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Review

Re-orienting participatory plant breeding for wider impact

A Lone B. Badstue[1], Jon Hellin[1]* and Julien Berthaud[2]

[1]International Maize and Wheat Improvement Center (CIMMYT), Mexico.
[2]Institut de Recherche pour le Développement (IRD), Montpellier, France.

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This paper concerns the need to re-conceptualise participatory crop improvement in order to explore new ways of making the outcomes of scientific plant breeding and knowledge production more effective, accessible and relevant to those smallholders who hitherto have been unable to benefit more fully from the advances in formal crop improvement. Main perspectives on participatory crop research are reviewed and the epistemological basis of formal crop improvement is briefly discussed. Meanwhile, the notion of technology diffusion implicit in much formal plant breeding and technology development is contrasted with the reality that farmers are seldom passive adopters of technology: they are often curious and eager to acquire new knowledge and frequently carry out their own experiments. On this basis, and with emphasis on the not-uncommon discord between plant breeders' recommendations and farmers' practices, the need to move beyond the conventional model for crop improvement is highlighted. A re-thinking of participatory crop research is suggested, including a change of roles by way of a shift towards a notion of participatory crop improvement in which researchers are the participants in farmer projects.

Key words: Participatory research, crop improvement, technology diffusion, knowledge processes, impact enhancement.

INTRODUCTION

The Green Revolution and subsequent phases of agriculture and rural development increased yields of a number of crops in developing countries. This arose through the development and spread of modern high-yielding crop varieties[1] and new agricultural practices (Byerlee, 1994; Cleveland, 2001; Delmer, 2005; Evenson and Gollin, 2003a, b; Muir, 1998; Stirling et al., 2006). The early improved and high-yielding varieties of crops such as rice and wheat spread quickly in tropical and subtropical regions with good irrigation systems or reliable rainfall. While this focus undoubtedly had beneficial impacts in terms of global food production and improvement in national food security, there were large differences across crops and regions. Research to adapt modern varieties of rice, wheat, and maize as well as other crops to "marginal" environments took time to yield dividends. Furthermore, the diffusion of modern varieties into less favorable agro-ecological zones was slow and more limited (Sumberg et al., 2003; Witcombe et al., 2005).

Recently, however, this has started to change and efforts to broaden the Green Revolution are showing increasing success (Evenson and Gollin, 2003a, b). As part of these initiatives, much attention has been directed at the role of participatory research and development (Bishaw and Van Gastel, 2009). The use of participatory approaches is not new in agricultural development and

*Corresponding author. E-mail: l.badstue@cgiar.org.

[1]An 'improved or modern variety' is a population that has been scientifically bred and conforms to the International Union for the Protection of New Varieties of Plants (UPOV) criteria of being distinct, uniform and stable (UPOV 1991).

over the last few decades it has found its way into formal crop improvement (Ceccarelli et al., 2009). This has been in response to the need to improve the impact of research on the livelihoods of farmers. The reasoning has been that if farmers' priorities, needs and capacities are valued and better understood by researchers, extension agents and other professionals, they will be better equipped to make appropriate and sustainable recommendations (Scoones and Thompson, 1994), which, in turn, will positively influence farmers' access to new technologies. In recent years, therefore, research and extension agendas have stressed the need for a better understanding of farmers' realities and for active farmer participation at all stages of the development process. The so-called farmer-first approach, and more recently the focus on sustainable livelihoods, represent a paradigm shift whereby farmers are engaged to help construct outsiders' understandings of the ways in which their worlds operate, rather than having outsiders' realities foisted on them (Bellon, 2001; Chambers, 1997; Edwards, 1989).

Participatory development can also be seen as a process of empowerment, whereby local people gain ownership and strengthen their capacities for addressing problems affecting their own livelihoods. Thus, the dependency associated with top-down development initiatives is diminished or, at best, avoided (Edwards, 1989). Experience with a range of participatory extension and research models such as Farmer Field Schools, Local Agricultural Research Committees and Farmer-to-Farmer extension models demonstrate that these initiatives may be effective in empowering farmers and supporting them in their own identification of solutions to local problems (Bentley et al., 2006; Humphries et al., 2000; Johnson et al., 2003; Meinzen-Dick et al., 2004; Williamson, 2002). Farmer participation in agricultural research can be defined as a systematic dialogue, in which the specialized knowledge of farmers and scientists combine and complement each other in the search for practical solutions to local problems related to agriculture. The involvement of farmers and other stakeholders in agricultural research can contribute to the development of solutions to problems that influence people's livelihoods, and to the identification of guiding principles for their implementation, as well as in the overall definition of research priorities. This, in turn, plays the important role of informing policy and, thus, preparing the ground for fostering an enabling environment that allows individuals and communities room for maneuver to improve their livelihoods.

Although farmer participation is part of the development lexicon, the term has been used in many different ways. Pretty (1995: 173) identifies a seven-level typology of participation that ranges from manipulative and passive participation, where farmers are told what is to happen and act out predetermined roles, to self mobilization, where farmers take initiatives largely independent of external institutions. Biggs (1988) outlines four degrees of participation: 1) contractual, 2) consultative, 3) collaborative, and 4) collegial. Contractual participation is when scientists contract with farmers to provide lands or services. Consultative participation signifies that information is sought from farmers and, sometimes, from other target groups; collaborative means that there is some degree of task sharing between researchers and farmers, along lines determined by the formal research program; while collegial means that researchers support a farmer-initiated, farmer-managed program which is accountable in a direct way to the farmers and other client groups with a stake in the results of the technology (e.g. germplasm) development. Morris and Bellon (2004) suggest a more comprehensive typology of participation in participatory plant breeding (PPB).

However, despite broad recognition of the benefits of participation, the reality appears to have changed less than the rhetoric, with many development and research projects tending to a more passive participation (Bunch, 1982; Fujisaka, 1989; Röling and de Jong, 1998; Sperling et al., 2001; Warren et al., 1995). Thus, it remains necessary to explore and cultivate new ways for agricultural research to enhance farmers' participation in research and technology development and actively to use this to strengthen people's access to the benefits of research. As Chambers (1997: 211) noted, the changes needed are radical because they go beyond putting the last (farmers) first, and require what might sometimes be misconstrued as disempowerment of researchers and extension agents who appear to be put last. The push for local people's participation and increased understanding and use of local knowledge in agricultural research is not about undermining science, or about promoting 'second-best' solutions to local problems, thus denying farmers access to the 'best' and newest technologies. On the contrary, the issue is rather how to make the outcomes of scientific research and knowledge production more effective, accessible and relevant to people in their local contexts.

PARTICIPATORY RESEARCH AND THE EPISTEMOLOGICAL BASIS OF FORMAL CROP IMPROVEMENT

Commercial and 'traditional' agriculture

The term "participatory plant breeding" has been used to refer to different forms of interaction between farmers and researchers at different stages of the crop research process. It emerged as a concept during the last two decades with efforts to extend the success of modern crop improvement to areas and groups that had benefited less, e.g. small-scale farmers in agro-ecologically and socio-economically marginal and variable environments (Almekinders and Elings, 2001; Ceccarelli and Grando, 2007; Hellin et al., 2008; Sumberg and Reece, 2004; Witcombe et al., 2005). The objective of participatory plant breeding is to facilitate quicker and more extensive uptake of new cropping technologies by shifting the locus of plant genetic research and improvement toward the local level through direct stakeholder involvement, e.g. scientists, farmers, extension agents, industry, consumers and others, at different stages of the breeding process (Morris and Bellon, 2004). There are numerous examples of successful participatory plant breeding, especially from South Asia (e.g. Witcombe et al., 1999; Witcombe et al., 2005) and the Middle East (Ceccarelli et al., 2003; Ceccarelli and Grando, 2007).

When addressing the challenges and opportunities in participatory crop research it is important to understand the roots of modern crop improvement as well as the context in which it developed (Cox, 2009). Modern crop improvement emerged as a product of developments in the natural sciences in the 19^{th} and 20^{th} centuries (Bishaw and Van Gastel, 2009; Soleri and Cleveland, 2009). As a discipline it is firmly rooted in western science and closely linked to the development of modern agriculture (Cleveland, 2001). Indeed, epistemologically, modern crop improvement can be said to build on an understanding of farming as this has evolved in the 'developed world', that is as in commercial agriculture. Commercial agriculture can be described as operated by a series of specialized actors and institutions, of which farmers are just one element, albeit a key element. The role of farmers in the context of modern agriculture is cropping: other actors in the value chains are engaged in activities such as processing, packaging and distribution that link the farmer to the end-consumers (Hellin et al., 2009; Soleri and Cleveland, 2009). Likewise, other actors are in charge of the production of seed and other inputs, as well as the continuous research and development of new, improved technologies, and the development and implementation of regulatory and financial frameworks to facilitate production and marketing processes. Thus, the individual farm enterprise is part of a complex system constituted by a series of specialized entities. The use of modern varieties, routinely acquired from the formal seed sector each cropping season, as well as the use of other modern technologies and inputs is widespread in this context. Farmers' access to information and new technologies, as well as to credit and insurance is often good. Together these various aspects complement each other, and while on one hand they provide farmers with options and opportunities, they also help reduce farmers' risks and vulnerability. In contrast, in what is sometimes referred to as 'traditional agriculture' farmers often have multiple roles, being both the producers, processors, sellers and consumers of the harvest and other farm products. In addition farmers frequently produce and use their own seed (often of local varieties) and carry out their own small-scale experiments (Soleri and Cleveland, 2009). 'Traditional' agriculture is based largely on local knowledge and though, in most places, farmers exchange ideas and information with each other (Badstue, 2006; Bentley, 2006; Wu and Pretty, 2004), access to new information and technologies based on scientific knowledge and research may be limited and at best moderate. Often, this is also the case for farmers' access to market information, as well as credit and insurance (Poulton et al., 2010). Furthermore, for 'traditional' farmers, protective or 'market-enhancing' measures, e.g. in the form of regulatory frameworks and enforcement is often non-existent or largely irrelevant; even if such measures do exist they often target commercial or specialized agriculture, and may be out of reach for traditional small-scale farmers. Though the use of local networks of support and mutual help is common, the elements beyond farmers' influence or control are many and contribute to what is often a considerable level of vulnerability in the case of households in so-called 'traditional agriculture'. Table 1 presents the aforementioned comparison between commercial and traditional agriculture in a summarized form.

Adapting plant breeding approaches to farmers' livelihood patterns

Farmers in marginal areas are often faced with adverse agro-ecological, social and economic conditions including erratic rain, low fertility soils, fluctuating market prices for agricultural products, and labor shortages (Douglas, 1993; Soleri and Cleveland, 2009). Under such circumstances, farmers seek to minimize risks (Bishaw and Van Gastel, 2009) and seldom take chances that might lead to hunger, starvation or loss of their land. Their livelihoods tend to be diverse and complex: farmers are often reliant on non-agricultural and non-farm as well as agricultural and farm sources. Their complex and diverse livelihood and farming systems should be seen as an effort to reduce vulnerability and enhance security. Crop varieties favored by 'traditional' smallholder farmers often have multiple uses e.g. young leaves as vegetables and dried stalks for fodder, in addition to grain. Yield is therefore frequently assessed by farmers not only in terms of grain, root or tuber production *per se* but also in terms of an optimum function of production of different plant parts. Furthermore, in many areas, quality traits, for instance of consumption or market related character, are highly valued and play a significant role in farmers' choice of varieties (Bellon, 2001; Berthaud et al., 2001; Keleman and Hellin, 2009; McGuire, 2000; Perales et al., 2003). Likewise, farmers in marginalized areas with low agricultural potential and heterogeneous agro-ecological conditions often have special needs and value crop

Table 1. Differences between 'commercial' and 'traditional' agriculture.

Parameter	Commercial agriculture	Traditional agriculture
Role of the farmer	Cropping	Cropping, processing consumer, vendor seed producer
Crop varieties	Modern, improved	Local landraces, farmer varieties, creolized varieties
Source of seed	Formal sector	Local, personalized
Technology	Modern, science based	Based on traditional/local technologies
Knowledge	Based on local and scientific knowledge	Based on local knowledge
Market information	Good	Poor
Access to credit, insurance etc.	Yes	No
Legislative infrastructure	Favourable	None or irrelevant
Access to new information, new technologies	Good	Poor
Vulnerability	Moderate	High

varieties with adaptation to low soil fertility, drought, resistance to pests and diseases, and storability of grains and seed.

Simple profitability analyses that may work well under the conditions of good market development, common in developed countries or in areas of commercial agriculture in developing countries, may be a poor guide to decision-making about new varieties where multiple traits are valued by farmers but not reflected in market prices. Therefore, even if they are high yielding, modern varieties may not be attractive to farmers unless they also possess other characteristics that farmers consider important (Almekinders and Elings, 2001). In response to these observations, several formal plant breeding programs have experienced shifts in research priorities towards increased attention to issues affecting poor farmers in marginal areas (Sumberg et al., 2003; Witcombe et al., 2005). For example, over the last 15 to 20 years, research conducted by the International Maize and Wheat Improvement Center (CIMMYT) has increasingly focused on problems which are of special importance to smallholders in marginal areas, e.g. drought tolerance, low N and acid soils tolerance, disease and pest tolerance, yield stability and improved storage ability, particularly through the use of participatory variety selection (Bänziger and De Meyer, 2001).

Similarly, a CIMMYT pilot study explored 'targeted allele introgression' in Mexico as a way of addressing the production and quality traits demanded by farmers in the poorest and highly marginalized regions, where adoption of improved maize varieties has so far been very limited (Pixley et al., 2007). In a collegial, joint effort between farmers and plant breeders, 'targeted allele introgression' was used to provide smallholder farmers with maize that widely corresponds to their own local maize varieties, yet also expresses additional traits desired by, but not currently accessible to farmers. Drought tolerance and resistance to storage pests were identified as the traits most demanded by farmers, while the traits they did not want to change in their local maize varieties included seed size, grain quality, as well as length and color of husk leaves, which are sold commercially, often at a higher value than the price of grain. In order to add these traits to farmers' local maize varieties, scientists were charged with the task of identifying improved maize populations containing the desired traits and crossing these with farmers' varieties. This was done on research stations during the winter season, and seed of these crosses were returned to farmers in May in time for planting.

When researchers returned later in the year to meet and assess the process together with farmers, it became clear that backcrosses needed to be made with the landrace variety as the female, so that the seed subsequently returned to the farmer would look and perform very similar to the original landrace variety. Furthermore the need to strengthen farmers' knowledge on how to maintain the newly added traits in their landrace material was recognized. These issues were addressed and the procedure was repeated over several cycles. 'Targeted allele introgression' shows promise in several regards, and in addition to increased productivity and food security for these households; it is also expected to contribute to the on-farm conservation of maize genetic diversity. Nevertheless, challenges have also been identified, including the question of scaling up and making this a sustainable strategy for crop improvement (Pixley et al., 2007).

Participatory crop research can, therefore, make important contributions not least because of the heterogeneity of environments and specificity of farmers' problems. In order to develop germplasm that suits farmers' needs, multiple traits must often be considered. The traits, which may be important to the farmers, may not be easily recognized by outsiders. Participatory methodologies can play an important role in identifying

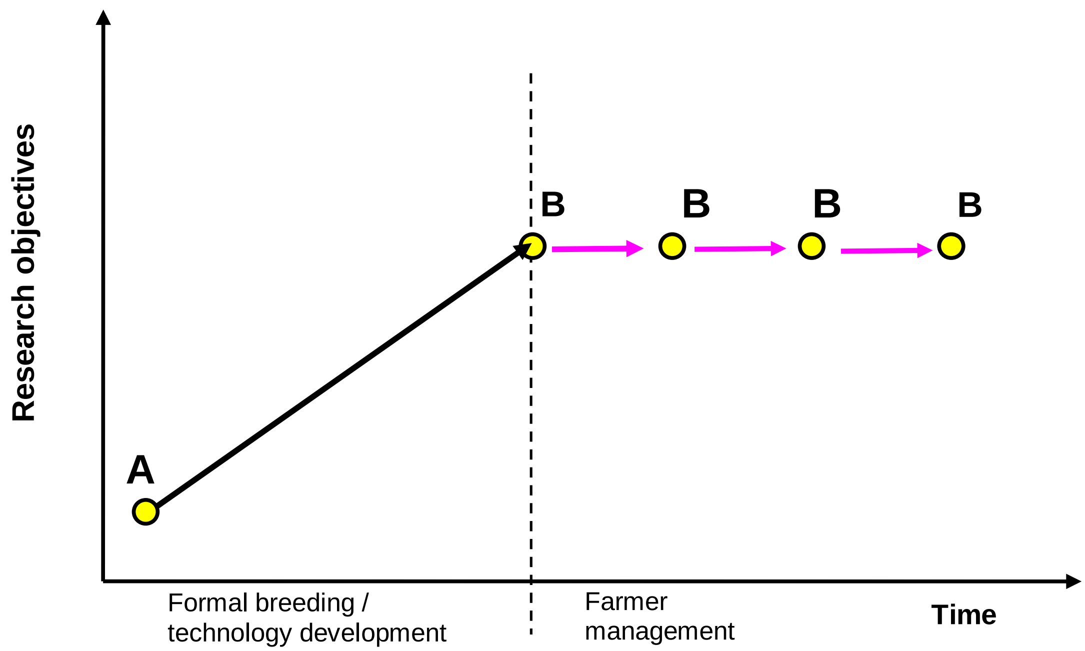

Figure 1. Conventional development and transfer of technology from plant breeder to farm. Adapted from Bellon and Berthaud (2002).

and valuing these traits, and in facilitating the targeting of breeding programs for greater impact (Witcombe et al., 2005). If this information is fed back into the design and development of new varieties, it can help to make them more relevant and appropriate, so that they generate greater benefits to smallholder farmers (Ashby, 2009; Bellon, 2002; Bishaw and Turner, 2008; Lilja and Bellon, 2006; Sumberg et al., 2003).

GETTING THE PRODUCTS OF RESEARCH 'OUT THERE'

In the past, outsiders have often failed to understand and appreciate the complexity of farmers' realities and the impact that this complexity has on farmer decision-making. For example, it was often assumed that new technologies would spread automatically due to their inherent technological advantages; or, because they were more profitable than existing alternatives.This approach has an appealing simplicity: technology development is seen as uniform and is mass produced as a standard package destined for wide diffusion across multiple local conditions (Hallsworth, 1987; Pretty and Shah, 1997; Warren and Cashman, 1988).

Figure 1 illustrates the conventional model associated with crop improvement as an example of technology modification. The finely dotted vertical line represents the moment the technology, e.g. improved germplasm, is handed over to farmers. The technology, in this case a new crop variety, is developed by the formal research system.

The research objective is to increase the performance of the germplasm from A to B. The technology is then released to farmers (point B) and it is assumed that farmers will follow breeders' recommendations and hence, that the technology will perform as expected. However, in countless cases the adoption of technology does not happen as illustrated in Figure 1. Often, the comparison between the empirical results and the deterministic theories has proved confused and contradictory (Campbell, 1996), and as noted by Kloppenburg (1991) empirical studies often show that reality is much more complex. First, genotype x environment interactions can cause low production in farmers' fields (Banziger and Cooper, 2001). Second, from the perspective of these theories, farmers are seen merely as passive 'adopters' or 'non-adopters' of technologies, rather than as active originators and moderators of technical knowledge and improved practices. While consideration of both technological and economical factors in the generation and adoption of new success. In fact, most technologies that fulfill these criteria have had no or very little practical impact. Often it can be observed that the technology that achieves widespread adoption is neither the best from a technological standpoint, nor necessarily the most profitable (Campbell, 1996). In most cases new

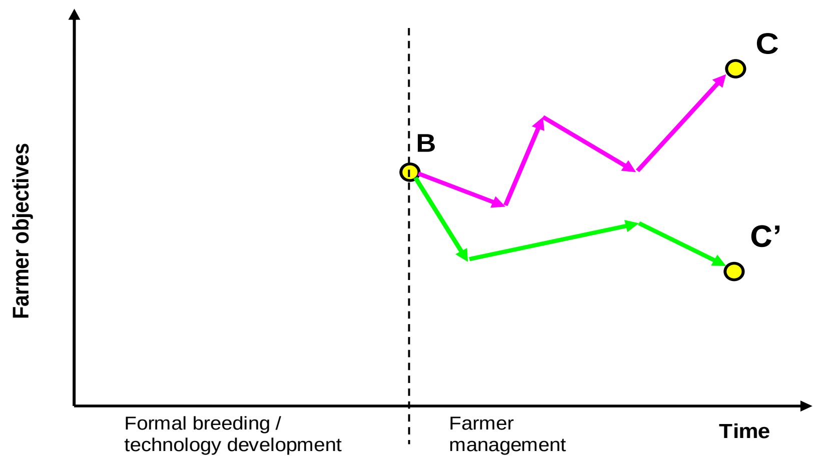

Figure 2. Farmers' management and adaptation of technology.

technologies are inserted into existing production generally seek to adapt the technology to the production system considering their individual circumstances and preferences, and often modifying or augmenting the technology in this process (Bentley, 2006).

In addition, farmers' modifications and use of new technologies do not always coincide with the ideas or the intentions of those who originally developed or introduced the technology. Figure 2 illustrates that once the new technology, e.g. germplasm from formal breeding programs, reaches the farmer it becomes subject to a process of change. This process may follow different trajectories, e.g. B to C or C' as in Figure 2. Unlike the previous model, illustrated in Figure 1, which assumes that farmers adopt the technology exactly as prescribed by the scientists and therefore achieve the performance expected by the scientists, reality shows that improved crop varieties change under farmers' management, in particular for maize, and other open-pollinated crops due to their high degree of outcrossing (Bellon and Berthaud, 2004; Bellon et al., 2005). Moreover, information about varieties and other technologies does not flow linearly from researchers to farmers. Rather, information spreads through diffuse information networks. In that process, the information is interpreted and enriched in various ways to become decision-relevant knowledge for different actors. Farmers management/adaptation of the technology take place according to the circumstances and preferences of the individual farmer, and performance of the new germplasm may be superior (C) or inferior (C') compared to the researchers' expectations.fit the new technology in order to put it into practice under ideal conditions, farmers systems. Rather than changing the production system to fit the new technology in order to put it into practice under ideal conditions, farmers generally seek to adapt the technology to the production system considering their individual circumstances and preferences, and often modifying or augmenting the technology in this process (Bentley, 2006).

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A process of social interaction and adaptation

Various paradigms of development have tended to underestimate the innovative nature and resourcefulness of local peoples and their ability to be pro-active in adverse

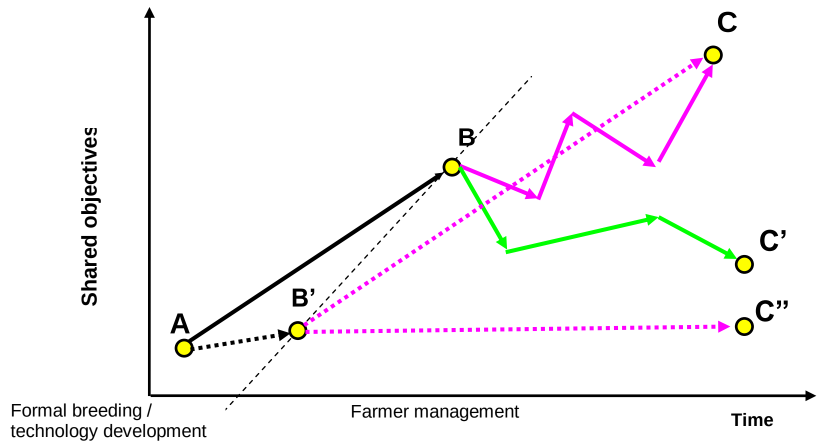

Figure 3. When should farmer participation be incorporated?

conditions (Chambers, 1997). The reality is that farmers are often curious and eager to acquire new knowledge and frequently carry out their own experiments (Chambers et al., 1989; Richards, 1985; Scoones and Thompson, 1994; Wu and Pretty, 2004). Modern approaches to technology diffusion regard individuals as social actors whose strategies and interactions contribute to shaping the outcome of development within the limits of the information and resources available (Long, 1992, 2001). The elements of social interaction and adaptation are stressed, thus emphasizing technology development and diffusion as a social process including the adaptation of technology, a process in which people's perceptions, interpretations and networks play a crucial role. Technology diffusion is seen as the result of interaction between the technology and potential users within particular cultural and environments, the social interactionist approach suggests that the process of diffusion is both complex and unpredictable. Consequently, even in relation to exactly the same technology, the response of potential users is likely to vary considerably (Campbell, 1996).

For research to contribute to sustainable livelihoods and poverty reduction, it must provide solutions to problems that influence people's livelihoods, and help identify guiding principles for their implementation. Special attention must therefore be given to the accessibility and applicability of appropriate knowledge. As such, the research and technology development process should focus on and closely interweave with the practical application of appropriate knowledge in real-life situations. For this to happen, and in order to adapt the technology development as much as possible to real-life situations, it is necessary to incorporate comprehensively the perspectives of end-users and other relevant actors in the process. With the recognition of technology diffusion as a social process which includes modifications to the technology or practice in question, the question is no longer whether or not to include participation by farmers and other actors: it is simply un-avoidable. The issue is rather: how and when in the process to do so? Farmer participation and the move from researcher-led to farmer-led technology development process can take place at different stages (B or B') (Figure 3). For example, farmers and researchers may decide that farmers should take over the lead on the process at an earlier stage (B'), in order to increase the likelihood that the 'final' technology will be adopted and make a positive difference in the lives of individual farming households.

Figure 3 illustrates the need to integrate the process of crop improvement that is conducted by the formal system with the actual management practiced by farmers. The change in the performance of the variety under farmers' conditions is often complex, and can lead to completely different outcomes from those assumed in Figure 1. Farmers must, therefore, be actively involved in agricultural technology development: the issue at stake is the varying roles of farmers and researchers and other stakeholders, along with the institutions that link them.

Moving beyond the A-B continuum in participatory plant breeding

The recognition, that it is critical to involve farmers in the formal crop improvement process is, clearly, a healthy development in the field of crop improvement. However, there is a strong need to develop further the field of participatory crop improvement, and to do this it is necessary to move beyond the conventional model for crop improvement. Much participatory crop improvement research remains narrowly focused, concentrating only on the development of new germplasm. Too often in participatory plant breeding the main objective is the

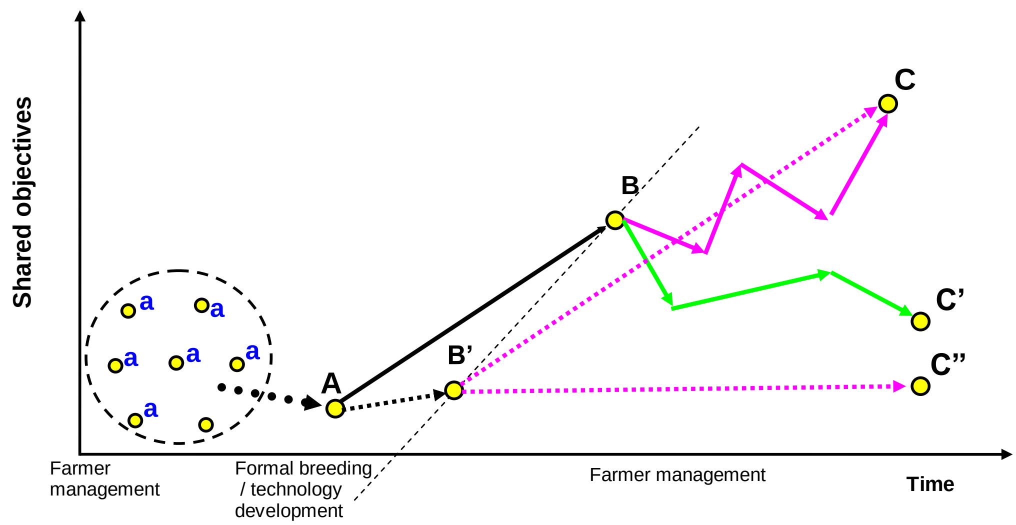

Figure 4. Moving beyond the A – B continuum.

same as in conventional crop improvement with the same starting point (e.g. overall breeding purpose, as well as the germplasm to be used, defined by the researchers), and same ending point or end product (e.g. an improved variety). The only difference may be that on one or several occasions during the crop improvement process, some form of farmer-consultation is sought (Sperling et al., 2001). By this we do not mean to say that these initiatives are not valid - according to the situation we believe that each of the different forms and degrees of aforementioned participation can be useful. The point we wish to make here is that by further expanding our ways of thinking about crop improvement, participatory or otherwise, we can make outcomes and benefits from modern crop research accessible to more farmers. Participatory crop improvement research should not be limited to the AB route (Figures 1 and 3).Participatory approaches provide excellent opportunities to explore other routes to crop improvement, e.g. ABC (Figure 3) or the aABC route (Figure 4).

In this diagram “a” signifies the definition of what goes before A; for example, the definition of the crop improvement objective, the desired traits or combination of traits, and/or the type(s) of germplasm to work with. The researchers’ role becomes one of providing key inputs and technical assistance to an otherwise farmer-led process. The notion of what constitutes technology development, here as crop improvement, is no longer an isolated focus on the A – B process, but includes what comes after as well as before. If it is agreed that projects ought to consider an “aABC” route, then new technological routes could be explored because there is not always a specific technical requirement to go through B on the road from A to C. It can be just as effective to go via B’ (Figures 3 and 4). The case of targeted allele introgression, and the approach described as ‘participatory seed diffusion’ (Rios Labrada, 2009), which aims to improve yields in farmers fields by increasing their access to diversity and stimulating farmers’ own experimentation and innovation, can both be regarded as examples of this perspective. Likewise, as the need to adapt crops to changing agro-ecological and socio-economic conditions is continuous, participatory crop improvement should be an iterative and continuous undertaking in which farmers and researchers share and interchange specialist knowledge. In this process C, C’ or C” may also serve as the starting point, that is as “a”, for a new cycle of improvement.

Conclusions

Participatory crop research is often built on the same model as conventional crop research, only with the add-on element of participation from farmers. However, crop improvement practitioners need to look beyond this conventional model. Depending on the aims and context of the research, participatory crop improvement can benefit substantially by involving the active participation of different stakeholders, especially farmers but also scientists, extension agents, policy makers, industry, retailers and consumers. Most participatory research falls in the consultative category with researchers consulting farmers or other stakeholders. This can provide researchers with focused inputs, e.g. from farmers, without otherwise causing any changes in the research process or influencing the role of the researchers as the leaders of the endeavor. In other words, the researchers remain in control of the research process and while the research now involves some measure of farmer input and can claim to be participatory, it still very much follows the conventional research approach.

One way to develop participatory research further is for scientists to engage more actively in the participatory process and learn as much as possible about the farmer realities they are trying to influence. Just as science has a lot to offer in relation to construing solutions to problems affecting traditional small-scale farming, scientists have a lot to learn from farmers about the reasoning underlying diverse farming practices and management strategies as part of complex livelihoods (Witcombe et al., 2005). However, this often requires courage on the part of researchers. By exploring more ‘active’ participatory approaches and engaging more actively with stakeholders, hitherto established patterns and roles may be challenged, including those of researchers. Nevertheless, the better the scientific community understands local contexts and farmers’ perspectives, including the factors that influence farming practices as an integral part of farmers’ livelihood strategies, the better it will be equipped to envision new opportunities and conceive new, alternative A-C routes in innovative ways, which take advantage of farmers’ strengths, while recognizing the limitations they live and farm within.

The ideas presented here regarding how to further develop the field of participatory crop improvement, face a number of difficult issues, including the question of how to control or manage such a process, and the question of how and to whom to assign responsibility for the outcomes it may result in. It also raises question of how to measure and evaluate the impact of research and the work of researchers. In comparison to the conventional model of crop improvement depicted in Figure 1 as a relatively straight forward and controllable process (A-B), what we suggest can be described as a diffuse, cyclical process that looks messy and complex, involves many different actors, is difficult to control and where no clearly defined start or end point is apparent. We like to put it differently: what we propose is simply “actively to use in formal crop improvement what is already going on in the realm of local level crop genetic resource management”. The ‘targeted allele introgression’ pilot study mentioned earlier explored these questions. In this project, the improvement of local maize materials was conceived as a farmer-owned process in which the scientists had the role of participants. Once the desired traits were successfully incorporated into farmers maize germplasm, this was returned to farmers, each of whom could then continue to work with or modify it in the ways they found most relevant. The active involvement of stakeholders throughout the process inevitably adds to its complexity. Different types of conflicts may arise and compromises are likely to have to be made, which may well lead to changes and redirections in the research as well as to the redefinition of roles and objectives, including those of researchers. The research process becomes iterative rather than one carried out in strict accordance to a preconceived design. As research progresses, it becomes increasingly difficult to keep detailed track of all parts of the process, a fact, which may be compromising in general, but particularly so in the case of individual researchers affiliated with the research in question. Furthermore, the challenges of carrying out impact assessment and mapping of impact pathways increase.

A research process guided more by farmers needs and opinions may be interpreted as a slackening of scientific rigor and the weakening of the role of scientists: turning a scientific research process into both art and science. The point, however, is to what extent researchers can be held accountable for all outcomes of such a project? When answering this question one should keep in mind that, though previous models of crop improvement (Figure 1) did not perceive farmers experimentation and adaptation, as part of the technology development process, they still take place whether researchers like this or not (Figure 2B and C). Similarly, one should keep in mind the failure to diffuse and the abandonment of so many technologies and practices developed without sufficient involvement of the supposed end users and other stakeholders. Thus, the issue of responsibility may not depend so much on how we conceive of technology development, as on the processes we initiate by engaging in it.

A final comment regards stakeholder involvement in general. Participatory approaches have a tendency to create expectations. This can represent a challenge, particularly under circumstances when results take long to show or are of a particularly abstract kind, or, when there are problems in the flow of information between the different parties involved. When expectations are not met it can lead to loss of trust - a highly important element in participatory work, but one, which it is generally a lot easier to loose than to gain. Similarly, involvement in a participatory project can imply certain costs or risks for the individual. Though this may be of little concern to some participants, to others the same issue may present serious risks, which in some cases can have devastating effects.

There is also a danger that by embedding participatory research in complex livelihood and farming systems the result may be the opposite to that desired: namely that plant breeders and agronomists become weary because of the seeming complication of their mission and retreat into more ‘upstream’ research (Loker, 2006). This would be a great shame because genuine participatory plant breeding has the potential to draw natural and social scientists into productive dialogue with farmers, leading to practical and realistically sustainable initiatives that can play a critical role in sustainable agriculture intensification and a reduction in rural poverty.

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