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ON-FARM TRIALS; AN OVERVIEW°

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Introduction

Research institutes have traditionally developed new technologies* under controlled (station or sub-station) conditions and passed on "proven" technologies to the extension service for demonstration and introduction to farmers. The conditions on the stations are often far from comparable with those of farmers, even physically. Soils may be different as to their intrinsic properties or because of the long-term effect of station utilization. The cropping systems used at the station, if any, hardly resemble the farmers' as regards crop associations, successions etc. Futhermore, typical "whole-farm aspects" are not considered such as the technologies' effect on the farm's labour film, the farmers' scarcity of resources, subsistence needs of the farm household etc.

It has become clear that there exists a wide gap between station research and extension, which hampers the transfer of new technologies to farmers or even prevents the development of technologies which are relevant for farmers. Station research can to some extent be improved

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*"Technology" is throughout used in a broad sense and means any (combination of) physical production factors employed in farming (cropping techniques, use of chemicals, implements crop varieties etc.)

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upon to narrow this gap, e.g. by paying more attention to mixed cropping or by modelling a farm enterprise on station. (e.g. the "Unit farm" approach; Menz, 1979). Farmers' conditions can only very partially be reproduced in experiment stations and the only relevant testing grounds are to be found in farmers' fields. Tests under farmers' conditions are therefore a necessary step in a technology development process.

The place of on-farm testing in the research process

The end product of conventional agricultural research are "improved production packages", consisting of a number of components which interact to yield the desired optimum results. The development of these packages usually takes place under controlled conditions.

The argument for the inclusion of several components in a package is that best results are obtained when each component is combined with an optimum combination of other components because of the synergistic effects between them. For this reason new varieties are rarely offered to farmers as such, but mostly with several recommendations attached such as sole cropping, recommended density, fertilizer dose etc. (Because of this pre-occupation with packages, breeders rarely know how their varieties perform under otherwise unchanged, i.e. farmers' conditions).

Each component in a package may deviate from the farmers' practice and may or may not meet with his resistance. In case of rejection it will be more difficult to find the reason for rejection as the package is more complex. Furthermore, the originator of the package is often not involved in the introduction process and the deficiencies of the package may go completely unnoticed.

The On-Farm Adaptive Research approach departs from conventional research methods by adopting the following principles:

a) new technologies will only be adopted if they are appropriate for a given area and for a given farm type. In order to make an adequate choice of technologies for testing under farmers' conditions the scientists need to know these conditions. An exploratory survey should therefore preceed any on-farm testing program.

b) A new technology must fit into the farmers' existing system. If the technology requires a change in that system the researcher should be aware that unintended side effects may cause rejection. He must therefore monitor not just the new technology itself but also its interaction with the rest of the system.

c) The farmers' judgment on a new technology is the end result of several separate judgments. For a new crop variety this may include its competition with associated crops, lodging, yields, taste, storability, processing characteristics etc. The researcher needs to evaluate these separate judgments in order to unerstand the farmer's overall opinion.

The implications for the farmer of a technology or package can only be predicted very partially in the research station. The OFAR approach therefore advocates a shift of the research process to the farm, by making the performance of a technology under farmers' conditions and the farmers, evaluation an object of study. A technology is not considered "proven" and the task of the researcher is not completed until the technology is adopted by farmers.

Objectives of on-farm trials

The broadest objective of on-farm trials is to identify new technologies that will improve the productivity of the farm and are acceptable to farmers. This objective leaves a lot of latitude: a new variety that is resistant to a major disease may single-handedly bring about such an improvement, albeit small, without the need to change anything else in the farmer's system. At the other end of the scale, a completely new farming system may be conceived

which could drastically increase the farmer's productivity, but at the cost of upsetting his whole way of life.

More specific objectives are needed to formulate an on-farm testing program. Such objectives are initially identified through an exploratory survey and continuously adapted as the testing program proceeds. It is most important that the objectives be made as explicit as possible in order that the trial treatments can be derived from them in a direct and logical way. General objectives such as "to improve farmers' yam production techniques" need to be refined before they can be translated into a testing program. A more "operational" objective would be "to improve farmers' yam production through better mechanical and biological weed control measures."

To a farmer a new technology will only be of interest if it is better than what he already does. A trial must therefore enable him to compare and this comparison must be built into the design of the trial.

Many trials do not obey this rule and are therefore difficult to evaluate, both for the researcher and for the farmer.

As an example, consider a "demonstration trial" where a new maize variety is compared with the farmer's, with and without fertilizer. If the non-test factors, such as land preparation, intercrops, density etc. in this trial are

the same as the farmer's and the trial is laid out in a farmer's maize field, this will allow a clear comparison between the farmer's and the new variety at two fertilizer levels, under farmer's conditions. If, as is often the case, the trial is done under sole crop conditions, at a "recommended" density, both different from the farmer's, and in a separate field, then the relevance of the trial becomes dubious. The trial will of course correctly measure the performance of the two varieties at two fertilizer levels under the conditions of that trial, but there is no comparison with what should be the standard, i.e. the farmer's practice. The farmer may wonder why the researcher uses sole cropping and a high density but the answer will not obvious from the trial results. At best he may be impressed by the looks of the new variety and next year try it in his own system, ignoring the other elements. This example introduces the crucial issue that a trial should only deviate from the farmer's system as far as the intended test variables are concerned.

If the stated objective of the above trial had been to test a more productive maize variety plus a moderate dose of fertilizer, then the test variables are variety and fertilizer and nothing else. The objective does not justify other changes such as sole cropping or a different density, unless the expression of the higher productivity of the new variety requires these additional "technologies." This is

often claimed by breeders, some times for no other reason than the fact that they bred their varieties under those conditions.

This is not to say that there may not sometimes be merit in testing a technology package around a new variety instead of only testing variety + fertilizer in the farmer's system. This should then however be the explicit aim and the trial must be designed accordingly to enable relevant assessment both by farmers and researchers. The design issue will be discussed in more detail below.

Apart from avoidable mistakes as in the above example unintended differences between a trial and the farmer's practices may occur in several and often unexpected ways. A farmer may wish to keep a trial out of his favoured fields and offer land which otherwise would not be cropped at all or which he intends to use for another than the trial crop (combination). A yam trial may then end up in the middle of a cassava field or a weed control trial may be planted in a field that would normally remain fallow and is heavily infested with difficult weeds.

In summary, a general rule a team has to keep in mind is that a trial should not deviate more from the farmer's system that it is intended to do. Or, stated in other terms: any on-farm trial should be imposed on the farmer's system and differ from that system only in the intended test variables. Only in that way can a trial measure the

advantage that a new technology represents over the farmer's own.

Classes of Test Technologies

1. *Elementary technologies*

A technology will be called elementary if it cannot be broken down into separate elements and if it can be applied without requiring additional changes in the farming system. Examples of elementary technologies are a disease resistant variety or fertilizer applied to one of the crops in a farmer's mixture.

A combination of two elementary technologies would be a new maize variety with fertilizer. Sometimes a technology requires a modification in the system in order to be applicable as when an increase in the density of a crop requires ridges instead of the usual mounds. Such simple "composite technologies" will also be considered members of this class.

Researchers should be aware that what they consider as elementary may in fact be or turn out to be more complex, as when a new cassava variety does not allow staggered harvests and thus requires a change in the farmer's harvesting technique.

2. *Composite technologies*

A technology will be called composite if it is made up of several interdependent elements, which cannot be considered in isolation. An example is alley cropping which

consists of the following elements:

- establishing the alleys
- major pruning at the start of the growing season and disposing off the branches
- regular trimming during the growing season
- continuous cropping on the same field

Sole cropping could also be considered a composite technology from the point of view of a mixed crop farmer. It involves:

- growing the target crop in sole stand
- growing less of that crop in his other (mixed) fields
- if it is a one season crop, replant the field to another crop in the next season.

3. *Technology packages*

A combination of several (composite and elementary) technologies will be called a technology package. Each or part of the elements in the package may have an effect on its own but the combination is thought to exploit the synergistic effect among the elements, thereby producing an optimum result.

A technology package does not necessarily deviate dramatically from the farmer's practice. IITA and other institutes for example are developing packages around traditional crop combinations such as maize/cassava.

The package may include mutually compatible varieties, fertilizer, row tillage with improved implements etc. The conventional "improved production packages" for single crops which have been produced extensively by experiment stations of course also fall in this class.

Researchers are often tempted to use package trials because of their wish to maximize impact and make rapid progress. They must be aware that each element in a package may involve more changes from a farmer's point of view than they perceive at first sight. This may greatly increase the difficulty of monitoring, evaluating and interpreting the results, both for the researcher and for the farmer.

Whether a given technology belongs to one or the other of these classes depends to a large extent on the reference base, i.e. the farmer's system. For a farmer who is used to grow sole maize at high density with fertilizer, a new variety with the attached package of fertilizer and recommended planting density is an elementary change, because he was already accustomed to the other elements of the package.

It is useful, as part of the so-called ex-ante evaluation of a technology, to meticulously enumerate the changes that technology requires in the target system. This will aid the research team in choosing an appropriate design and in monitoring and evaluating the trial and the farmer's opinion about it.

Types of on-farm trials

Elementary technology trials

In this group of trials a small number of elementary new technologies are compared with the farmers' own in an otherwise unchanged system. They are based on the assumption that improvements are possible in an existing system, without changing that system drastically. Such trials will be particularly useful in a new OFR program, when the researchers have insufficient knowledge of the system to venture into more consequential technologies or packages.

The limited use that has been made of this kind of simple trials may be due to two causes:

1. Until recently there has been little interest of researchers and developers in the improvability of traditional systems, which were often thought of as simply obsolete and should be replaced by "modern" techniques. These modern techniques, in the form of packages would often be tried in isolation from the traditional systems.

2. Station research sets the standard for on-farm trials. An important requirement for field trials are uniform experimental (within block) conditions to reduce experimental error. This uniformity is obtained by choosing uniform land, but also by applying all non-treatment operations (land preparation, planting,

density, fertilizer, weeding) in a uniform way. In on-farm trials with elementary technologies the trial conditions are the farmer's land and his cropping system on which the treatments are imposed. There is often a great within-field variation, both as to soil conditions and management, including composition of the crop mixture. The non-treatment variation therefore appears unacceptably large and conclusions are thought to be barely possible. Package trials are "cleaner" because most trial conditions are part of the treatments and can therefore be controlled by the researcher.

The non-uniformity of trial conditions is an important problem that deserves attention. This and other complications of on-farm trials are discussed in the following example. Many of the issues raised will also apply to other types of on-farm trials.

Example

Consider an "exploratory" trial where 2 new maize varieties are compared with the farmer's variety, with and without fertilizer. There will thus be 6 treatments. The farmer's system consist of growing maize in association with cassava. Cassava is grown on mounds with the maize planted at the foot of the mounds. Some vegetables are

grown at low overall density on the sides of the mounds. A first source of variation between experimental plots within farms will be variable mound distance, especially when plot size is small. The average mound spacing used by farmers should be known from the exploratory survey or other observations. The farmers may then be asked for the purpose of the trial, to make the mounds at a fixed distance, equal to the average.

It should not be too difficult to explain to farmers why this will improve the trial. If there are important differences among farmers regarding plant density, this difference should be used for a separate classification.

Another source of within-farm variation may be unequal maintenance, e.g. some plots being weeded earlier than others This will be more of a problem as the trial is bigger.

In an initial, exploratory trial, the farmer will be reluctant anyway to devote a large area to the "improved" treatments, particularly an unknown variety. In that case, with 6 treatments, and one rep per farmer, (see below) the total size of the trial will be such that it is easily weeded in one day.

The minimum plot size for this type of exploratory trial should not be less than $50m^2$. There are statistical advantages in having more than one replicate per farmer. The farmer x treatment interaction can then be easily

separated from the error. The accuracy of a trial will often be greatly improved if this interaction term is accounted for. Farmer x treatment interactions may arise from physical differences among fields (e.g. soil type) or from differences in management. Poor maintenance (weeding) for example will have a strong effect on the expression of treatment difference, with, in the extreme case zero yield for all treatments!

Often, however, it will not be feasible to use more than one replicate per farmer. In the above example, two full replicates would require 12 plots per farmer, which may meet with his objections, when the trial is embedded in an existing field, as it should be.

Furthermore, the "visibility" of the treatment differences is reduced by a multitude of plots. In such a case the following method can be used to partially account for the farmer x treatment interaction. It will normally be necessary to consult a statistician.

An additional quantity which is expected to influence the treatment effects can be measured in each field. If well chosen, the interaction between this covariate, suitably adjusted for means, and the treatments will in many cases account for a large part of the treatment and farmer interaction. (The remainder of the treatment x farm interaction is of course the error term of the Analysis of variance). The simplest solution is to choose the experiment's average block (farmer) yield, averaged over all treatments as the "additional" quantity, which may be expected to reflect management quality, everything else (soil!) being approximately equal. A numerical example is given by Morris (1981).

Assistance by a statistician will be required for this types of analysis, particularly in the case of missing plots.

After an elementary technology or a combination ha been adopted by farmers, new elements can be added on. In this way one actually develops a package in a step by step manner. This piecemeal approach should be seriously considered as an alternative for direct package testing.

The end result of the two approaches should theoretically be the same.

To extend the above example in this sense, assume that one of the new varieties and a moderate fertilizer dose are accepted. The next step could be to increase the number of maize stands, which will require ridges instead of mounds. Increased density will also require a higher fertilizer dose (on an area basis). An important aspect of these additional elements, to be closely monitored, is the effect of the increased maize density and vigour on the associated cassava. It may be necessary at this point to introduce cassava variety as an additional factor.

Composite technology trials

These trials are characterized by a small number of treatments, often only two, viz. the farmers' technology and the alternative. IRRI's "cropping pattern trials" are examples of this type, where one or a few new cropping patterns (e.g. two short cycle rice crops annually) are compared with the farmers' traditional pattern (e.g. one long cycle rice crop per year only). It will be clear that growing two rice crops per year instead of one is a composite change: there are two land preparations, plantings and harvests; direct dry seeding of the first crop instead of the usual transplanting may be necessary to match two crops

with the rainy season; the use of herbicides may be necessary because of direct seeding; new, short cycle varieties are required; a heavier fertilize dose is required to compensate for the increased nutrient removal by two crops, etc. Another example is a trial where a permanent alley cropping system is compared with the farmer's system of alternating cropping and bush fallow.

The treatments in composite trials will have to be applied on a fairly large scale to be at all feasible and to allow measurement of all relevant parameters. In the cropping pattern example the water management for two crops is different from that for a single crop and the experimental unit must therefore have independent water supply. In the case of alley cropping, a small alley plot cannot be managed by a farmer after the surrounding field has gone into fallow.

Furthermore, labour requirements for the two systems can only be monitored if the experimental plots are of a realistic size. A major problem of these trials is the basis of comparison for the new technology. The researcher should try to lay out the new technology and the farmer's system side by side, as in any other field trial. Furthermore, the trial period must cover at least one full cycle, suitably defined. In the case of the cropping pattern example this will be several years, because of the cumulative

treatment effects: the intensive cropping pattern will put heavier demands on the soil than the usual single crop, the effect of which will not be immediately apparent. The heavier fertilizer dose does not exculde unexpected effects. It has therefore been found useful to "superimpose" a fertilizer level trial upon the new cropping pattern, in order to monitor such effects and to be able to quickly respond with a modified fertilizer regime (Dr. K. D. Sayre, pers. comm.).

In an alley cropping trial a full experimental cycle would at least cover one full cropping-fallow cycle of the traditional (reference) system.

"Pure" composite technology trials are probably rare. In the Asian cropping pattern trials the experimental patterns are invariably combined with an optimum combination of improved practices, imposed on that pattern. These trials are therefore actually package trials (see below). A soil management technology such as alley cropping can however be profitably tested within an otherwise unchanged system.

Technology package trials

The simplest package trials are those that test a combination of elementary technologies imposed on an existing cropping system or pattern. In a maize + cassava system this could be mutually compatible, improved maize and cassava varieties, at a recommended plant arrangement, with fertilizer

and herbicides. The design of the trial is obvious, with the farmers' maize + cassava system being the basis of comparison. It would be straightforward to use one or two intermediate packages as additional treatments, which results in an "add-on" type of trial allowing the assessment of the added effect of each additional (set of) technologies. It has the great advantage of making it clear to the farmer that he has a choice and may select that part of the full package that suits him best. Such package trials are relatively easy to analyse both for farmers and researcher because of their clear objective, viz to improve upon an existing system through a limited number of interventions.

A more complicated case is a package that consists of a composite technology such as sole crop maize as an alternative to the farmer's maize + cassava mix, combined with an improved maize variety, fertilizer, recommended density etc. First of all, the reasons for opting for sole cropping must be made explicit, because there are no obvious biological reasons for separating the crops of the farmer's mixture. In many conventional package trials these reasons are not at all obvious. Secondly, growing maize as a sole crop entails growing cassava as a sole crop as well, in case the farmer wants to grow both crops, for example because of his subsistence needs or risk spreading.

Therefore, the experimental package could consist of both maize and cassava grown sole, one or both of them with a set of new technologies attached. However, the growing period of cassava is at least double that of maize, so after the sole maize a second crop must be grown to make the new package fully comparable with the farmer's. The full package thus consists of an alternative cropping system combined with a number of elementary new technologies.

The divergence between the package and the reference system is large and evaluation by the researcher requires the collection and analysis of many data.

The researcher, after his analysis, may be convinced of the superiority of his package, but this may not be so obvious to the farmer. Again, as in the first example, a small number of intermediate steps may be included in such trials, e.g. the farmer's own mixture, combined with a package of improved technologies.

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