RESERVE

DESIGNING AGRICULTURAL TECHNOLOGY FOR HIGH RATES OF DIFFUSION THROUGH FARMER POPULATIONS: CIMMYT'S EAST AFRICAN ECONOMICS PROGRAMME

by

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ABSTRACT

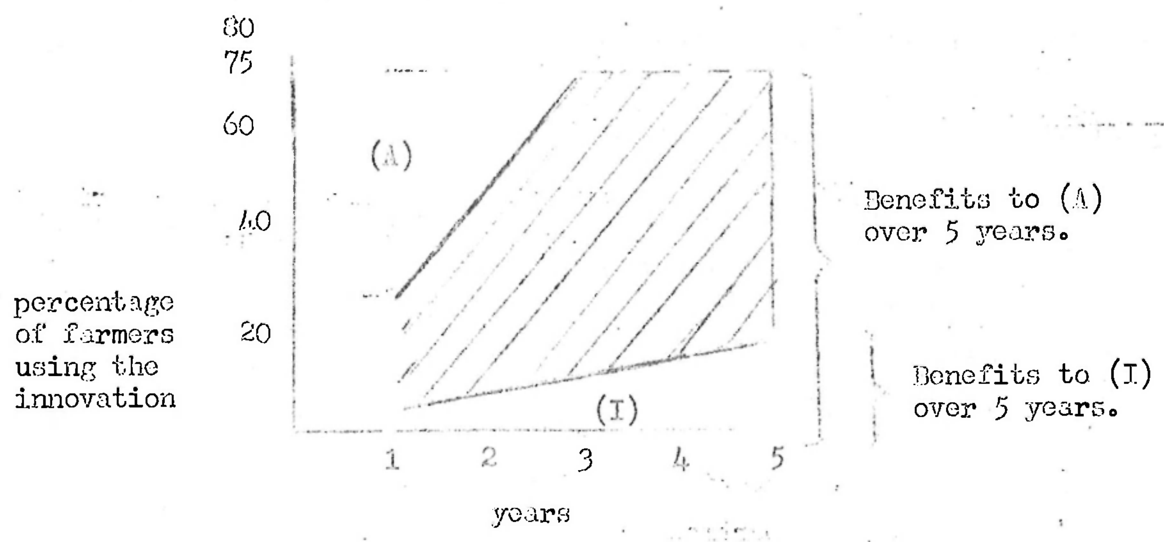
There is need for an interdisciplinary effort which includes social scientists in planning and designing adaptive agricultural research. The need is founded on the fact that farmers take decisions on what to produce, how much of it to produce and how to produce it in the light of the economic circumstances in which they find themselves. The full set of these circumstances should be brought to bear in research design if experimental programmes are to produce the appropriate, improved technology which is the key to broad based agricultural development.

The paper sets out an interdisciplinary procedural sequence for research orientation and experimental design in which the agricultural scientist is the expert in crop improvement and the microeconomist the expert in farmers' circumstances, and the result of which is a more relevant, effective research effort.

Introduction

In rural development programmes huge institutional and infrastructural edifices, often covering roads, water supplies, marketing, credit services and extension - or a selection of these - are built up around a chosen technology to enable it to be used by farmers. If the wrong technology is chosen for the programme, not only is the research effort in producing the technology wasted, but a whole range of development resources have been misapplied. Even if the sheer weight of effort pushes the new technique to some farmers, diffusion through the farming community will be poor and even those accepting the technique may not sustain their adoption once the special push is removed.

The more appropriate the new technology is to the needs and conditions of the majority of farmers in the community, the more rapidily will it spread and the more farmers it will eventually reach. A comparison of the effects of introducing (relatively) inappropriate (I) and appropriate (A) technology into a farming community is shown in the Diagram below:



The appropriate technology (A) reaches 75% of the community in a three-year period. The (relatively) inappropriate technology reaches only 20% of the community over a five-year period. The incremental economic benefits to A over the five years, represented by the shaded area, are several times the benefits to I, from a similar level of Government investment in research, enabling facilities and services. The social benefits of reaching 75% of the community in three years compared to 20% in 5 years are equally clear.

The Economists Contribution to Research Planning

The key to these increased benefits in agricultural development efforts is in identifying and designing appropriate technology through problem oriented research efforts.

The desirability of a contribution from economists is based on the fact that economics - whether of family security or profit - plays the dominant role in farmers' decisions. Farmers decide what they will produce, how much of it they will produce and how they will produce it in the light of the full set of circumstances in which they find themselves. This set of circumstances includes both natural conditions of climate and soil, important to the farmer for their economic implications, and direct economic conditions such as existing market opportunities and the availability of resources including capital and technology. In order to design appropriate improved technology, the orientation of research work and the content of experiments must reflect as closely as possible the set of circumstances which the farmer faces in taking his production decisions. The work of the economist is in describing the set of circumstances in which the farmer operates, in evaluating how these influence his production decisions, how he manifests these decisions in his farming system, and how this will colour the acceptability of the many potential facets of a new technology.

The acceptability of new techniques is coloured by the contribution they make to the farmer's basic production objectives: family security, particularly important to the subsistence and semi-subsistence smallholder, and profitability. Many breeders and agronomists now accept that yield, in terms of physical output per unit area, is an inadequate criteria to measure the potential impact of a change in management practice on farmers' production objectives. Experimental yields, unlikely to be reproduced under farmers' conditions, are particularly problematical. Only when representative of expected results in farmers' fields do yields become a starting point for evaluation in economic terms. For evaluation, in addition to valuation of the physical output in market terms, yield data need three major qualifications to reflect farmers' production objectives adequately:

- Discounting by the costs to the farmer of achieving the yield;
- Discounting by the year to year variability of the yield, and of the costs of achieving it;

- Discounting by the complexity of the management re-organisation required to implement the practices needed to achieve the yield.

Each set of qualifications creates 'costs of change' for the farmer, and deserves further comment:

(1) Farmers costs

Direct costs to the farmer as a result of adopting new technology can be put into three categories:

(a) Items to be purchased such as fertiliser, insecticides, sprayer, etc. in order to implement the practice.
(b) Increased labour costs when the methods involved in implementing the new technology and harvesting the extra output take more labour than under existing management.
(c) Opportunity costs, particularly relevant to the small farmer who has no access to, or the means for hiring, extra resources. Increasing his labour input in implementing the new technology may be at the expense of another crop which may not get planted, or may not get weeded so well, so that its yield falls. These losses are seen as a cost of the new technology by the farmer; such costs may also arise as a result of changes in the timing of operations demanded by the new technology. These costs may be increased as far as the farmer is concerned where the losses are crops which contribute to security of his family food supply, or which are highly preferred as food by him and his family. Opportunity costs are often difficult to measure in money terms; nevertheless their identification, if not precise measurement, is vital as they are often decisive to the farmers' reaction to new technology.

(2) Variability, year to year, in yield, price and costs

Stability in the results to be expected from new technology is also of particular importance to the small farmer, especially, in the case of the subsistence or semi-subsistence farmers, with new technology for their basic food crops. Such farmers live relatively close to subsistence level. Significant year to year variations in output, which to a large grower may make the difference in the size of car he can afford to run, may mean semi-starvation to the small farmer. Thus, although on a year to year average results may be better from the new technology, with family security as a dominant objective of small farmers, wide variations in yields are unacceptable. Interactions between crops in the farming system are also inevitable: New technology on cash crops often demands changes in management on basic food crops, this also may increase the year to year variability of food production and reduce farmers' security. Similarly security may be reduced by the uncertainty created by wide fluctuations in the costs of inputs required to implement the new technology.

(3) Management complexity

Absorbing new technology into the farming system demands a degree of management reorganisation. The more complex the repercussions the new technology creates within the system, the more complex the reorganisation required. Managerial ability is an attribute distributed approximately normally in a farming population. The more complex the reorganisation required to absorb new technology, the fewer the farmers with the required ability and the poorer the diffusion of the technology over the population. Each component of a technological package (improved seed, correct spacing, pure stand, correct time of planting, timely weeding, use of fertiliser, etc.) contibutes both to added profitability and to added management complexity. Dropping components which make large contributions to management complexity increases the degree and speed of diffusion over the farm population, more farmers are capable of handling the reoganisation required by simpler new technology. At the same time, dropping such components entails some loss of profitability. Using hypothetical examples based on Fig. 1, if (I) is a complex technological package and (A) a relatively simple one, the comparison of benefits in a 100,000 farm population might be:

(A) (a) Profitability per farm of shs. 90, spreads to 75% of farms over 3 years at 25% per year
(b) Aggregated benefits of shs. 27 million over a 5-year period.

(I) (a) Profitability per farm of shs. 120, spreads to 20% of farms over 5 years at 4% per year.
(b) Aggregated benefits of shs. 7 million over the 5-year period.

From a similar investment in government services, gross economic benefits to the country would be three times as high from A. and would be shared over 75% of the farming community, against 20% for benefits from I. Such a comparison, although based on hypothetical examples, clearly demonstrates the importance of management complexity as a criterion in identifying appropriate new technology.

To illustrate the variety of facets which can be involved, it is worthwhile setting out a hypothetical example of an existing and recommended maize growing practice, showing what each offers the farmer and detailing the costs of changing to the recommended practice from the farmer's point of view

Present practice: Maize production is wholly for subsistence. Maize is grown in mixtures with groundnuts and sweet potatoes. Maize is planted into the prepared field spaced approximately 75 cms between rows and 75 cms in the row. A weeding is done at three weeks when groundnuts and sweet potatoes are interplanted and rapidly cover the ground. No further weeding is done. Three or four fields are planted with this mixture at intervals, as the rain falls, between mid-November and mid-January. A short term variety of maize is used for the first and final plantings.

This enterprise gives the farmer the following returns:

(a) Dry maize, usually sufficient to feed his family until the following harvest, mainly from the middle plantings of a longer term variety which has good storage qualities under traditional storage practice.

(b) A complementary, high flavour, food in the form of groundnuts used to garnish the maize staple as the basic dish in the local menu.

(c) The staggered planting times give a prolonged flow of fresh foods; initially green maize afrom the short term variety planted early, than green maize from subsequent plantings followed by the sequence of sweet potatoes. In a good year the family will have fresh foods available as part of their diet the season round, as the sweet potatoes can be kept in the ground and used, fresh, as required.

(d) The staggered planting reduces the risk of crop failure as maize will be at varying stages, with varying water requirements, over dry periods.

(e) The short term variety used in the first planting gives early food availability in seasons following poor harvests. The short term variety used in the final plantings fits into the water availability pattern where a longer term variety would come under severe stress at tasselling from the same planting date.

Recommended practice for maize growing: Maize should be planted in a pure stand in the first week of December. Fresh hybrid seed (a long term variety) should be purchased each year. The seeds should be spaced 75 cms between rows and 30 cms between plants in the row. Weeding should be done at 2, 5 and 8 weeks. 50 kg/ha P should be applied in the seedbed and 75 kg/ha N top dressed after the second weeding. At knee- high the crop should be protected from stalk-borer by the application of DDT dust into the funnels of the plants.

This gives the farmer (if planted on the same area as his traditional maize mixture enterprise) more dry maize than he needs to feed his family in most years. A relatively short period of green maize before the crop dries off.

It can be questioned whether the new maize enterprise is really a substitute for the old one. Costs of changing, as they will appear to the farmer, are listed under the three sources: Direct costs, Opportunity costs and Complexity.

(1) Direct costs Direct costs of the change will be for hybrid seed, P and N fertilisers and DDT dust.

Where hired labour is used, the costs of extra labour for planting, increased weeding, fertiliser application, thinning and harvesting the larger crop will all be direct, additional costs to be set against the value of the increased output. The changes in the timing of operations, when it creates peaks, may require an additional work force to adhere to the recommended crop calendar. These would be additional direct costs.

(2) Opportunity costs In farming situations where additional resources are not available for one reason or another, opportunity costs are incurred when resources are re-allocated from other uses to implement the change and are represented by the last output from other uses or opportunities. In situations where there is a full knowledge of the existing farming system, of the resource allocations and their productivities, these costs can be quantified. In situations where there is little or no knowledge of the farming system, quantification becomes difficult and even impossible. Even where there is knowledge of the system, quantification is difficult where risk is a large factor weighting farmers' decisions, and when a significant part of the farm operations are in subsistence

production. The opportunity costs in this example can be divided into: (a) Possibly quantifiable; (b) not quantifiable in practice.

(a) Possible quantifiable: Where there is no labour market and existing labour resources must be re-organised to implement the change:

(i) Extra labour required may mean reducing the production of another existing enterprise.

(ii) The concentration of planting date, or indeed any change in the timing of operations, may create or increase labour peaks, at planting, time, weeding time or harvest time. This also may enforce a reduction in the size of other farm enterprises, the losses from which would represent a cost of the change.

(b) Not usually quantifiable in practice.

(i) Concentration of planting time will increase the risk of crop failure in areas of uncertain rainfall.

(ii) We can say that the recommended hybrid is a relatively poor keeper under existing storage and processing practices.

(iii) The single planting time reduced the length of the period when green maize as a preferred food is available. Together with the fact it is a long term variety, this also sacrifices early staple food in years when stocks are poor and sacrifices early green maize from the early planted short term variety in all years.

(iv) The pure stand involves; the sacrifice of the legume intercrops grown as complementary food; the sacrifice of sweet potatoes which gave a fresh food to follow the period of green maize.

(3) Complexities Several facets of this change create complexities in the management re-organization required to absorb it successfully.

(a) Growing maize in a pure stand raises the problem of how to obtain the legumes and sweet potatoes valued for their dietary contribution.

(b) Shifting the time of planting, and consequently of most subsequent and preceding operations, involves re-scheduling of long-established, routine timetables both on the maize mixture enterprise and other enterprises. Where there are periods of labour shortage or capital scarcity, re-allocation problems may present difficult management situations.

(c) The purchase and application of inputs demands a new management function. It may also aggravate the capital allocation problem.

Which of these costs and complexities are relevant, and whether the extra labour requirements will be direct costs or will create opportunity costs, depends on a detailed description of the local farming system for which the adaptive research programme is being planned. But it is clear that evaluating the true profitability of such a change to the farmer requires consideration of all these aspects.

The heart of the contribution of the economist is a description of the existing system in farming populations to allow advance diagnosis of the likely importance of these three sets, or sources, of costs of change. With such a diagnosis, agricultural researchers can guide their programmes into those components of new technology most compatible with farmers' production objectivies and therefore most appropriate to the local situation. In short, the aim is to identify the line of least resistance to change in the existing farming system.

PROCEDURES FOR A CO-OPERATIVE EFFORT BETWEEN NATURAL SCIENTISTS AND ECONOMISTS IN PLANNING ADAPTIVE AGRICULTURAL RESEARCH

Some space has been used in setting out the role of the economist because of the newness of the idea of his contributing to research design. The success of the approach proposed depends on interaction between natural scientists, as experts in crop and livestock improvement, and farm economists, as experts in the economic circumstances facing the farmer. There has been considerable reference in the literature to the need for an interdisciplinary approach to research problems in developing agriculture, but little practical guidance as to how such an approach might be organised. Having noted that the economist has been playing an exposte role, usually in criticising the inappropriateness of the results of adaptive research programmes, CIMMYT economists have sought procedures for a positive approach by bringing an economics input into research planning. To do this, a rapid turnover of data is needed which precludes a protracted full farm economic survey. The emphasis is on descriptive information and an intuitive evaluation of the relationships it reveals, the whole effort demanding only a six month period. The sequence of procedures which follows is essentially an interaction between natural scientists and economists to produce a more relevant orientation of research programmes. The sequence would be appropriate for scientists working from a centre with responsiblility for adaptive agricultural research in a region with a farming population operating under a variety of natural and economic conditions. The sequence can cover the orientation of as many crop or livestock research programmes as are mounted from the centre. The economist will liaise with each of the specialist groups involved. The sequence is outlined in relation to a single crop programme.

(1) Crop specialists, breeders, agronomists, pathologists, entomologists and soil scientists relate critical aspects of crop physiology to natural conditions as they occur in the region. Working from basic principles, they attempt to establish the relative importance of possible package components to potential yield, given local conditions of climate and soil, and the prevalent pathogens.

(2) The economist outlines critical aspects of crop economics, present end uses, product specifications, cropping patterns and existing production technology for all areas of the region.

(3) From these two sets of information

(a) The region is divided into 'Recommendation Domains' or 'Customer Zones'. This is an initial agro-economic zoning of the target population into domains which, because of the variability among them in natural potential or economic conditions, are likely to require different technologies and for which different experimental programmes may be justified. Zoning also creates a framework for deciding research priorities. If the criterion is the the greatest benefit for the greatest number, other things being equal, zones with the largest farmer population would take priority in experimental work. However, crop scientists and the economist would weigh factors such as the number of growers of the crop in each zone, the importance of the crop to these growers, and the potential performance of the crop in each zone in allocating priorities.

(b) The economist builds a schedule of descriptive information required for each zone as a whole and for the on farm situation in each zone. The schedule for the on farm situation seeks a description of how farmers currently manage the crop, and how this management interacts with management practices on other crops in the farming system. It emphasises how farmers presently manage those aspects of the crop which the specialists have identified as probably important to yield potential.

(4) The economist makes a preliminary, informal pre-survey of the zone. He discusses the scheduled information with officials and farmers in the area over a period of one or two weeks. This pre-survey verifies the homogeneity of farming within the zone and provides a basis for the organisation of a farmer survey.

(5) The economist mounts a farmer survey within the zone. The main objective of the survey will be to verity the incidence of features of existing farm management and identified farmer problems among the farming population. Close coordination will be required with crop scientists in drawing up the survey content and training the enumerators. The survey will be used to establish the incidence of pests, diseases, present variety usage, soil condition and other technical characteristics of present farming, as well as economic features of the farming population. The information is analysed and used, together with that collected less formally during the pre-survey, to give a detailed description of existing farm management practices. It will show how each facet contributes to the achievement of farmers' production objectives. The economist will identify the 'costs of change' related to each potential component of an improved technology package.

(6) Crop scientists discuss with the economist the weighting of these costs and the implications for experimental programmes aiming to develop technology to take advantage of 'lines of least resistance' into the existing system for easy absorption by the farming population. There will be four areas of discussion:

(a) Programme framework. It is important to breeding, agronomy and crop protection work that a general context is fixed for the research programme. Ideally existing farm practice should form a basic framework; any step away from it may contribute to profitability and to 'cost of change' and need assessment in the programme itself. Mixed cropping is a particular pertinent and critical example. For zones in which farmers grow (say) 80% of the crop in question mixed with other crops, an explicit decision is required whether improved varieties and management practices should be sought within the framework of a crop mixture. Crop scientists will evaluate the physiological inter-relationships between plant components and between plants and the local soil and water conditions. The economist will evaluate the importance of the practice to the farmers' production objectives and the management complexities consequent on reverting to pure stands. It may be decided that mixtures are crucial to water utilisation or soil conservation, and to the subsistence farmers' preferred food supply patterns, or that the managerial consequences of changing to pure stands would be too complex for most farmers to cope with. In this case, the best strategy would be research to improve the productivity of the mixtures, breeding and agronomy within the context of mixtures already present. On the other hand it may be decided that there are no physiological or crop protection or soil conservation advantages to mixtures, nor are the managerial consequences of changing to pure stands too complex. In this case the experimental work would be done in the context the crop scientists believe would offer the greatest potential for the improvement of crop productivity. The important point is that the framework for the experimental programme is given explicit consideration and not settled by default. An important part of the framework for consideration would usually be whether experimentation should be done within the rotational sequence followed by the farmer.

(b) Specification of supplementary breeding criteria. Present cultural practices as well as harvesting, processing and storage techniques will have implications for desirable features in any new varieties. An economic assessment can be made of the costs of changing present practices or, alternatively, of the losses involved in putting a poorly adapted variety through the existing techniques.

(c) Locational characteristics of experimental fields. The descriptive survey data will allow the location of experimental work on the soil types and topographical situations characteristic of farmers fields.

(d) The content of agronomic trials. Perhaps the most detailed area of discussion is the content of agronomy trials. Having emphasised the need to document the profitability and complexity of each step away from existing farmer practices to allow the compiling of appropriate technological packages, in practical terms few research programmes have the capacity to treat all management practices as experimental variables. The selection of experimental variables requires a detailed dialogue between the agronomist and the economist.

(i) The description of present management practice from the survey provides a basis for control treatments in the agronomy programme. Similarly it provides a basis for the levels of all non-experimental treatments.

(ii) All potential experimental variables - facets of management which the agronomist believes will improve the yield of the crop - should be discussed by the agronomist and the economist. The agronomist will be concerned to estimate, from first principles, their likely impact on yield. The economist will be concerned to establish the 'cost of change', including management complexity, for the farmer in absorbing each facet. Those facets which will have low costs of change but have a significant potential impact on yield may be rapidly incorporated as blanket, non-experimental treatments for all plots except the control under farmers practice.

(iii) Out of the remainder candidates for the experimental variables, a balance will be struck between the weighting given by the agronomist in terms of possible contribution to yield and that given by the economist in terms of 'cost of change'. Initial factorials should incorporate as experimental variables those facets of management with the highest possible contribution to yield and the lowest 'cost of change' to the farmer.

This sequence of interaction between crop scientists and the economist will be extended to lower priority customer zones as manpower and funds permit expansion of the research programmes. Where more quantitive information on existing resource use and productivity is required to crystallies the costs of change to the farmer, a full scale farm economic survey may be mounted as a follow-up to the intial survey aimed primarily at identifying the nature of these costs. In most cases the initial, non-quantitive but rapid survey will be adequate to provide clear research guidelines. The diagram below summarises the sequence.

Diagram. Interactions between crop scientists and economists in the orientation and planning of a programme of agricultural research