but, on the other hand, you see, these plants are much more healthy even though they got a lot of water. My husband thinks that I offer a special prayer to God so that only a little water falls on them. They don't fall over. And the grain is such a nice colour although its size is not quite as big as I would like. It's nice and round and it's the right shade of red that is very popular. This is really a great variety!

6. About climbers? Well, from the point of view of yield, climbers definitely do better than bush types; and the taste too—it's nicer. But if you compare all that work, I would say that bush are the better deal.

To summarise the feedback given in the interview, the farmers say that:

1. The variety stays the same, whether it rains or shines (i.e., the variety is resistant to diseases and possibly to drought);
2. The variety flowers evenly and rapidly (i.e., early maturing);
3. Yields are poor; most pods are empty (i.e., poor pod-filling and low yields);
4. The plant climbs too high (too vigorous) and stake material is expensive: 1 birr here and same bundle 3 elsewhere; longer stakes more costly (i.e., stake costs are a possible constraint to using climbers);
5. Healthy plants (i.e., resistant to diseases); do not fall over (i.e., strong stems); grain pretty, although not as big, and round and red (grain size, shape and colour); and
6. For yield and taste, climbers are preferable; but for work, bush beans are a better deal (labour productivity for climbers is lower) (Sperling, 1990).

Soliciting assessment through questionnaires, ranking sessions or group interviews

Generally, there are three major steps to follow: first, to list the treatments; second, to develop ranking criteria; and, third, to evaluate the treatments by using the criteria. A work sheet for recording the results should be designed with extra space left for unforeseen comments or new criteria that may be added by farmers. The researcher or data collector must also have room to add their own comments. A list of questions, similar to that used as guideline in an informal survey, can also be included. This work sheet will help the researcher have data which support the statements that farmers make on the treatments. These responses can be analysed.

Criteria must first be developed by soliciting the farmers' own criteria through informal interviews. The farmers can rank or prioritise the criteria themselves so that the relative importance of each criterion is understood, perhaps separating them into groups of high, medium and least importance. If several farmers are being

1. birr, Ethiopian currency: 1 birr = US$0.50, 1991.

interviewed, then ranking can be performed by using the frequency with which criteria are mentioned. All people involved in the trial should be included, such as labourers, wives, husbands and decision makers.

A rating scale or system must be established to judge the technology. Each criterion is rated, e.g., excellent, good, moderate and poor. Wherever possible, the farmer's terminology should be used, but this requires understanding of the nuances of their rating system.

Once a tentative list of criteria is agreed upon, *the treatments should be ranked.* For some criteria, only certain characteristics may be listed, such as seed colour. The farmers can then be asked to rank their preferences for seed colour among different varieties. A grid can be developed and filled in, e.g., by ranking each variety for each criterion (Sperling, 1988) (Table 4).

Another ranking method is to use cards, seeds of the varieties, or plants representing treatments. The farmer can arrange them in order from best to worst, and, if the treatments have the same ranking, stack them together. A second step is to place a number of stones, sticks, or coins next to each pile to indicate the relative degree of difference or preference (e.g., consumption characteristics). The researcher can then construct a grid to reflect the farmer's answers (Table 4).

Table 4. Variety ranking[a] by farmers.

Variety name	Criteria						
	Yields	No shattering	Taste	Maturity time short	Colour	Large seed	Pest tolerance
Rose Koko	1	1	2	3	1	1	4
Canadian Wonder	1	1	3	4	1	1	3
Bako 142	3	2	1	3	2	4	1
Mwezi Moja	4	1	1	1	2	3	2

a. Ranking: 1 = excellent; 2 = good; 3 = moderately good; 4 = not good.

Figure 74. Farmers assess various bean varieties by placing an appropriate number of coins to indicate the relative ranking, Tanzania.

The researcher has to know how to interpret the results; for example, Mwezi Moja is fast maturing, moderately tolerant of pests but has a small seed size. This variety may be acceptable to some farmers, particularly if they are interested in a quick food source and pest tolerance; however, if the farmer wants a bean that is acceptable for marketing, with large seeds and a good colour, then Rose Koko would be a better choice.

A system must be devised whereby the *degree of relative differences or preferences can be determined*. For example, a particular variety is ranked as having excellent yields and the next variety as having good yields. The relative difference may mean that the excellent yielder is three times better than the local variety or, perhaps, is only slightly better. It would be easier to choose the best and worst first.

When assessing varieties, farmers may have a difficult time distinguishing varieties that are similar in appearance or growth habit in the field. For example, if merely shown the variety name with a seed sample beside it during a trial that tests only white-seeded pea-bean types, the farmer will not be able to easily or honestly assess the differences. It is therefore useful to either conduct the assessment earlier, when the beans are formed on the plant but before senescence, or to include a sample of the vegetative plant with the seed. The varieties can be marked with colour-coded stakes throughout the growing season, thus helping the farmer to distinguish the different varieties.

Cooking and taste assessment

In areas where people care about the taste of varieties, where there are fuel shortages, or monetary and time limits, the cooking characteristics of different varieties should be assessed. In some cases, laboratory tests can be done; however, it is wise to involve the farmers and use their normal preparation conditions and methods. Allow adequate time for the activity; if rushed, a false assessment may be produced. Farmers may be unwilling to donate seed for this purpose, in which case researchers can either provide the seed or use seed from border rows. The farmers must be able to differentiate between varieties which are similar in appearance.

Figure 75. A tasting evaluation has been organised for farmers to assess five varieties that they grew in on-farm trials, Ethiopia.

Data Collection Problems

Biases

Biases may occur when collecting data, making observations, collecting farmer impressions and in the actual management of the experiment (see p. 80-81).

Although communication with farmers and field assistants is thought to be adequate, misunderstandings can occur, or farmers or research assistants report findings they feel the researcher wants rather than the actual facts. Usually these misunderstandings are minimised once the researcher and field assistants are more experienced. Subjective impressions can be compared with objective evaluations to check if the impressions farmers or field assistants report are accurate. If biased information is collected, the researcher may have to increase the sample size to get a more realistic balance.

Timing

It is often difficult to make timely observations and monitoring visits. The researcher must determine whether observations should be made at 'days after planting' or at a certain 'crop stage'. Farmers may carry out the same operation at different times, making it more difficult to plan monitoring and to correlate activity with results. The researcher may have to record data on a field-by-field basis, noting differences between different situations. If the area is new, monitoring may need to be more frequent.

Timing also depends upon trial objectives, type of data being collected, and timing of collection (such as before or after treatment application). For example, weed rating scores should be taken before the weeding treatment is implemented so that the researcher can interpret the amount of competition encountered by the crop up to that point. Then subsequent weed rating scores may need to be taken at intervals after treatment to ascertain the durability or success of the treatment.

Making estimations

Estimating distances and areas, quantities of inputs, and time to do an operation may be difficult. To facilitate communication with the farmer, local measurements should be used whenever possible and translated into scientific measurements. A scale can be taken to the field for accurate conversion. When working with a number of farmers, the researcher should check that they all use the same local measurements.

Both researcher and field assistants should train themselves to estimate areas by using paces (the approximate size of each pace should be known) in order to check farmers' estimates.

Study Questions

1. Three general types of data are more important in on-farm research than in on-station research. They are:

   a. ______________________

   b. ______________________

   c. ______________________

The following sentences are either true or false. Indicate by writing T or F:

2. Replications should be applied one at a time for large trials in case implementation is interrupted before it is finished. ____
3. Data should be recopied into field notebooks so the presentation is neat and clean. ____
4. All weed species are equally competitive so they do not have to be noted. ____
5. If the trial yields unexpected results, not related to the original objectives, they should be ignored. ____
6. Always indicate on the data sheets the size of the harvested area. ____

For some questions you need to fill in the blanks:

7. Give two reasons for measuring labour inputs.

   a. ____

   b. ____

8. Labour estimates can be ascertained through ______________________ ______________________ and ______________________.

9. Measurements made in on-farm trials are __________________ and not __________________ measurements.

10. Name the three major types of analyses used for interpreting on-farm trial results:

    a. ______________________

    b. ______________________

    c. ______________________

11. There are seven things that a researcher can ask farmers about a technology. Name five:

    a. ______________________

    b. ______________________

c. ______________________________

d. ______________________________

e. ______________________________

12. A researcher can do two things to help farmers assess varieties with similar appearance. These are:

    a. ______________________________

    b. ______________________________

The following sentences are either true or false. Indicate by writing T or F:

13. Researchers should carry out farmer assessments during the trial and return in the following season for further discussion. ____

14. For an assessment, the researcher should set the criteria for the farmer. ____

15. A good ranking system allows the farmer to express relative differences. ____

For answers see p. 113-114.

Appendix I

ANSWERS TO STUDY QUESTIONS

Part 1 (p. 10)

1. a. diagnosis
   b. planning
   c. experimentation
   d. evaluation

2. a. A better understanding of the farmer's circumstances.
   b. Faster, more accurate feedback from the farmer.
   c. Rigorous test of technology under realistic conditions.
   d. Better linkage between research, extension and farmer.

3. To design acceptable technology for use by small farmers that will provide a greater number of options for solving problems, relieving constraints and/or exploiting new opportunities in a sustainable way.

4. a. Farmers are involved in managing experimental and non-experimental variables.
   b. Data collection includes farmer assessment.
   c. Site selection and logistics take more time.
   d. Experiments tend to have fewer treatments and perhaps less conventional designs, and be simpler.

5. (T) 6. (F) 7. (F) 8. (T) 9. (T) 10. (F)

Part 2 (p. 25-26)

1. Mapping can help the researcher visualise the area's differences and similarities and hypothesise to where technologies can be transferred and tested.

2. Labour calendars show bottlenecks and where labour for new technology competes with other tasks.

3. causes, effects

4. A homogeneous group of farmers who would most likely adopt the same recommendation because they have similar resources, problems and opportunities for development.

5. a. an experiment
   b. further diagnosis
   c. better extension
   d. policy change

6. (T) 7. (F) 8. (T) 9. (F) 10. (T)

11. Clustered

12. Stratifying

13. transport, communication and staffing

14. a. brief description of the situation
    b. objectives
    c. plan of work
    d. cost estimates
    e. reporting schedule with progress indicators

15. a. discontinued
    b. changed
    c. technology was recommended
    d. new problems identified

16. a. informal feedback from those involved
    b. informal survey

Part 3 (p. 51-54)

1. a. site selection
   b. treatment selection
   c. management aspects
   d. data requirements
   e. design

2. a. Exploratory—Further diagnosing the causes of problems in order to find solutions.
   b. Refinement—Refining the technology by testing a number of possibilities and narrowing them down.
   c. Verification—'Fine-tuning' technologies under a number of environments and verifying that they work.
   d. Farmer experiments—Involving farmers in technology verification.
   e. Demonstration—Comparing one or two technologies with farmer practice. Some data or observations are still taken.

3. a. Diagnostic—Gathering specific information on a problem or investigating an unknown problem.
   b. Simple factorial—Sorting out the most important factors.
   c. Add-on, take-off—Testing partial packages to see which combinations or portions are the best.
   d. Yield loss study—Discovering the amount of yield loss attributable to different factors.

4. Because there is a large array of treatments and the trial complexity is greater.

5. variable

6. Economic evaluation and systems interactions

7. (F) 8. (T) 9. (F) 10. (F) 11. (T) 12. (T)

13. a. easier for farmers to understand
    b. lowers the risk factor
    c. takes up less land
    d. reduces the amount of compensation
    e. easier to manage

14. a. intercropping
    b. some pest control trials
    c. machinery or tillage trials
    d. labour measurements
    e. agroforestry

15. superimposed trials and an incomplete factorial

16. It depends upon the risk of the technology and the amount of confidence the researcher has in duplicating results.

17. a. optimum
    b. standard practice
    c. farmer's practice
    d. current recommendation
    e. untreated

18. To avoid confusion when farmers use different 'local' varieties or practices. It maintains uniformity for standard comparison.

19. a. It may be a source of unwanted pests.
    b. It may be unrealistic and academic.

20. Controllable: those factors, management and cultural practices applied to the treatment area other than the treatment itself.

    Uncontrollable: environmental conditions

21. a. plant population
    b. weeding
    c. fertiliser levels
    d. pest control

22. (T) 23. (F) 24. (T) 25. (T) 26. (F) 27. (F)

28. long and narrow; square

29. a. use fractional factorial design or incomplete block
    b. reduce plot size
    c. reduce treatment number
    d. eliminate paths and alleys within the trial
    e. use shared border rows/areas

Part 4 (p. 69-70)

1. a. necessity of interdependence
   b. consensus of domain and analysis of conditions in that domain
   c. effective linkage mechanism

2. a. diagnosis as informers or enumerators
   b. site and farmer selection
   c. monitoring, data collection, general follow-up
   d. evaluation

3. a. researcher
   b. shared between farmer and researcher
   c. farmer

4. a. supplies site
   b. advises on treatment selection
   c. assesses treatments

5. superimposed; Researcher supplies seed to farmer for variety test, which the farmer plants and manages.

6. Advantages:
   a. Good way to get farmer assessment.
   b. Farmer may know best how to use the technology in his/her situation.

   Disadvantages:
   a. Difficult to collect quantifiable data.
   b. If the technology is too complicated the farmer may have problems using it.

7. a. understanding the farming system
   b. choosing the trial site
   c. source of technology
   d. choosing treatments
   e. manage experiments
   f. anticipating problems in treatment selection
   g. assessing technology

8. One that is indirectly related to participating in an on-farm trial by the farmer such as entertainment costs.

9. (F) 10. (F) 11. (T)

12. a. return expected yield or more
    b. return seed or in kind
    c. give credit
    d. give cash

13. a. Involve extension in advance to teach about the crop and how to use it.
    b. Involve the farmers in the solution-finding process from the beginning so they are convinced of the potential viability.

Part 5 (p. 87-88)

1. a. uniformity
   b. representativeness
   c. accessibility
   d. hazards
   e. size

2. biased

3. 28 kg of seed for each variety is a minimum amount

4. (F) 5. (F) 6. (T) 7. (F) 8. (T) 9. (F)

10. By taking measurements from the stakes to a stationary object when laying out the trial and indicating these measurements on the trial map in the field notebook.

11. a. Give inputs and instructions to the farmer in advance.
    b. Assign a technician who lives nearby to oversee the activity.
    c. Plan logistics carefully, so staff time is efficiently used throughout the area.
    d. Use a superimposed trial design.

12. a. Compare trial management with that of adjacent fields having the same crop.
    b. Check the farmer's subjective reports with objective data.

13. a. Assign one farmer to weed each replication
    b. Take weight of weeds removed from each plot
    c. Have farmers assess the job

14. local; scientific

15. Because greater system interactions are expected, especially in terms of risk, resource and labour use.

16. a. The life cycle is longer.
    b. Several outputs are expected and need to be measured and valued.
    c. Objectives may change over time.

17. Work with groups of farmers rather than with isolated individuals.

Part 6 (p. 106-107)

1. a. detailed environmental data
   b. management practices
   c. socio-economic data

2. (T) 3. (F) 4. (F) 5. (F) 6. (T)

7. a. to estimate labour costs
   b. to identify labour-related systems interactions

8. farmer interview and making measurements in on-farm trials

9. relative and not absolute

10. a. statistical
    b. economic
    c. farmer assessment

11. a. performance
    b. interactions
    c. risk
    d. causes for problems
    e. systems interactions
    f. environmental factors
    g. economics

12. a. use colour coding
    b. assess bean seed with the whole plant before senescence

13. (T) 14. (F) 15. (T)

Appendix II

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