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Plants, Genes and People: Improving the Relevance of Plant Breeding

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PLANTS, GENES AND PEOPLE:
IMPROVING THE RELEVANCE OF PLANT BREEDING

Angelique Haugerud and Michael P. Collinson

Introduction

Plant breeding dominates international agricultural research, accounting for some 50% of the budgets of the International Agricultural Research Centres. Recent innovations in breeding programmes for developing nations highlight differences in selection criteria between farmers and scientists, and among farmers themselves. Scientists' and farmers' assessments of new crop varieties diverge, not because farmers lack formal scientific knowledge, but because scientists often fail to use farmers' knowledge and to accommodate their constraints. Farmers' own cultivar preferences vary according to characteristics such as farm size, family structure, gender, wealth, and market opportunities.

Overlooking both types of divergence in breeding criteria carries the twin risks of releasing new crop varieties farmers do not adopt, and rejecting germplasm farmers find valuable. Ignoring the differences can also mean a breeding programme's new cultivars reach only a narrow range of farmers. This paper addresses ways to reduce such risks.

Plant Breeding and the IARCs in Africa

In Africa, the International Agricultural Research Centres (IARCs) have spent more per head, hectare and tonne of food, with less to show (as yet) for the effort than elsewhere. Africa's position in the world economy, its diverse environments, economies and sociopolitical systems all contrast sharply with the conditions of the Asian 'Green Revolution'. Communications, food transport costs, the means to distribute agricultural inputs on time, water availability, soils and climatic conditions are all less favourable in Africa than in Asia. Foreign exchange to import chemicals and fertilizers is scarce, and both foreign and domestic terms of trade often work against agriculture. African farmers diversify their economic pursuits and limit their dependence on uncertain markets and government services.

Wheat and rice, Asia's food staples, are luxuries in Africa, yet staples such as sorghum, millet, cassava, chickpeas and cowpeas have only recently received research attention from both national programmes and IARCs, as have regions with poor soils and low and unreliable rainfall.

Africa's national research institutions often retain the orientations of western agricultural education (Collinson, 1988). University agricultural curricula are still centred on large fields, machines, straight lines and intensive management. These biases threaten the long-term sustainability of African agricultural systems, and limit the relevance of national and international research. Relevance is also jeopardised by a single-discipline focus, narrow peer group evaluation, unquestioning adherence to inherited breeding strategies, and inadequate exposure of plant breeders to small farmers' circumstances.

Traditional western agricultural curricula, for example, discount inter-cropping, though many plant scientists today recognise that insufficient research has been done on possible positive interactions of species and cultivars planted in mixtures (Altieri, 1985; Willey 1979). Complementary effects involving the uptake of soil nutrients or water, for example, are poorly understood, as is the degree to which crop and cultivar mixtures may slow the spread of pathogens and pests. Yet intercropping research in Africa is often considered a retrograde step.

Attempts in the last decade to institutionalise processes for agricultural researchers (both national and international) to learn directly from farmers, and for farmers themselves to do more than react to scientists' proposals have been dominated by various types of farming systems research (FSR) (Byerlee et al., 1982; Collinson, 1985, 1988; DeWalt, 1985; Horton, 1986; Merrill-Sands, 1986; Norman et al., 1982; Rhoades, 1985; Eicher and Baker, 1982; Hildebrard, 1981). Though the term FSR itself has become controversial, its basic principles are of lasting importance. These include:

- the need for close collaboration among technical scientists (both physical and biological) and social scientists;
- the usefulness of multi - rather than single-commodity approaches (since farmers themselves pursue multiple enterprises and evaluate technical innovations in any one crop in the context of the systems they operate);
- an explicit recognition that the farmer and other agents in the food system are the primary clients of agricultural research, and that farmers' current production systems must be understood in order to design and assess on-farm and on-station experimental programmes intended to improve production.

The less effective alternative has been for researchers to seek the optimal way to grow crops and to expect farmers to adjust to these requirements. When scientists' selections of new crop varieties are based solely on features of the natural environment (such as rainfall, soils and temperatures), farmers may reject the high-yielding varieties scientists most admire. More than maximum yield, African cultivators often favour yield stability, short maturation periods, suitability for intercropping, storability and particular taste or cooking characteristics.

How African Farmers Use Cultivar Diversity

Breeding programmes have rarely exploited small farmers' sophisticated knowledge of differences among cultivars, and their use of these differences in cropping strategies. Cultivators classify varieties, and value particular characteristics, for different purposes. They often manage a combination of cultivars in the production process, and multiply or eliminate varieties as they evaluate their performance over time (Brush et al., 1980; Conklin, 1988).

Farmers themselves are expert experimenters with new plant materials (Johnson, 1971; Ninez, 1984; Rhoades, 1987; Richards, 1985). When testing promising new plant genotypes, scientists can improve the relevance of their research by drawing upon farmers' own informal methods of experimenting with unfamiliar cultivars and practices. Farm innovators over thousands of years have enabled the human population to double ten times since agriculture began, including eight doublings before industrialisation and the use of fossil fuels:

> The human population expanded as traditional agricultural societies learned to domesticate animals, select crop varieties, manage weeds and insects, and enhance nutrient recycling. Both ecosystems and social systems were modified to sustain improved agricultural technologies. The transformations occurred through experimentation, fortuitous mistakes, and natural selection (Norgaard, 1985).

African farmers are less likely than scientific breeders to seek a single best cultivar for any given crop. Instead, an accepted new cultivar usually joins other valued genotypes of the same crop in a farmer's fields. Mixed stands (of cultivars as well as species) are conventional. Plant breeders can ease their own task by combining groups of relatively compatible traits into different cultivars in the knowledge that farmers will readily manage more than one.

Yield stability in Africa, unlike that in industrial economies, depends on a patchwork of many different varieties planted on the same farm, rather than on a continuous supply of new cultivars (Plucknett and Smith, 1986). In the West, rapid evolution of new races of pathogens prompts a frequent turnover of cultivars of such crops as wheat, for which the average lifespan of a new variety in northwestern US is only five years (Plucknett and Smith, 1986). Wheat mixtures have recently been rediscovered as a means of managing pathogens. The biological hazards of genetic homogeneity in the US are demonstrated by the speed with which Florida's citrus crop succumbed to citrus canker bacterial infection in the mid-1980s, and by the devastating southern corn leaf blight in 1970. In 1983, for example, 86% of Florida's commercial orange harvest consisted of just three varieties, while two-thirds of its grapefruit crop was made up of a single strain (MacFadyen, 1985).

In developing countries, cultivar specialisation may increase short-term profits for a few large farmers, but threaten the long-term environmental and economic sustainability of production. The IARCs can help national programmes to reduce the likelihood of epidemics caused by breakdown of monogenic resistance in popular cultivars.

In addition to epidemiological reasons for monitoring cultivar specialisation in Africa, the local relevance of breeding agendas depends upon understanding farmers' everyday strategies of cultivar diversification. Some maize and potato examples illustrate this point.

How Rwandan Farmers Use Potato Cultivar Diversity

Farmers in Rwanda recognise several dozen different potato varieties, which they distinguish according to plant and tuber traits, as well as agronomic and culinary characteristics. Most grow three to eight different cultivars at once. They mix cultivars within fields, and use variability in traits such as the length of the growth cycle, dormancy (time elapsed between physiological maturity and sprouting), disease resistance (particularly late blight), tolerance of rainfall excesses and deficits, and dry matter content (which affects taste and storability) to manage the vagaries of both nature and the market (Scott, 1988; Durr, 1980, Poats, 1981).

Since most potato varieties introduced into Rwanda before the late 1970s were from a relatively narrow genetic base (European-adapted *Solanum tuberosum*), cultivar diversity provides less protection against environmental hazards than in the crop's Andean homeland. Nonetheless, Rwandan farmers do use the available diversity to help reduce their production, consumption and marketing risks, and to spread labour requirements and food supplies more evenly across the annual cycle. Cultivar mixtures allow the use of staggered harvests and varied growth cycles, which permit farmers to extend the period of fresh food and cash availability.

Distinctions between 'traditional' and 'modern' varieties, always problematic, are quickly blurred in Rwanda, where potatoes have only been grown for about a century, and where in recent decades dozens of cultivars have been introduced, from Europe and South America in particular. The four most frequently grown potato cultivars in Rwanda (*Montsama*, *Sangema*, *Gashara*, and *Muhabura*) have diverse origins. Agricultural research institutions introduced *Montsama* and *Sangema* into Rwanda from Mexico in the 1970s, and *Gashara* from Europe a number of decades ago. Farmers and traders probably brought *Muhabura* into Rwanda from Uganda. *Montsama*, *Muhabura* and *Sangema* were multiplied and distributed by the Rwandan national potato research programme (PNAP) in the late 1970s and early 1980s.

Farmers rate these four popular cultivars as having distinctly different maturity and dormancy periods, water content, cooking time, storability, late blight resistance, market acceptability, response to moisture stress, and suitability for intercropping (Haugerud, 1988). The variety *Muhabura*, for example, though disliked for its taste and poor storability, is appreciated for its short dormancy. Farmers appreciate *Sangema* for its taste, market acceptability, yields under good rainfall, and late blight resistance (which Rwandan farmers equate with good yield under heavy rain), though they appreciate less its long dormancy and long growth cycle.

The degenerated cultivar (degeneration refers to accumulation of viruses) *Gashara* would have been abandoned long ago if disease resistance and yield were farmers' sole decision criteria. Many farmers continue to cultivate *Gashara*, however, because of its short growth cycle, short cooking time, short dormancy, and good taste (low water content). The continued popularity of this cultivar suggests one neglected strategy for current breeding and germplasm screening. We return later to this and other implications of the farm survey work for germplasm screening in Rwanda.

East African Farmers' Use of Maize Cultivar Diversity

Farmers recognise in maize, as in potato cultivars, important differences in taste, texture, storability, marketability, disease and pest resistance, and response to moisture stress. At least nine possible end uses, many of them simultaneously relevant on a single farm, help to determine the maize genotypes east African farmers prefer. The crop may for example, be consumed at home green or dry brewed for beer, or sold green or dry. In addition, the plant and grain may be used green at various stages of maturity, or dry as food for livestock. Cultivar mixtures in maize, a sexually-reproduced, allogamous species, behave differently from those in an inbred, vegetatively-propagated crop such as potatoes. The 'purity' of individual cultivars planted in field mixtures is less in an outbreeder such as maize, while the possibilities for farmers themselves to improve the crop through rustic forms of recurrent selection are greater.

As in the case of potatoes, many farmers plant both early and late maturing maize cultivars in order to manage seasonal food gaps, to meet varied end uses of the crop, and to manage environmental hazards (uncertain rainfall, diseases, pests). Maize farmers in parts of Zambia, for example, plant traditional short-term cultivars (100-120 days) early in the season to obtain food and because they taste better as green maize than do the later-maturing hybrids SR52 and ZH1 (170 days), which are produced mainly for sale. Zambian farmers give priority to the planting of traditional varieties, which delays planting of the hybrids that require a 170-day season; 25% of the hybrids are planted with only 125 remaining days of rain. When asked whether an improved 120-day cultivar would be useful to them, 96% of the farmers thought it would, and 63% mentioned the advantage of early food (CIMMYT, 1978).

In Zimbabwe, farmers in Mangwende use maize varieties with differing times to maturity to manage the variable timing of the rains. An October start to the rainy season results in first plantings of SR52, a 170-day variety with high yield potential. If farmers have to replant because of early drought, or delay planting because of late onset of the rains, they switch to shorter-cycle cultivars such as R201 or R200 (both 135-140 days). Multiple plantings are common, and late plantings of R201 or R200 extend into January. Late plantings help to insure against losses in the crop planted earlier and allow a spread of oxen use over a longer period (Shumba, 1985).

The relative economic value of maize stover and grain also affects farmers' choice of cultivar. In Somalia, there is a market for maize stalks that have been cut and dried. In land-scarce central Kenya, some farmers prefer to plant a proportion of their land to the 600-

series maize hybrids, rather than the 500-series recommended for the zone, because its larger plant structure provides more biomass for stall feeding of dairy cattle, a major source of cash for many households.

Farmers in the densely settled parts of western Kenya show the same interest in maize stover. Both green plant material and dry maize stover are important sources of cattle feed, and proposals for two adaptive experimental programmes have been identified (Wangia, 1980). One was to examine the increase in maize plant density needed to increase fodder production without sacrificing grain yields in both the long and short rains. The second was to examine the effects on grain and fodder yields of alternative times of picking the leaves and tops of maize when green.

Breeding Implications of Farmers' Cultivar Diversification

In industrialised economies, field mechanisation and consumer markets favour genotypic and phenotypic uniformity. Standardised plants and products are less relevant to Africa's resource-poor farmers. Crop breeding in Africa can benefit from the comparative advantage of the skilled labour of small farmers in handling cultivar diversity, and in giving detailed attention to individual plant types. Understanding decisions about the adoption of new cultivars requires knowledge of farmers' present diversification strategies. This is not to suggest that scientists cannot stimulate changes in existing cropping patterns or husbandry practices, or that farmers will adopt only those new cultivars that are higher-yielding replicates of currently popular varieties. Rather, researchers must consider carefully the costs and risks farmers face, before investing time and money in developing particular types of new cultivars.

Balancing Yield and Maturity Period as Selection Criteria

Conventional varietal selection based on yield favours later-maturing cultivars, given the correlation of yield and period of photosynthetic intake. Farmers, however, may adopt shorter-term varieties in agroclimatic zones where long-duration cultivars offer higher biomass and yields. The rationale for such a choice becomes apparent once the scientist's analytical framework shifts from the individual cultivar to a multi-crop and multiple season perspective. Rather than assume farmers will accommodate any maturity period in a high-yielding cultivar, breeders must first assess local constraints on maturity periods and then select for high yields within locally appropriate maturity classes.

Although farmers are skilled at managing cultivar diversity, including multiple maturity periods, even minor departures from current types can have wide ramifications for cash flow and food security. If land is scarce, for example, adoption of a longer-maturing cultivar may mean an unaffordable delay in the planting of another essential food staple on the same plot. A new variety may require earlier planting or harvesting of a previous season's crop on the same land. It may compete for scarce labour at critical points in the production cycles of other crops. A later-maturing cultivar may introduce a constraint in the family consumption calendar if its longer period in the field coincides with a period when food substitutes are unavailable. It may introduce a family cash constraint if delayed harvest prolongs a period of cash shortage. In short, single-crop or commodity research programmes cannot ignore other crops and enterprises that compete for farmers' land, labour and cash resources, and that help farmers meet their food and cash needs.

Under conditions of bimodal rainfall and land scarcity, single season yields may be less important to small farmers than annual productivity. In this situation farmers may choose to plant the combination of cultivars that gives the best yields in two growing seasons, rather than a single cultivar that gives the best yield in one season but precludes a second crop the same year and therefore forces the farmer to purchase food on an expensive pre-harvest market. Some examples from areas where land is scarce and rainfall bimodal illustrate these points.

Maize Maturity Classes in Western Kenya

Farming systems research has highlighted the disadvantage of the highest-yielding hybrids in western Kenya's densely settled, high rainfall zone. The long maturation period of the high-yielding 600-series Kitale hybrids makes it difficult to plant a second maize crop. The hybrids are planted in March and not harvested until mid-September. Because rainfall is unreliable from December to February, the late-standing 600-series crop leaves only 100 days for replanting with a second maize crop in the last months of the year. The second maize crop is essential to poorer families who have little land because maize prices in July and August, before the new long rains harvest, often reach three or four times the post-harvest prices. Unless they plant a second crop, small farmers are forced to buy maize for food at high prices and then, for lack of cash, or because they have mortgaged the crop to buy food earlier, they are forced to sell their crop at low post-harvest prices. Such food purchases take precedence over input purchases from their limited cash resources.

In recognition of farmers' need to secure a second crop, new on-farm experimental research began to reconsider cultivar recommendations. Trials were designed to compare the performance of maize varieties in the 130-to 180-day range in the long (March to August) and short (August to December) rainfall periods and to identify the varietal combination that gives the best production over the two seasons (Collinson, 1985).

Potato Maturity Classes in Rwanda

Farmers in Burundi rejected a new late-maturing (220-day), high-yielding maize variety although it yielded 20 to 40% more than cultivars released previously (Zeigler, 1986) because they had to wait six weeks longer to harvest it, so that the new variety did not permit a good second pea crop. Field trials based on farmers' traditional practices showed that the higher yields of the late-maturing maize cultivar occurred at the expense of family food security and nutritional balance, since it did not fit into the complex local system of intercropping maize and beans and relay cropping maize with peas. The late maize also had less stable yields.

In such a situation, selecting a new cultivar on the basis of single crop yield trials (rather than the mixed cropping and relay cropping actually practised by local farmers) may result in the release of a cultivar that is incompatible with farmers' needs and limitations, and that actually decreases their nutritional and economic well-being.

Maize Maturity Classes in Burundi

In Rwanda - the most densely populated country in sub-Saharan Africa - extreme land scarcity, bimodal rainfall, and late blight all affect farmers' potato maturity class preferences. Rainfall distribution permits double, and in some zones multiple, cropping of potatoes. Late blight increases with the spread of fungal spores in heavy rain, and farmers' traditional means of coping with the disease is to plant late in the rainy season. Although higher-yielding, later-maturing (120+ days) potato cultivars resistant to late blight became locally available in the late 1970s, by the mid-1980s few farmers chose to rely on them. Short-duration cultivars allowed them greater flexibility in managing very scarce land resources, in dealing with uncertain rainfall distribution, and in managing food and cash needs.

For example, some farmers in the northern volcanic soils zone intercrop potatoes (planted in April/May and harvested in August/September) with maize (planted in May and harvested in January). After the potato harvest, they plant beans in the same maize field in September and harvest them in December and January. The longer the cycle of the potato crop, the more difficult it becomes to get the bean relay crop planted in time to catch the short rains.

Most farmers prefer either short-duration cultivars alone (70-90 days), or a mixture of early, medium and late cultivars (Haugerud, 1988). One rationale for the mixed strategy is that short-cycle cultivars, by filling food and cash gaps, enable some farmers to grow long-cycle varieties as well. Wealthier farmers with large land holdings can devote more land to late cultivars. Given the nearly universal demand for some early cultivars, the Rwandan germplasm screening and seed production programme, which had previously emphasised late cultivars, recently increased the emphasis on short-duration cultivars. Previously, the programme had taken insufficient account of the multi-crop and multiple-season framework in which farmers decide what cultivars to adopt.

Defining Appropriate Experimental Conditions

Efforts to match the conditions of resource-poor farmers in experimental fields are controversial. Should varietal selection on the research station be conducted under husbandry conditions beyond the reach of most African farmers? Identification of superior genotypes is more difficult under low input conditions, where heterogeneity makes it difficult to apply equal selection pressure over an entire plant population. More experimental replications are required, since differences in productivity may be small and statistical error large. Adjusting on-station research to farmers' practices and priorities can complicate experimental design and analysis. Classic experimental methodology, however, has its own shortcomings. Both conscious and unconscious decisions by crop scientists produce more favourable crop environments on research stations than in farmers' fields, and lead breeders to select genotypes that respond well to favourable environments (Maurya et al., 1988; Simmonds, 1984).

One problem is to identify the changes to farmers' practices and priorities which it is reasonable to expect them to adopt. The yield is in part due to circumstances beyond farmers' control (eg. whether fertiliser or irrigation water arrives on time), as well as to farming practices that make good biological, nutritional sense. Small farmers may use low inputs for a number of reasons: the mix of production, consumption, and marketing priorities within the farming system; limited cash resources; inadequate personal influence to obtain inputs; and limited capacity to risk high losses. Small cultivators operate multiple enterprises as an integrated system, which requires compromises in management, and therefore productivity, of any one constituent enterprise. Traditional mixed cropping is a further dimension of this systems context with its own implications for germplasm selection.

Another way in which germplasm screening can take greater account of the diversity of actual farm conditions is to decentralise screening by the earlier release of promising material to farmers for testing in on-farm trials, as in a successful rainfed rice breeding programme in India (Maurya et al., 1988).

When scientists define treatment and non-experimental variables for cultivar selection, they manipulate management practices such as time of planting, soil fertility, water availability, chemical protection against diseases and pests, intercropping, relay cropping, cultivar mixtures, crop rotation and plant spacing. The more explicitly they take such decisions from a knowledge of farmers' practices, and the less tied they are to traditional textbook experimental design, the more useful research results are likely to be. Some illustrations follow.

Time of Planting and Maize Performance

Maize yields are substantially reduced each day that planting is delayed after the onset of rains Acland (1971) reported reductions of 55-110 kg ha-1 for each day planting was delayed in Kenya's Rift Valley Province, and as much as 170 kg ha -1 d-1 in the Eastern and Central Provinces, where the season is shorter. Labour and draught power constraints, however, lead many small farmers to continue to plant maize for two or even three months after the start of the rains. Contrary to conventional wisdom that late planting demonstrates small farmers' irrationality, scientists now recognise that labour and power constraints limit farmers' ability to plant at the 'optimal' time. Indeed, the appropriate variety for small farmers will often be 20-30 days quicker maturing than the breeders' preferred full-season cultivar. In addition, some cultivars intentionally avoid planting early in order to reduce the risks from hazards such as uncertain rainfall or diseases and pests associated with rainfall. Interest has therefore grown in the effects of late planting on varietal choice, and in the selection of cultivars adapted to small farmers' power constraints.

Fertilisers and Maize

Agronomic recommendations aimed solely at yield maximisation underestimate the importance of yield stability and hazard management to resource-poor farmers. Improved maize cultivars tested without fertilizers in on-farm trials in Malawi, for example, were more than twice as unstable as local maize. With fertilizer, yield stability improved for both local and improved maize, though the latter remained significantly less stable than the local maize (Hildebrand and Poey, 1985). Farmers also limit their use of purchased inputs such as fertilisers when they fear damaging losses from environmental hazards. Producers in southern Zimbabwe, for example, apply a basal dressing of compound fertiliser after rather than before the maize crop emerges, in order to reduce their losses from poor germination (Shumba, 1985).

Experimental Conditions and Potato Varietal Selection in Rwanda

One potato research programme in Rwanda owes its success in part to the screening of germplasm without fertilisers or fungicides. The programme recognised early that most farmers' only commercial inputs would be occasional seed purchases; since degeneration rates (accumulation of viruses) are low in the highlands, farmers can multiply their own seed for five to ten years. In order to benefit the minority of farmers who can afford other inputs, scientists in the Rwanda programme also carry out separate fungicide trials and train extension officers in their use.

In its first five years Rwanda's low-input screening programme introduced six improved cultivars whose yields without chemical inputs were two to five times the previous national average (PNAP, 1984, 1985). Germplasm sources for the improved cultivars included South America, Mexico and Europe. Two previously introduced cultivars which the programme re-released in 1980 were found in all the country's major potato producing regions in 1985. In nearly two-thirds of 360 potato fields observed in 1985, either *Montsama* or *Sangema* occupied the largest area (Haugerud, 1988). As about half of all potato fields are intercropped with maize, beans, sorghum, colocasia and sweet potatoes.

On-station trials began to consider the comparative performance of the improved cultivars in these various crop associations. Trials of potatoes intercropped with maize in 1987 showed that land equivalent ratios increased with increasing plant densities, even when plant densities of associated crops were those normally used in pure stands (7.2 potato plants and 8.0 maize plants per square metre; preliminary results are reported by Jeroen Kloos in the 1987 CIP regional progress reports). Trials to test the performance of field mixtures of improved potato cultivars were also recommended, after farm surveys showed that most farmers grow three to five different potato cultivars at once, most of their fields being planted with cultivar mixtures.

Participatory Breeding Research

It is easy to assert that defining appropriate varietal screening priorities and experimental conditions require frequent and direct communication both between farmers and researchers and between researchers of different disciplines (economists, anthropologists, breeders, agronomists, phytopathologists, soil specialists). Few biological scientists, however, are trained in techniques to elicit and to apply knowledge from farmers (Richards, 1985; Brokensha et al., 1980).

> Although it sounds straightforward for scientists to learn from farmers, and to convene groups or panels or innovator workshops, how to do this is rarely part of scientists' training, and good methods are anyway not well known. Nor has discussion of such methods penetrated the harder professional literature (Chambers and Jiggins, 1985).

After a decade of rhetoric about feedback of farmers' problems to extension workers and scientists, a large gap remains between the ideal and the reality. Innovations in both training and methods are required to bridge this gap. To the usual on-station and on-farm trials, and formal and informal surveys must be added less familiar approaches such as panels of farmers who regularly meet with and advise scientists, one-shot group interviews, the training of scientists in role reversal, workshops with innovative farmers, and village meetings in which farmers decide on the design of on-farm trials. Farmers included in the design of on-farm trials can "contribute to defining evaluation criteria, before researchers [have] screened out most of the options by fixing the experimental design" (Ashby, 1986). When setting up on-farm variety trials, scientists can begin by asking farmers how they themselves would test a new cultivar on their own land (Biggs, 1988). In addition, researchers can track farmers' own innovations, which take them beyond the limitations of reductionist methods of on-station trials, as they adapt new cultivars to complex intercropping, rotation and agroforestry practices, and as they exploit diverse microenvironments (Chambers and Jiggins, 1985). Large-scale formal surveys, with their well-known problems of data reliability, sampling biases, logistical costliness, and lengthy processing requirements, are also increasingly replaced by less formal and more innovative techniques. In such attempts, team work, rather than 'lone ranger' research (Robert Rhoades' term) increases the credibility of results.

Farmer Participation in On-Station Germplasm Screening

Normally when on-station germplasm plots were harvested in Rwanda's national potato research programme, the entire research team (breeder, agronomist, pathologist, anthropologist) were present to select by consensus genotypes to keep for further stages of testing and multiplication. In a novel initiative, farmers were invited to make their own selections from the station fields, and to explain their reasoning to scientists. Researchers found that they had previously assumed too narrow a range of local acceptability in traits such as tuber colour, size, shape and uniformity. Whereas some researchers, for example, had for years favoured red-skinned clones, farmers found red, white and purple skins all to be acceptable. The only skin types farmers strongly rejected were russets, which they believed to be diseased.

In other words, the scientists were more conservative than the farmers, and their misconceptions led to unnecessary rejection of some potentially useful potato germplasm. Formal farm surveys of existing varieties and preferences confirmed these findings. Incorporating farmers into on-station germplasm screening can produce useful information at little cost.

Participatory research, then, can become a two-way flow that both takes scientists to farmers' fields and brings farmers to the scientists' fields. CIAT's bean research programme in Rwanda subsequently adopted this approach. Female bean seed experts now participate in on-station bean varietal assessment (Sperling, 1988). Women farmers (since they rather than men tend the crop) visit on-station germplasm trials at two or three critical points in bean growth (at flowering and formation of pods, at maturation, and at harvest). Also valuable to both the scientists and visiting farmers are the observations of station field labourers (themselves usually small farmers) who see the scientists' trials through the entire crop cycle. In the Rwandan potato research programme, local scientists knew that some station labourers were both very keen observers of experimental germplasm, and experimenters with promising plant material on their own farms. These labourer-farmers were among those who assessed potato germplasm in the exercise mentioned. This technique is a useful complement to farmer-managed trials in farmers' fields.

Recommendations

Plant breeders cannot respond to every quirk of farmers' circumstances. Their task becomes more complicated, costs increase, and progress slows as the number of selection criteria increases. Breeders require general guidelines based on accurate prior identification and ranking of cultivar traits that particular categories of producers and users find important, discarding less relevant screening criteria, and assessing farmers' capacities to change existing practices. Crop breeding is a long-term investment; decisions taken at the outset have implications for many years to come.

If farmers in Africa, Asia and Latin America are to influence agricultural research more directly, researchers and extensionists need better incentives and improved ability to address farmers' needs. Skills to bridge the social distance between 'authoritarian' scientists and 'deferential' farmers are essential, so that "when farmers experiment with low fertiliser applications to find out what works and pays best for their conditions", researchers will see them as experimenters rather than as "deviants who do not adopt recommended practices" (Chambers and Jiggins, 1985; Ashby, 1986).

Social science skills are often under-utilised in the design and analysis of on-station and on-farm experiments. In on-farm trials, for example, anthropologists' field skills and knowledge of rural social organisation are helpful in selecting collaborators, judging their representativeness, monitoring experiments and farmers' opinions of them, exploring the implications of innovations in particular crops, and reformulating hypotheses for further testing (Tripp, 1985). Although increasing the participation of both farmers and social scientists in agricultural research has been one aim of farming systems research, progress has been slow. Fundamental changes in the organisation of agricultural research, and in the attitudes of agricultural scientists, remain necessary.

The gap between what is technically or biologically possible, and what is practicable for small farmers sometimes translates into conflict between excessively optimistic biological scientists and excessively pessimistic social scientists. In defining relevant breeding priorities, however, the essential starting point is for anthropologists, economists and breeders alike to give close attention to farmers' own detailed knowledge of existing crop varieties and to how they select, manage and use them. On-station trials to test improved cultivars should take farmers' cropping systems and husbandry practices explicitly into account (as in the Burundi maize and Rwanda potato programmes). On-farm trials should incorporate farmers' own methods of informal experimentation, their standards of judgement, and their suggestions concerning experimental design. As scientists adjust their research priorities and experimental techniques to solve clients' problems, they will require the courage to depart from the textbook experimental design and disciplinary paradigms.

Finally, researchers should keep in mind that farmers' powers of observation and skills in innovation contributed to eight doublings of the human population before industrialisation and the discovery of fossil fuels (Norgaard, 1985). Sustainable agriculture in all nations will require greater scientific respect for, and more effective collaboration with, those who possess the wisdom of generations of 'nonscientific' farming.

Notes

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