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FARMING SYSTEMS ADAPTIVE RESEARCH: ACHIEVEMENTS AND PROSPECTS IN SOUTHERN AFRICA

By ALLAN LOW† *and* S. R. WADDINGTON

International Maize and Wheat Improvement Centre (CIMMYT), Southern Africa Regional Programme, PO Box MP 154, Mount Pleasant, Harare, Zimbabwe

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SUMMARY

Farming Systems Adaptive Research (FSAR) has contributed much to the understanding of maize production constraints on smallholder farms in southern Africa in the last six to eight years. But its production impact has been constrained by the often inappropriate technology available to FSAR from component research and the ineffective use of its results by extension staff. However, FSAR has demonstrated the utility of a problem (client) orientated approach to technology development, which is now being taken up by some maize commodity research and extension programmes, though effective linkages have not usually been developed. Nevertheless, experience in southern Africa suggests that the FSAR approach can provide a framework for developing more effective integration between key groups involved in technology generation, dissemination and support.

Investigación para la adaptación de sistemas agricolas: logros y perspectivas en Africa del Sur

RESUMEN

La Investigación para la Adaptación de Sistemas Agrícolas (Farming Systems Adaptive Research—FSAR) ha contribuido en gran medida a la comprensión de las limitaciones de la producción de maíz en las granjas de pequeño tamaño en Africa del Sur durante los últimos 6 u 8 años. Sin embargo, su impacto en la producción se ha visto restringido por la generalmente inadecuada tecnología a disposición de FSAR respecto de la investigación de componentes, y el uso ineficaz de los resultados por parte del personal de extensión. Con todo, FSAR ha demostrado la utilidad de un enfoque orientado hacia un problema (cliente) para el desarrollo de la tecnología, lo cual ahora está siendo utilizado por algunos programas de investigación de programas de investigación y extensión del género del maíz, si bien en general no se han desarrollado enlaces eficaces. No obstante, la experiencia en Africa del Sur sugiere que el enfoque del FSAR puede proporcionar una cuadro para el desarrollo de una integración más efectiva entre los grupos claves involucrados en la generación de tecnología, su diseminación y apoyo.

INTRODUCTION

Farming Systems Adaptive Research (FSAR) (Sands, 1986; Collinson, 1987) has been adopted by most National Agricultural Research Systems (NARS) in southern Africa as a complement to traditional station-based research. It is expected to improve the capacity of NARS to respond to the production problems and opportunities of smallholder farmers, who are not well placed to make their

† Present address: Development and Project Planning Centre, University of Bradford, West Yorkshire, BD7 1DP, England.

needs known to researchers directly, and who operate under diverse circumstances.

FSAR has had two major roles: first, to identify research opportunities for improving the productivity of target groups of smallholder farmers, through an understanding of production problems, current production practices and the circumstances influencing farmers' current choice of enterprise and production techniques; and secondly, to test and develop improved technologies that will be adopted by target groups of farmers, mainly through participatory on-farm trials and demonstrations.

Early expectations were that the rapid adaptation of appropriate technologies was possible in southern Africa through FSAR (e.g. USAID, 1983). Such expectations drew on experiences from Latin American countries, such as Panama (e.g. Martinez and Arauz, 1984) and Colombia (Woolley *et al.*, 1988), where technologies tested and modified in FSAR were adopted by most target farmers within four years of the start of the research programmes.

Many FSAR teams in southern Africa have been operational for six years or more and donors and directors of agricultural research and extension are increasingly asking what results have been achieved so far and how Adaptive Research (AR) can be made more effective. This paper attempts to look at those questions, focusing on maize, the staple food crop in the region. We suggest that the stock of available technology has limited the options for adaptive experimentation although, within these limitations, imaginative and relevant methods of raising productivity above current levels have been devised and tested. In addition the 'fine tuning' and cost reducing types of output that have been generated from this research have created problems for traditionally orientated extension services, and adoption is further restricted by input supply constraints.

We go on to suggest how FSAR could be made more effective by better integration with component (commodity/disciplinary) research and with extension, and how further training could contribute to this objective.

TURNING RESEARCH OPPORTUNITIES INTO APPROPRIATE TECHNOLOGIES

A major focus of Adaptive Research in southern Africa has been to improve the often low productivity of maize grown by smallholder ox and hand-hoe cultivators. FSAR has identified a number of relevant research opportunities (Low and Waddington, 1989) but the rapid uptake of new technologies demonstrated by early programmes elsewhere has not been matched in southern Africa.

In a study into the use of outputs from FSAR programmes in Zambia, Zimbabwe and Swaziland, only about one third of the original research thrusts identified were finally adopted by farmers (Table 1). Most of these were adopted only partially or by limited numbers of farmers, largely because of input supply constraints.

Maize specific technology development followed a similar pattern. Seventeen maize technologies from three FSAR programmes in Zambia were tested in FSAR trials but only seven were actively examined by extension, six of which included new varieties. Adoption of three of the technologies was limited to collaborating farmers. The other four were more widely adopted but seldom as the complete package demonstrated (Waterworth and Muwamba, 1989).

The limited impact of FSAR on production has been recognised for several years (Waddington and Low, 1988) and has been partly due to implementational weaknesses in FSAR itself. Superficial problem diagnosis, poor implementation of field trials, inadequacies in analysis and interpretation of trial results and high turnover of local and expatriate research staff have all contributed to ineffective output.

In this paper we examine how research opportunities identified through FSAR in southern Africa have been incorporated into experimental programmes and how the output generated from these programmes has been used. We suggest that there are fundamental limitations to the exploitation of research opportunities by FSAR, which will continue to operate unless addressed, and which have wider implications for the efficiency of agricultural research and extension in general.

Collinson (1982) described how the role of FSAR in eastern and southern Africa was to determine productivity problems or shortcomings in smallholder cropping systems and adapt technologies from component research to alleviate

Table 1. *Analysis of the extent of farmer adoption resulting from 53 on-farm research initiatives*

Outcome of initiative	No. of initiatives	Cause of loss	No. of initiatives
Lost before recommendation produced	18	No follow through by researchers	5
		No improvement over current practice	5
		Suspended pending suitable seed	3
		Inconclusive results obtained	3
		Inputs not available	1
		Wrong problem identified	1
Recommendation produced	35		
Lost before extension message developed	12	Input supply problems	5
		Poor research or extension communication	4
		No improvement on current practice	2
		System incompatibility	1
Extension message developed	23		
No adoption	5	Poor research or extension communication	3
		Input supply problems	2
Limited adoption	15	Input supply problems	11
Widespread adoption	3		

Source: Waterworth and Muwamba (1989); C. Seubert (personal communication).

them. Existing commodity-based technologies developed on station, mainly for large-scale commercial farmers, were and remain the major source of solutions for use in FSAR (e.g. Collinson, 1987; Merrill-Sands and McAllister, 1988). For a well researched crop like maize it was thought that the pool of available and suitable technology was large and complete. However FSAR has shown that many existing maize technologies are unsuitable for smallholders. In addition little adaptive research has been possible where relevant component technology was not already available, as in the case of shorter season, drought tolerant maizes for late planting or for semi-arid areas, of maizes suitable for intercropping or tolerant of weeds, of planting guidelines for use on drying seedbeds or of labour saving fertilizer management on sandy soils.

The adaptive research that has taken place has been mainly concerned with 'fine tuning' current technologies and not with testing technology designed to lead to much greater yields. This has led to difficulties with the use of research results by extension workers and farmers which are considered under three headings: the reduction of inputs, the adjustment of management, and the introduction of methods enabling farmers to move towards ideal practices.

Reduction of inputs to levels suitable for smallholders

Fertilizer. Maize fertilizer recommendations in southern Africa typically advise placement and covering of a compound below or beside the seed at planting. Top-dressing with nitrogen is then recommended when the maize is about knee height. A further top-dressing at tasselling is sometimes also recommended. Recommendations concerning the quantity to apply are varied by agro-ecological region but not according to management practice. These recommendations assume responses obtained under optimal conditions on station (adequate pH, early planting, hybrid seed use, and accurate fertilizer placement and timing) which often do not occur in reality.

In Central Province in Zambia, for example, on-farm trials compared the response to nitrogen and phosphorus of early and late plantings. No response to phosphorus was obtained and no nitrogen × phosphorus interaction observed. Nitrogen was profitable at up to 200 kg N ha^{-1} for early plantings (the recommended rate), but was unprofitable above 100 kg N ha^{-1} on plantings 30 days later (Waterworth and Muwamba, 1989).

In Zimbabwe responses of hybrid maize (R201) to nitrogen on sandy soils were only economic if it was applied as a straight fertilizer (not compound) up to 60 kg N ha^{-1} in high rainfall situations (700 mm), around 65% of the current recommendation, although yield responses were obtained up to the current recommendation. In low rainfall situations (400 mm), nitrogen was economic only up to 30 kg N ha^{-1}, around 60% of the current recommendation (Mataruka *et al.*, 1990).

Similarly, localized studies on the nitrogen response of composites in semi-arid areas such as the Mwanza area in Malawi indicated that the most economic application rate was 40 kg N ha^{-1}, i.e. around half the current recommendation (communication from ART Coordination Unit, 1989).

Variety. Similar problems arise with varietal recommendations, which for maize hybrids or varieties are generally based solely on the yield and rainfall characteristics of a region and which assume early planting. Thus only long season materials are recommended for better rainfall areas. However, FSAR teams are finding that shorter duration maize may also be accepted by farmers in good rainfall areas.

In Zambia farmers indicated a preference for the early maturing variety MMV400 over higher yielding alternatives because of its flintier grain type and ability to mature in time to provide food during a mid-rainy season hunger period (ARPT-EP, 1987). In Malawi, Adaptive Research Teams at Kasungu, Mzuzu, Lilongwe and Blantyre in cooperation with the Maize Commodity Team compared the performance of the early maturing maize composite CCD (semi-flint, 110–120 days) with that of longer season hybrids and 'local' maize. The trials showed that CCD provided mature maize grain earlier to relieve hunger, it allowed the possibility of growing chickpea as a relay crop with the maize, and the possibility of partly compensating for yield losses resulting from late planting (communication from Malawi ART Coordination Unit).

Adjustment of management to fit smallholder circumstances and operational constraints

Farmers make management compromises such as delaying weeding and fertilizer application to overcome labour shortages. The FSAR team in Eastern Province in Zambia compared a mixed basal and top-dress fertilizer application two weeks after emergence with a split application of a basal dressing at planting and a top dressing at four and six to eight weeks after emergence. The results confirmed those of earlier station trials and showed that a mixed fertilizer application combined with the first weeding gave a 25% yield advantage over a late top dressing (six to eight weeks after emergence) on demonstration plots over 58 sites (Waterworth, 1989). Similar work in Central Province showed that top dressed fertilizer combined with a weeding when the maize was 20 cm tall gave a saving of six man days per hectare during the peak labour period, and increased yield by 19% and the net benefit by 40% compared to the normal farmer practice of weeding and top dressing when the maize was 70 cm high (Waterworth, 1989).

On-farm trials in Mangwende, Zimbabwe, showed that the currently recommended basal fertilizer dressing at planting on sandy soils gave no yield increase over the farmer practice of applications 10–14 days after emergence (Shumba, 1989a, 1989b).

Introduction of methods enabling farmers to move towards known ideal practices

Reduced tillage. Since shortage of oxen contributes to late planting and poor seedbed preparation, reduced and zero tillage options have been tested to help farmers plant earlier and overcome problems associated with poor seedbeds.

On-farm trials in Mangwende, Zimbabwe, compared reduced tillage (use of a ripper tine) with conventional mouldboard ploughing. The tine treatment gave no significant yield difference, but resulted in increased weed competition (Shumba, 1989a, 1989b). However, use of the tine resulted in a reduction of oxen and labour time for ploughing of 11 hours ha^{-1} and a reduction in planting time of 22 hours ha^{-1}. The time needed for hand weeding was increased by around 106 hours ha^{-1}, but this could be avoided by incorporation of herbicide into the reduced tillage option, resulting in a marginal rate of return of 1680% on the extra cash investment (Shumba, 1989a, 1989b).

Zero tillage combined with Gesaprim (pre-emergence) and Gramoxone (post-emergence) herbicide gave no yield advantage in Central Province, Zambia, but released 14–24 man days ha^{-1} from hand weeding and provided opportunities for earlier planting by those farmers without oxen for ploughing (Waterworth and Muwamba, 1989). A greater cash outlay was required than for conventional tillage but rates of return on the increased investment were around 400%.

Modifications to methods of planting. On-farm trials in Swaziland looked at ways of helping farmers achieve higher plant population densities. Modifications to an ox drawn planter were tested which, by placing basal fertilizer 2 cm to one side of the seed rather than above it, increased seedling emergence from 60% to 80–100% with low rates of fertilizer (11 kg N ha^{-1}), and from 20% to 80% with higher applications (22 kg N ha^{-1}) (Seubert *et al.*, 1988). Associated trials demonstrated that the economic benefits of higher fertilizer applications were dependent on high plant population densities. Other tests showed farmers how to calibrate the fertilizer hopper to deliver the required amount of basal fertilizer at planting and how to match seed size with planter plates to minimize seed damage at planting (Seubert *et al.*, 1988).

OUTPUT USE CONSTRAINTS

These and other examples (see Low and Waddington, 1989) show that imaginative adaptations to current recommendations, based on a good understanding of farmers' circumstances, could raise maize productivity above current levels through adjustments in management and input use. But there are difficulties in developing such results from FSAR into extension recommendations, demonstrations or messages. For example, the results obtained from reduced fertilizer trials for late planted maize in Central Province, Zambia, were never included in formal recommendations. The mixed basal and top dressing option was not successfully demonstrated in Eastern Province in Zambia and was wrongly demonstrated in Central Province. Zero tillage has not been promoted in Central Province, Zambia, and the tine technology in Zimbabwe has only been adopted by 10% of participating farmers. The problems seem to arise from limitations in the capacity of the extension service to handle output emanating from the trials described and from input supply problems.

Extension orientation

Much of the output generated from FSAR trials has characteristics that extension services find difficult to handle. Less than ideal management recommendations conflict with the technical training extension officers have had on how best to grow a crop and the technical orientation they receive in service. Thus, FSAR results often get simplified towards their concept of an ideal system. Similarly changes in practices that save resources or give indirect benefits to other crops or farmers, but do not raise yields per unit of land of the target crop, are difficult to extend through demonstrations and require a systems or community approach. Results that suggest the use of reduced input levels often reflect what farmers are already doing and are therefore seen to have no extension implications.

Examples of these difficulties include the following:

> Results from a number of adaptive research programmes which show that the application of basal fertilizer after planting and the mixing of basal and top dressing as a single application give risk and labour use advantages with little or no yield loss have not been accepted as extension recommendations.
>
> Recommendations formulated on varieties and fertilizer rates in Luapula Province, Zambia, only mentioned the use of hybrids and 60 kg N ha^{-1}. Consistent adaptive research results indicating the superiority of an open pollinated improved variety when no fertilizer was applied were totally omitted from the recommendations.
>
> In Central Province, Zambia, adaptive research results showing the advantage of combining fertilizer application after emergence with an early weeding were turned into a demonstration of early weeding with fertilizer applied at planting (the standard commercial recommendation for timing of basal fertilizer).

Supply constraints

Even where technologies are demonstrated by extension, input or equipment supply problems can block adoption. In southern Africa some of the on-the-shelf maize production technologies developed originally for large scale commercial farmers were found to be appropriate in some smallholder situations. These included zero tillage and chemical weed control in Central Province, Zambia. However, they have not been widely extended because of chemical and equipment supply problems. In three Provinces in Zambia, 44% of adaptive research trials used in extension demonstrations got no further because of input supply problems (Waterworth and Muwamba, 1989).

FUTURE DIRECTIONS FOR PROBLEM ORIENTATED RESEARCH

Over the longer term we suggest that FSAR has more to contribute to improving the productivity of smallholder crop enterprises than better adaptation or fine tuning of technologies developed on station. There is increasing evidence that FSAR has generated an awareness among commodity/disciplinary researchers and extension services of farmer decision making criteria and the importance of non-technical factors in the adoption of technology. There is a better appreciation of the variation in circumstances between groups of farmers, which makes nonsense of 'standard, technically ideal' recommendations and suggests the need for a range of 'sub-optimal' technical options to fit different circumstances, priorities or capacities of farmers. This awareness now needs to be effectively harnessed. This involves integrated research planning, a problem orientated approach to extension and consideration of policy makers as clients for research.

Integrated research planning

The development of strong linkages between FSAR and component research is essential, yet in practice such cooperation has proved difficult to initiate and maintain. This is partly because FSAR has been introduced as an activity done by teams separate from the rest of already established research units. Because of its close contact with farmers and extension, FSAR is in a unique position to help orientate component research agendas towards technologies which are useful to farmers, as has long been recognized (Collinson, 1986; Merrill-Sands and McAllister, 1988; Haugerud and Collinson, 1990).

Information to be shared needs to cover more than just the problems to be addressed. It is also necessary to consider their causes and which types of solution would be most appropriate in view of farmer circumstances. In return, component research may be able to suggest new topics for FSAR.

There are examples in southern Africa where the interaction between FSAR teams and component research has been effectively developed (for Zambia see Kean and Singogo, 1988; for Zimbabwe see Merrill-Sands and McAllister, 1988). But the orientation of component agricultural research with FSAR has been very much a secondary activity and needs strengthening. Merrill-Sands and McAllister (1988) have suggested several important ways in which this could be achieved.

Problem orientated approach to extension

In general, links between FSAR and extension services remain ineffective (Ewell, 1989). Currently, extension involvement in FSAR is restricted to helping to implement diagnostic and trial activities and attempting to use the results. Experience in southern Africa (Seubert, 1989; Kean and Singogo, 1988; Chipika, 1987) suggests that the technical training and background of extension staff make it difficult for them to understand even why different sets of recommendations are needed for different target groups of farmers. For this reason extension staff need to be more fully involved in diagnosis, problem identification, activity planning and evaluation as well as in the implementation of FSAR. Extension officers must be trained, as researchers have been, in the problem orientated approach to research and extension (Cernea *et al.*, 1984).

A start has been made by AGRITEX in Zimbabwe (Low, 1988) and by the Department of Field Services and Research in Lesotho. In Zimbabwe five provinces have run field diagnosis courses for their specialist staff and agricultural extension officers with CIMMYT assistance. Teaching in these courses approaches problems from the farmers' viewpoint in a practical setting and has begun to reorientate the way in which AGRITEX staff view their roles. AGRITEX are also improving their on-farm demonstrations and trials. An on-farm research programme has been jointly planned in one district of Lesotho and is being jointly implemented by a team of 20 extension staff and five researchers (all Basotho), in cooperation with CIMMYT.

The Swaziland Cropping Systems Research and Extension Training Project is a well established FSAR programme that has recognized extension as the major client for its research output. Field Support Guides are written directly for extension officers, and extension training has focused latterly on the development of a problem orientated approach to extension (J. Diamond, personal communication).

Kean and Singogo (1988) and Ewell (1989) describe considerable interaction at many levels between the Adaptive Research Planning Teams (ARPT) and extension staff in Zambia. The establishment of Research Extension Liaison Officers and the use of extension workers as trials assistants by ARPT have been important and reports and newsletters have been developed specifically for extension staff.

Policy makers as new clients for research

FSAR needs to have clients other than farmers, and component research and extension staff. Although input supply problems have been recognised as a constraint to the use of some of their technologies (e.g. Waterworth and Muwamba, 1989 for Zambia), FSAR teams have not been adept at orientating their research results and reports towards staff in planning ministries, or at impressing on supply and marketing organizations the need to change input supply policies (or showing the costs of not changing them). Economists employed as members of FSAR teams should be able to take a lead in addressing agricultural policy makers as they gain experience and as their involvement in diagnostic studies is reduced. They will need guidance, encouragement and perhaps some training, to help identify opportunities and conduct appropriate analyses.

Implications for FSAR methods and training

Most FSAR staff realize that their roles involve linking with component research and extension staff, as well as with agricultural policy makers. However, the development of these roles often remains a secondary activity and early papers and texts describing FSAR methods at best mentioned such activities in passing. The appropriate training combined with development and documentation of case studies is urgently needed. CIMMYT FSAR training workshops in eastern and southern Africa now place some emphasis on the importance of linkages and show

how FSAR might use research findings to influence policy makers, yet the subject is proving difficult to teach. It is also necessary to extend the training beyond the current range of research and extension participants to reach a wider group.

In conclusion, a future challenge for individuals involved in agricultural research and extension for African smallholder farmers is to develop ways for more effective integration between key groups involved in technology generation, dissemination and support, and to teach those methods to new staff. Management specialists and techniques can be expected to make a useful contribution in this area. The beneficial integration of social with technical sciences through FSAR can perhaps be enhanced by a further integration of management science into the overall process of technology generation and dissemination.

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