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## **On-Farm Experimentation with Intercrops: A Summary of Issues From a Workshop Held in Malawi**

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### **Introduction**

Most intercropping research has been conducted on experiment stations with the aim of proving or understanding the efficiency or advantage of intercropping systems, or of designing new systems on the basis of biological principles. However, experiment station trials often make poor predictions of the best varieties, fertiliser rates and application methods, population densities, and sometimes disease control techniques for use by smallholder farmers in their intercrops.

A workshop, *Research Methods for Cereal/Legume Intercropping*, was held in Lilongwe during January 1989. The workshop participants reached the consensus that much intercropping research should aim to offer farmers improvements on their existing intercropping systems and that to do this more research should be conducted on-farm using a production problem orientation. Many presenters and discussants at the workshop emphasised that most of the general issues and techniques related to farmer oriented on-farm intercrop research are similar to those for other forms of on-farm agronomic research. There are however some aspects that differ. These special considerations, rather than the similarities, are emphasised here.

This summary draws on presentations and discussion at the workshop in Malawi. Emphasis is on concepts and methods for on-farm adaptive intercrop research and little attention is paid to specific intercropping experimental factors, such as genotypes, weeds, fertiliser, and plant spatial arrangements. No attempt has been made to address other relevant issues not covered in that workshop. Also, some of the points made here did not enjoy unanimous endorsement at the workshop.

### **Formulation of Intercropping Research Programmes**

**Farmer focus and on-farm research**--Much previous intercropping research in eastern and southern Africa (and elsewhere) was in the form of isolated experiments with limited biological objectives, conducted within commodity programmes and generally on research stations.

In spite of the large amount of intercropping research done, very few appropriate intercropping recommendations to extension and smallholder farmers have emerged from that work. Intercropping systems are complex and there are myriad opportunities for fine-tuning them, but most such innovations will be unacceptable to farmers. Because several technology factors are involved and are likely to interact strongly with the farmers' environment, a higher proportion of on-farm experiments may be justified in an intercrop research programme than in sole cropping. Most intercropping experiments should be very adaptive in nature.

Intercropping research needs a higher level of farmer involvement than is needed in most other forms of research. A high level of farmer participation is desirable because of local agro-ecological adaptation and because of farmers' multiple objectives in intercropping.

Thus more appropriate formulation of intercropping research programmes is vital.

**Organization of intercropping research**--To ensure good technical content and the relevance of proposals to farmers' needs, research policy makers, researchers from several disciplines, and extensionists need to interact effectively at various levels. Social and economic scientists play a large role in ensuring that intercropping research is relevant to farmers' needs. Intercropping research might therefore best be organised in the form of interactive working groups made up of members from

several commodity and disciplinary teams, rather than as separate dedicated intercropping teams. Researchers can often usefully treat an intercrop combination as a 'commodity' of several component crops together, rather than separately develop the ideas, treatments, and recommendations for each component.

Problem oriented intercropping research should follow the established process of diagnosis, planning, experimentation, evaluation and replanning, and dissemination. While a problem oriented intercrop research programme is underway, close interaction between on-station and on-farm components and with extension is vital. Finally, because of the complexity in intercropping research, much can be learned from success and failure elsewhere--information networks are useful.

### **Diagnostic Procedures**

Most intercrop research has emphasised the comparison of biological yields in experiments, yet intercropping experimentation relevant to smallholders first requires our understanding of farmers' problems and needs. This is the role of diagnosis.

**Aims of diagnosis**--Similar diagnostic procedures apply in intercrop research as in other forms of research oriented toward farmers' problems. Diagnosis aims to understand farmers' circumstances, describe farmers' practices, identify farmers' problems, examine causes of the problems identified, and develop some tentative ideas on target groups of farmers. All of this is done through close interaction with farmers. But since intercrops are more complex (involving two or more crops, possibly staggered planting times, different spatial arrangements, and so forth) then diagnosis of problems may require additional socio-economic as well as deeper technical insights. Frequently surveys underestimate the importance of associated secondary or 'subordinate' crops such as legumes. The care that is needed to examine these factors fully often justifies multi-visit surveys.

**Farmers' objectives**--A major aim of diagnosis is to learn farmers' objectives in intercropping. Usually farmers have several objectives which may be influenced by biological and socio-economic factors. For example, farmers may wish to:

- Spread requirements for labour over time
- Reduce risk of crop failure
- Improve output stability over seasons
- Increase yield per unit land area--for example, to maintain yield of a staple (often cereal) crop and produce some yield of a subordinate (often grain legume) crop
- Provide a greater range of secondary outputs--for example, legume leaves as relish, residues for livestock, or stems for roof thatch
- Comply with government/extension policy

It is unlikely that all of farmers' objectives or their degree of importance are immediately obvious to the researcher, so some investigation is needed.

**Farmer resources**--It is also important to learn about the resource requirements of farmers' current intercrop practices, particularly labour, since most intercrops are labour intensive.

It may be relevant to devote more time to assessing the sustainability implications of current farmer intercropping or other practices, with a view to developing intercropping experimentation that has a sustainability perspective. This may involve assessing resources and their use at several levels (e.g., the field, the whole farm, and the community). Resources to evaluate include: crop residues; soil organic matter; nitrogen fixation; animal manures; rainfall; farmer and family labour; non-family labour; animal power; groundwater (for small-scale irrigation); and household wastes.

**Followup diagnosis**--Followup diagnosis during on-farm experimentation is likely to be even more necessary with complex intercropping technologies. There may be more of a role for surveys and monitoring in farmers' fields and less of a role for exploratory trials in intercropping diagnosis.

### **Planning Intercrop Experiments**

**General**--The process of planning on-farm intercrop trials is the same as for other on-farm agronomic trials. Planning uses the information generated during diagnosis to develop appropriate targeted experiments.

On-farm experimentation with intercrops can be complex and expensive. Thus on-farm experimental programmes with intercrops need to be carefully planned and justified. Because of the greater

complexity with intercrop trials, a systematic approach to developing clear objectives and related appropriate treatments becomes more important than ever. Then the analysis and interpretation of results becomes easier and more productive.

Good information generated with farmer participation in the diagnosis will help ensure the planned experiments address farmers' needs. Feedback from farmers on proposed experiments before the trials are implemented is very useful for intercrop trials.

**Experimental factors and treatments for intercrop trials**--There has been relatively too much research on plant population density and spatial arrangements of intercrop component crops to the detriment of other issues relevant to smallholder farmers, such as fertiliser use, weed control, and pest control.

When identifying possible technologies as solutions for inclusion in intercrop trials, it is important to know whether we are considering:

- 1) Changing one or more components of an existing intercrop, or
- 2) Changing the cropping pattern (i.e. replacing sole cropping with intercropping or intercropping with sole cropping).

In problem oriented on-farm intercropping experiments we are usually looking at point (1) above (i.e., changes to components of an existing intercrop). Some general concepts for such trials are:

- We need to test new technology against current intercrop practices employed by the farmer.
- New technologies for testing should not differ in too many ways from the farmers' current practice if they are to stand a good chance of adoption.
- We must be clear about farmers' current objectives for intercropping and ensure that new treatments for testing are compatible with those objectives and with resource levels of farmers. For example, with weeding work it will be important to know the timing of labour bottlenecks using current weed control methods in order to think about modified weed control technologies that might reduce the problem.

Care is needed when planning on-farm intercrop trials on the basis of yield benefits or Land Equivalent Ratios (LER) obtained from experiment station trials. Benefits may disappear under farmers' conditions. For example, there are doubts about the technical performance or biological advantage of intercrops in some semi-arid areas.

Complex changes to intercropping systems may be difficult for farmers to accept. These changes may require more institutional support (e.g. training from extension) than sole crop technologies.

**Sole crop plots vs. plots of farmers' practice**--In many on-farm intercrop experiments, sole crop plots are not needed. The number and type of sole crop plots required depends on the objectives of the trial. Most on-farm intercrop trials aim to see how best to grow intercrops or to modify current intercrops, not to determine whether intercropping has a biological advantage over sole cropping. Here we need to think very carefully if any sole crop plots are needed at all.

Usually the important comparison is between the new technology and farmers' current intercrop technology, so far more important than plots of sole crops are plots representing the farmers' practice. This is especially true in adaptive verification trials.

Generally we only need to think about calculating LERs (and including sole plots) if land is clearly a limiting resource and if farmers intercrop mainly to increase the efficiency of land use. Where sole crop plots are needed for LERs these do not need to be randomised and grown on plots in the experiment. They can be obtained from sole crop areas near the experiment.

Sole crops may be useful to convince policy makers, extension staff and other researchers.

In on-farm trials, it may be impracticable to have plots of sole crops where intercropping is clearly the farmers' preference and land is in short supply. The farmer may regard plots of sole crops as wasteful.

**Experimental designs and treatment structures**--Good experimental design is even more important in intercrop experiments, whether on the research station or farmers' fields, than for sole crop experiments.

Underlying principles of design are no different for intercropping than for other areas of field crop experimentation. Design of any agronomic (intercrop) experiment consists of 3 stages:

- 1) Identification of experimental plots and variation between them, followed by control of variability through blocking
- 2) Identification of objectives of experiment and selection of treatments to provide answers to the questions proposed; develop treatment structure
- 3) Join chosen treatments to the structured set of experimental units

In intercrops we may need larger plots, both because of the need to have sufficient plants of all the component crops and the need for larger guard areas. The minimum plot size for the intercrop should be the largest of the minimum plot sizes for each of the component crops.

Some special designs have been developed for intercrop experiments on the research station. Systematic (e.g., modified fan) rather than randomised designs should often be useful for experiment station trials on spatial arrangements in intercrops in which many spacing treatments will be combined factorially with other factors. In these designs the plant density or spatial arrangement changes slowly from row to row across a plot, meaning that guard rows are usually not necessary. Statistical analysis of systematic designs is different, involving fitting a response function of yield on the factor that varies in each systematic plot.

Factorial treatment structures with several factors included are important for efficient intercropping research to develop technologies because there are many more possible factors to consider, but standard on-farm research practices of keeping trials as simple as possible still apply.

Therefore, with on-farm intercrop trials there is greater need to consciously restrict the trial to a few variables and/or levels of a variable. Appropriate choice of treatments is thus more critical than ever.

Many existing intercrop trials (on and off the research station) with two or more experimental factors use a split plot design, but usually this is not the most appropriate design. Split plots are inefficient and should only be used where it is not possible to apply a treatment to a small plot (for example, if large-scale machinery is needed).

Instead of split plots, confounded designs or incomplete factorial treatment sets may be useful in intercropping where we often have conflicting requirements to include several factors but also to have small blocks.

**Output comparisons**--During planning, some tentative decisions about how the trial will be analysed and assessed need to be made to help decide on the types of data to be collected while the trial is underway.

The most meaningful and generally useful output comparison for the farmer is usually total output from one or more experimental intercrops and total output from farmers' existing crop, with output expressed as monetary values or nutritional value (calorie output). The choice should depend on the ways that farmers use the output. Where the farmer sells at least some of the output to a formal or informal market (as is usually the case), or if the farmer buys some of one or more of the crops, then monetary value (or net income) is most appropriate. Thus monetary value is the best measure of output for most adaptive verification intercrop trials.

**Farmer assessment**--Given the multiple objectives farmers have with intercropping there is a more important role for farmer participation in intercrop trials and in their assessment. Opportunities for farmer assessment during trial implementation need to be planned for.

### **Implementing Intercrop Experiments**

The principles of selecting farmers and sites and determining field plot layout and technique for intercrop experiments on farmers' fields are all similar to those employed in sole crop experiments. The main difference relates to the increased complexity of the trial when two or more crop species are combined. More care and work are needed when implementing the experimental treatments and in managing non-experimental variables. There will often be additional data to collect.

## **Analysis and Interpretation of Intercrop Research**

**Form of analysis and interpretation**--Methods for evaluating on-farm intercropping trials will depend on the reasons farmers have for intercropping, especially the balance between market vs. subsistence orientation. If the farmers' aim is improved productivity with emphasis on sale of crops, then data interpretation should focus on yield outputs of the test intercrop technologies, probably finally as combined monetary values.

If the technologies being tested are intended to produce crops for home consumption, and especially if the technologies are germplasm, then their acceptability to farmers for flavour, leaf quality, grain colour/size/processing/cooking time, storability, and crop duration in relation to labour and land need to be assessed through farmer surveys. If stability of performance is paramount, then evaluation needs to take into account the levels of stress tolerance of component varieties when grown in a crop association.

**Measuring biological outputs**--Before the productivity or efficiency of intercropping systems can be assessed, the basis on which outputs are to be measured and compared needs to be decided upon. Intercrop practices should be evaluated in terms of the most limiting resource or production factor. In eastern and southern Africa this resource is often labour and only sometimes land.

Evaluations can be made on many different bases, including whole plant dry weight; grain dry weight; plant constituents such as fat, calorific values, protein, and fodder yields for feeding animals; or on the basis of net income. The choice of character(s) for which the technology is evaluated will depend on the objectives of the research and what is useful to the researcher and the farmer.

A whole series of indices have been developed to combine output data (usually biological yields) to assess the biological advantage of intercrops and competitive aspects of components of intercrops. These indices have been extensively used in more basic intercropping research on the experiment station. The most important indices of biological advantage are the relative yield total and the LER. In most cases these indices are inappropriate on the farm.

Farmers usually have multiple reasons for intercropping. One reason may be to intensify the use of land. Therefore LER may often not be useful, so often there is no point in calculating it.

Simple value indices such as money, protein, or dry matter are usually the most relevant for on-farm intercrop trials.

**Statistical analysis**--No single form of statistical analysis will be appropriate to all forms of intercropping data. In more basic technology generation intercrop experiments, which are sometimes done on farmers' fields, data structures will be complex. Different forms of yield information will be available for different sub-sets of experimental units.

A basic aspect of statistical analysis in intercrops is to obey the principle of comparing like with like. If yields are measured in different units, or over different time periods, or for different species, then comparisons will not be valid. Several forms of analysis are possible:

- Analysis of each crop yield separately
- Multivariate (bivariate ANOVA) analysis
- Analysis of crop indices (e.g. LER, monetary values)

Bivariate analysis of variance is a powerful form of analysis that does not lead to loss of information. It involves the joint analysis of the pairs of yields for two crops intercropped on a set of experimental plots.

In on-farm research the multiple products or outputs from an intercrop may be most meaningfully evaluated together since farmers will be interested in the total worth of all useful outputs from different intercrop systems. However, it is easy to do misleading statistical analyses using indices.

As mentioned earlier, in adaptive or verification OFR the most useful index is monetary value. The output (which may be something other than grain yield) from each component crop is converted to monetary units according to market values and all values are summed for all component crops on a per-plot basis, giving monetary units per hectare. These values are

then subjected to an ANOVA in the same way yields might be analysed. Monetary values have practical meaning for most farmers.

Comparisons of biological efficiency through LERs are not valid for different crop combinations. When calculating LERs, we must make sure the divisors are constant for all the values to be compared. Comparison of LER values within an analysis of variance is usually valid provided that a single set of divisors is used over the entire set of intercropping plot values. Questions about the precision of LERs are usually not important.

**Agronomic interpretation**--The general principles of agronomic interpretation for intercrop trials are the same as for other on-farm trials, but interpretation can be much more complex because of complex interactions and several output variables.

**Socio-economic assessment of outputs**--Many relevant evaluation criteria in intercropping may be socio-economic rather than related to agronomic performance *per se*. Thus, farmer evaluation is very important.

Farmers should be fully involved in the assessment/evaluation of on-farm adaptive intercropping trials, with less emphasis on conventional statistical methods. A qualitative evaluation involving farmers is often more cost effective than developing complex statistical measures and procedures to cover multiple objectives. Also, measuring all the relevant outputs from intercrops can be very difficult, whereas farmer assessment will integrate the outputs important to the farmer.

Assessment can be done through a survey of farmers' opinions on the benefits of the intercropping technologies being tested on farm, using an open-ended questionnaire.

Farmers may be interested in evaluating the technology on any of the following grounds:

- Compatibility with farmers' objectives in intercropping
- Outputs appropriate
- Labour implications
- Effect on timing of operations
- Cash implications
- Risk implications
- Land implications

- Relationship with decision making in household
- Effect on household food supply
- Availability of required inputs

The questionnaire may involve basic information on the farmer and the trial, treatment by treatment evaluation by the farmer, ranking of treatments by the farmer, and general comments made by the farmer.

**Economic analysis and interpretation**--An economic analysis of trials is essential if the researcher wants to check whether the technical responses are sufficiently attractive economically for farmers to adopt the tested technology. This will be an important objective with data from adaptive on-farm intercropping trials.

Relative comparisons of economic gains and losses will depend on the nature and objective of the trial. We can consider three situations in intercropping trials where gain/loss comparisons are different:

- 1) Comparison of output gains, caused by incremental changes in the levels of a key input, with the extra cost of each unit of input
- 2) Comparison of different combinations of intercrops given a fixed level of inputs
- 3) Comparison of different combinations of inputs for a given level of output

Comparisons 1 and 2 will be relevant where the objective of the trial is to make modifications to existing intercrops. Comparison 3 will usually be relevant where a sole crop is being compared to an intercrop.

Standard considerations before meaningful economic analyses can be done apply equally for intercrop trials: i.e., inclusion of farmers' current practice, data from sites representative of farmers' conditions, non-experimental variables at current farmer levels, and the use of real costs and benefits to the farmer rather than market prices or yields obtained by researchers.

With intercrop trials it is generally best to do the economic analysis on the weighted value of the crops combined, reflecting farmers' aims and objectives. This means a statistical analysis will have to be done first on the combined monetary values as indicated earlier.

If market values of the crops within the intercropping system vary greatly during the season, then evaluate the treatment effects in the experiment over a range of market price rates.

For analysis/evaluation of variety intercrop trials there is little need to consider costs. Price ratios between component crops can be used, and evaluation by farmers should occur early in the varietal development process, that is, on-station as well as on-farm.

Feedback to commodity/disciplinary research needs to reach a wider audience than results from sole crop research because of the multi-commodity nature of the work.

#### **Acknowledgement**

Many thanks to presenters and discussants at the Workshop on *Research Methods for Cereal/Legume Intercropping*, 23-27 January 1989, Lilongwe, Malawi for their ideas, which have formed the main body of this summary.

## **Announcement**

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The International Center for Living Aquatic Resources Management (ICLARM) is offering another useful publication in Farming Systems Research, titled *Training Resource Book for Farming Systems Diagnosis*. Those of you who are interested in obtaining a copy should write to:

Dr. Clive Lightfoot  
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