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A Synthesis of Findings concerning CGIAR Case Studies on the Adoption of Technological Innovations

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The Ghana Grains Development Project, Farm-level Technology Adoption - CIMMYT

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Background

The GGDP was launched in 1979 with funding from the Government of Ghana and the Canadian International Development Agency; its purpose being to develop and diffuse improved technology for maize and grain legumes. Together with the Crops Research Institute (CRI), the Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT) served as the primary executing body and ancillary support was provided by three other organizations. The Grains and Legumes Development Board and the Ministry of Food and Agriculture assumed the main responsibility for technology transfer activities, while the International Institute for Tropical Agriculture (IITA) supported technology development efforts for grain legumes.

The GGDP, which operated for 18 years before ending in 1997 when external funding terminated, can take credit for several important accomplishments. It contributed significantly to the strengthening of local research and extension capacity by supporting numerous staff training activities; it helped to establish methods and procedures for organizing adaptive research and linking research to extension programmes; and, it helped to develop technology recommendations for maize and grain legumes.

This report describes the main findings of the case study in examining the adoption of three improved maize production technologies developed through the GGDP: (a) improved germplasm, (b) fertilizer recommendations, and (c) plant configuration recommendations. These technologies were by no means the only ones developed by the GGDP but they are among the most important.

Description of the GGDP-generated maize technologies

Improved germplasm

Plant breeders at the CRI had developed and released several MVs of maize prior to the GGDP. However, these early MVs generated little interest among farmers and were not widely adopted. GGDP's success in improving maize breeding was in part due to its being able to capture 'spillover benefits' generated by CIMMYT's global germplasm improvement network. Each year of the project, CIMMYT breeders provided their CRI counterparts with a selection of experimental varieties. Trials were conducted at CRI to identify which of the CIMMYT varieties were best adapted to Ghanaian conditions, and the most promising seed was distributed to farmers for on-farm testing. Working hand in hand with farmers, GGDP scientists identified truly outstanding varieties which were then taken back to CRI for several additional cycles of selection and improvement. This collaborative process, involving CIMMYT breeders, CRI breeders and Ghanaian farmers, led to the release in 1984 of a series of improved maize varieties, all of which contain germplasm whose origins trace back to CIMMYT.

Fertilizer management

In spite of numerous government-sponsored projects designed to promote the use of fertilizer on food crops, when the GGDP was launched in 1979 few farmers in Ghana applied fertilizer to their maize fields. This was quickly identified as a priority for research as experimental evidence showed clearly that in many areas poor soil fertility severely constrained yields.

Although the relative unpopularity of fertilizer among Ghanaian maize farmers could be attributed to a number of causes, it was largely due to the lack of widely accessible recommendations for applying fertilizer to maize. In an attempt to rectify this, GGDP researchers

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organized an on-farm testing programme to develop fertilizer recommendations for maize. The challenge was to formulate recommendations sufficiently flexible to accommodate the wide range of soil fertility conditions found in farmers' fields, yet simple enough to be incorporated into existing extension programmes.

In contrast to the GGDP plant-breeding studies, GGDP research on crop-management practices (fertilizer use and planting practices) did not involve direct introduction of CIMMYT-generated technologies. Unlike improved germplasm, which can be developed at CIMMYT headquarters in Mexico and distributed around the world, crop-management recommendations are by nature location-specific. Thus, they have to be developed on a country-by-country basis, taking into account local agro-climatic conditions, planting materials, crop-management practices and prices.

CIMMYT's contribution to GGDP crop-management research took two main forms, training researchers and providing technical assistance. During the project, over 1000 CRI researchers and local collaborators received training in the design and management of crop-management trials. In addition, CIMMYT scientists based in Ghana throughout the project, actively participated in planning and implementing the GGDP crop-management research programme.

Following several years of trials, GGDP researchers came up with a set of fertilizer recommendations that distinguished among agro-ecological zones and took into account field cropping histories. Recommended application rates varied, ranging from no fertilizer application for forest-zone fields that had been fallow for five years or more to application of compound fertilizer at a rate of 90-40-40 for fields in the savannah zone that had been continuously cropped for two years or more.

Plant configuration

In most parts of Ghana, maize is traditionally planted in a random pattern, with a relatively large number of seeds placed in holes at least one metre apart. Although this strategy is appropriate for tall local varieties grown under low levels of soil fertility, GGDP researchers determined that this was less than optimal for short MVs, especially when chemical fertilizer was used. Early experiments at CRI established that Ghanaian MVs can tolerate a significantly higher planting density than the tall local varieties that farmers were accustomed to growing.

The GGDP plant configuration recommendations, and the fertilizer recommendations, were based on extensive on-station and on-farm experiments and were easily communicable to farmers. Planting in rows was emphasized as an aid in calibrating plant population densities and as a means of achieving plant spatial arrangements to facilitate subsequent crop-management operations, such as weeding and fertilizer application. In addition to stressing the importance of row planting, the recommendations focused on reducing the distance between holes and the number of seeds planted per hole.

Adoption of improved maize technologies

Data on the adoption of the GGDP-generated maize technologies were collected through a national survey of maize growers carried out between November 1997 and March 1998. A three-stage clustered randomized procedure was used to select a representative sample of 420 maize farmers. These farmers were questioned at length about their maize production, consumption and marketing practices; their preferences for different maize varietal characteristics; and their knowledge of, and access to, improved inputs, such as seed and fertilizer (for additional details about the survey, see Morris *et al.* 1998).

The survey revealed that adoption of GGDP-generated maize technologies was extensive. During 1997, over half the sample farmers (54%) planted MVs on at least one of their maize fields, and a similar proportion (53%), implemented the plant-configuration recommendations (Table 1). However, the rate of fertilizer use was lower as less than a quarter of the sample farmers (21%) had applied fertilizer.

These findings provide clear evidence that the GGDP-generated maize technologies have been diffused widely. In 1997, two thirds of all Ghanaian maize farmers used at least one of the three improved technologies – by any measure an impressive number, especially considering that in Ghana maize is grown mostly by small-scale farmers living in isolated communities. Clearly the GGDP has made good progress in achieving its objectives of developing and disseminating improved maize technologies.

Table 1. Adoption of GGDP-generated maize technologies, Ghana, 1997

	Percent of farmers that on at least part of their farm used:		
	Modern varieties	**Fertilizer**	**Row planting[a]**
Guinea savannah	66%	36%	73%
Transition	68%	29%	59%
Forest	38%	9%	39%
Coastal savannah	69%	29%	65%
All zones	**54%**	**21%**	**53%**

[a] n = 392 (excludes ridge planting).
Source: 1998 CRI/CIMMYT survey.

The impacts of the GGDP-generated maize technologies

In the absence of reliable baseline data, it was not possible to calculate quantitative measures of project impact. Based on farmers' assessments, however, it is clear that adoption of the GGDP-generated technologies has been associated with significant productivity gains, as well as noticeable increases in income earned from sales of maize. Impacts on the nutritional status of rural households appear to have been less pronounced. Even though the latest MVs have been extensively promoted for their improved nutritional status, relatively few of the survey respondents were aware of this, and those who were said they rarely seek out nutritionally enhanced MVs to prepare weaning foods for infants and young children.

Factors affecting adoption

In addition to documenting the uptake and diffusion of the GGDP-generated maize technologies, the Ghana case study provided important insights into factors affecting the adoption of agricultural innovations. The survey showed that three factors influence adoption: characteristics of the technology, characteristics of the farming environment and characteristics of the farmer.

Characteristics of the technology

It has long been recognized that the rate and extent of adoption of new technology are conditioned by the nature of the technology itself. Important characteristics that can encourage or discourage adoption include the complexity of the technology, its profitability, degree of risk, compatibility with other technologies or practices, and divisibility. By themselves, these characteristics do not determine adoption; technologies that are simple, inexpensive and risk-free may never be taken up, just as technologies that are complex, costly or risky may find wide acceptance. However, as the GGDP demonstrated, the characteristics of new technologies tend to matter and they deserve careful attention.

The three GGDP-generated maize technologies represented different levels of complexity. MVs were the least complex, because their adoption required relatively few changes to farmers' current practices. Plant configuration ranked next in terms of complexity, because in order to adopt the row-planting recommendation farmers had to learn how to use planting ropes or sighting poles, and how to measure row and plant distances. Fertilizer use was the most complex as its efficient use involved learning the names of different products, their nutrient composition, correct application rates, optimal application schedules and efficient application methods.

However, the complexity of the technology is only one factor influencing adoption and what actually happens in farmers' fields depends on other factors as well. One important determinant of adoption is the expected profitability of the technology. Farmers naturally are interested in technologies that promise to give higher returns for scarce factors of production (e.g. land, labour or cash). Of the three GGDP-generated maize technologies, fertilizer use has more potential to increase yields than the adoption of MVs or row planting, but the higher yields have to be balanced against the higher cash costs associated with fertilizer use. MVs and row planting generate lower net benefits but require very little cash investment, so the rate of return in relation to the investment required is extremely attractive.

Farmers also look at the risks involved in adopting a new technology and several types of risk can be identified. Although farmers may be convinced that a new technology works, they may be uncertain as to how it will perform on their own farm. Their uncertainty can usually be allayed by observing the technology in a neighbour's field or in a nearby demonstration plot. Another type of risk relates to the technology's performance during periods of unusual climatic stress (e.g. drought). This may be more difficult to assess because such periods do not occur very often. Research has shown that farmers often place a premium on stability and choose technologies that perform satisfactorily under a wide range of conditions, instead of technologies that perform exceptionally well, but only under favourable conditions. A third type of risk is the possibility of losing the investment made in an improved technology. This is particularly relevant in the case of fertilizer. Purchasing fertilizer involves a significant cash outlay and many farmers worry that in years of low rainfall fertilizer will have little effect.

New technologies stand a better chance of adoption when they are compatible with existing farming practices. In general, the maize technologies produced by the GGDP were not only compatible with other widely used crop-production practices, they were also compatible – and indeed highly complementary – with each other. Farmers who decided to adopt MVs were required to make few changes to their crop-management practices other than changing their seed. Adopting row planting involved learning a new planting technique and took longer, but the additional time required for row planting was more than made up for later on by labour saving in weeding and fertilizer application. Neither did the use of chemical fertilizer significantly affect existing practices, although it did increase the need for labour during certain periods of the cropping cycle.

A final characteristic of the three maize technologies was that they were divisible and could also be adopted on part or all of a farm. This reduced the risk involved by allowing farmers to adopt each recommendation in a step-wise fashion. Indeed, the survey results make clear that many farmers are partial adopters who even today use only one or more of the three technologies on part of their maize area. The divisibility of the three technologies also made them accessible to both large- and small-scale farmers.

Characteristics of the farming environment

Even when a technology is simple, profitable, relatively secure, compatible with farmers' current practices and divisible it still may not be adopted as adoption also depends on the environment in which farmers operate. Farming characteristics that can affect technology adoption include agro-climatic conditions, type of cropping systems used, the degree of commercialization of the cropping enterprise, factor availability, farmers' knowledge and access to technical information, and the availability of physical inputs.

Although maize is grown in most parts of Ghana, some areas are better suited for maize production than others. The most favourable areas are concentrated in the transition zone and in parts of the Guinea savannah as these areas receive more sun and have lighter soils and fewer trees, facilitating land preparation. Maize can be grown in forest areas but agro-climatic factors are generally less favourable for maize production and competition from tree crops is greater. In addition, arable land is still relatively abundant in the forest zone, which reduces the attractiveness of land-conserving technologies, particularly fertilizer. The observed differences in adoption rates between forest and other zones stem in part from the generally lower profitability of maize in forest areas in relation to alternative crops, especially cocoa.

Cropping systems in Ghana are complex and varied, and it is only to be expected that improved technologies will be used in different ways, depending on local practices. Although MVs appear to be compatible with most current maize-cropping systems, farmers who adopt the recommendations for row planting and fertilizer management may have to make adjustments. In the northern part of the country, many maize fields are prepared by ridging up the soil, a practice that improves moisture conservation and facilitates fertility management. Farmers who ridge their fields already plant in rows, so for them the GGDP-generated row-planting recommendation is of little relevance. In the southern part of the country, particularly in heavily forested regions, soil fertility is periodically replenished through a carefully managed bush fallow system. Farmers with access to extensively fallowed land may not face soil-nutrient deficiencies and chemical fertilizer will be of little relevance.

Farmers' choice of technology tends to be influenced by the degree to which the crop is marketed. Varietal selection criteria often vary depending on whether the harvest will be consumed at home or sold for cash. If maize is grown mostly for home consumption, food preparation qualities, such as appearance, taste, smell, grain texture, ease of processing and storage quality assume great importance. However, if maize is being grown for sale as a cash crop, grain yield and market price tend to be the most important factors.

The Ghanaian experience with MVs has been quite revealing in this respect. In the north of Ghana, where a lot of maize is retained for home consumption, in general MVs were judged acceptable for food preparation. Whereas initially in the south there was some concern about the suitability of MVs for preparing local foods and these concerns were sometimes reflected in lower market prices for MVs. However, the higher yields of the MVs offset this disadvantage and despite the occasional price differential, MVs have by now gained acceptance even among commercial farmers.

Regardless of how attractive a new technology may be, it is unlikely to be adopted if this requires farmers to contribute additional factors of production they do not have and cannot easily obtain. Of the three GGDP-generated maize technologies, the two that might have been affected by factor scarcities were row planting and fertilizer use, as both require additional labour and fertilizer use requires a significant cash investment. Judging from the survey results, the labour constraint does not appear to have been binding as few farmers gave this as a reason for not adopting the GGDP technologies. A lack of capital may have been more important, however, as many farmers reported not using fertilizer because they did not have the money to buy it.

Since farmers cannot adopt improved technologies unless they have first heard about them, successful adoption depends upon farmers having access to detailed and accurate technical information. This can reach farmers from various sources, but it is likely to reach them most rapidly (and with fewer errors) if there is a well-functioning extension service in place.

Regular contact with extension officers has been an important factor in the adoption of all three GGDP-generated maize technologies. However, extension resources are scarce in Ghana and not all farmers have been reached equally. In the past, extension organizations placed relatively little emphasis on promoting maize in forest areas, which may help to explain lower adoption rates in those areas. In addition, although good progress has been achieved in making extension activities gender neutral, survey results suggest that, on average, women farmers still have fewer contacts with the extension service than men.

Finally, even if farmers know of a new technology, it will not be adopted if it requires inputs which are not available. Of the three GGDP-generated maize technologies, two are based on inputs (MV seed and chemical fertilizer). Although theoretically improved seed should be available from local shops, in practice the seed industry is still very underdeveloped, particularly in more isolated areas.

Many farmers manage to procure improved seed from extension officers, who at times are able to provide seed samples as part of an extension programme or who sometimes sell seed on a commercial basis as a business sideline. Of course, once a particular MV is grown in an area, local farmers can usually acquire farm-saved seed from early adopters. Obtaining fertilizer is generally more problematic as fertilizer is bulky and must be purchased each season. Fertilizer distribution was recently privatized in Ghana, but the number of agents continues to be restricted by low demand.

Characteristics of the farmer

A third set of factors affecting technology adoption relates to farmers' personal circumstances, including ethnicity and culture, wealth, education, gender and security of access to land. Farmers considering exactly the same technology and operating in exactly the same farming environment can end up making very different adoption decisions.

Ghana's maize farmers belong to a large number of different ethnic groups, each with its own language, customs and form of social organization. Cultural factors frequently affect a farmer's access to resources, obligations to contribute to different types of agricultural production activities, claims to crops harvested from communally cultivated fields, and access to external sources of information, etc. Cultural factors are particularly evident when comparing the patrilineal societies of the north with the matrilineal societies that dominate much of the south. Women's access to land and capital, their decision-making responsibilities in maize farming and their ability to mobilize labour, all differ significantly between these two traditions and are factors directly affecting the attractiveness of improved technologies. To further complicate matters, many farmers are migrants from other areas who have to balance their own customs with those of the host culture. This can inject additional layers of complexity to technology adoption decisions.

The vast majority of Ghana's maize farmers cultivates only a few hectares of maize or less and thus can accurately be characterized as small-scale farmers. Nevertheless, despite the relatively restricted range of farm sizes, differences in wealth are evident between farmers and this can affect the technology adoption process. Farmers with higher incomes generally enjoy advantages that facilitate adoption. For example, they may find it easier to make contact with extension officers or to tap into other sources of technical information. Once they have heard about an improved technology, they may be more able to travel to distant towns in search of agricultural inputs and have fewer difficulties in raising the cash needed to purchase them. Considering these and other advantages associated with wealth, it is not surprising that the rate of technology adoption is slightly higher on larger farms which presumably are owned by wealthier farmers.

Another farmer-related characteristic of importance in the adoption process is the farmer's level of education. Survey results show that farmers who have adopted one or more of the GGDP-generated maize technologies have received significantly more formal schooling than those who have not adopted. Since the adoption of improved technologies requires the acquisition and assimilation of new information, this result is not surprising.

Keys to the success of the GGDP

Data collected in late 1997 and early 1998, through a national survey of maize farmers, indicate that GGDP-generated maize technologies have been disseminated widely throughout Ghana's maize-growing areas. Based on this evidence, it is clear that the project has succeeded in meeting its objectives of raising productivity, increasing incomes and improving nutrition for resource-poor households. In the process, an additional goal of the project has been realized, as CRI has greatly strengthened its capacity to carry out effective commodity-focused research.

In retrospect, the success of the GGDP can be attributed to four main factors:

- *The objectives of the GGDP were well chosen.* Maize is produced and consumed throughout Ghana, so improved technologies that succeeded in increasing the productivity of resources devoted to maize production were bound to have significant and widely felt impacts.
- *The GGDP adopted an extremely effective research strategy.* By extensively testing experimental technologies at farm level, researchers were able to foster the active participation of farmers in the technology development process, which helped to ensure that the recommendations were appropriate for farmers' circumstances.
- *Research was linked with an effective extension strategy.* Considerable efforts were made to familiarize extension officers with the technologies by involving them in on-farm testing activities. Once recommendations had been formulated, extension officers played a key role in implementing a national programme of demonstration trials which served to widely publicize the technologies.

- The project served as a model for collaboration between three groups of key players: (i) national agricultural research and extension organizations, (ii) IARCs, and (iii) a committed donor agency. These organizations interacted very effectively throughout the project, allowing the particular strengths of each to be exploited and ensuring that the product of the collaborative effort was far greater than the organizations could have achieved by acting alone.

Reference

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