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Introduction: Farmers, Scientists and Plant Breeding: Knowledge, Practice and the Possibilities for Collaboration

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Abstract

Control over management of the world's resources is increasingly contested because of economic, political and biophysical globalization, and increasing demands of a growing population of more than 6 billion. This has led to new interest in indigenous or traditional knowledge in many areas, including agriculture and plant breeding. Farmers were the first plant breeders, beginning with domestication of plants over 12,000 years ago. Modern, scientific plant breeding developed in the last two centuries, and has become increasingly separated from farmers, especially in non-industrial regions. Plant breeding systems consist not only of crop genotypes and growing environments, but also of the social structures in which plant breeding is carried out, and the knowledge of farmers and scientists. Because of the challenge to make plant breeding and agriculture more environmentally, socially and economically sustainable, there is increasing interest in reuniting farmer and scientific plant breeding.

Globalization, Indigenous and Scientific Knowledge, and Plant Breeding

Population growth, environmental degradation and the integration of physical, biological and sociocultural systems on a global scale, have all increased dramatically in the last few centuries, and especially in the last 50 years. With productive resources becoming scarcer and more contested, attention has focused on the potential value of local

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knowledge and local systems of resource use and conservation as more environmentally, economically and socially sustainable alternatives to modern, industrial systems. This attention has increased dramatically in recent years, especially since the Convention on Biological Diversity (CBD) in 1992, which asserts the importance of indigenous or local people's knowledge for sustainable development, as well as the rights of these people to this knowledge. As these ideas have achieved wider acceptance, local and indigenous peoples have gained a voice for their viewpoints in international fora (Fowler, 1994; Cleveland and Murray, 1997).

One of the greatest challenges for understanding the promise of local knowledge and practice for helping to solve global problems will be developing the required levels of communication, which will need to be 'broad and deep beyond precedent', will need to take advantage of global communication networks (Ostrom *et al.*, 1999), and that renders the search for a more balanced, indeed more scientific, treatment of disparate knowledge systems inevitable (Nader, 1996: 6–7). Therefore, at the centre of the debate about more sustainable alternatives to conventional, modern agriculture are questions about the comparative environmental sustainability of modern and traditionally based agriculture, about the degree of similarity between scientists' and farmers' knowledge, about who controls the representation of this knowledge, and about what all of this means for the possibility of collaboration between farmers and scientists (*Diversity*, 1998; Sillitoe, 1998; Dove, 2000).

A sign of the lack of information and of the political importance of this topic is that there is a great deal of disagreement over terminology. 'Indigenous knowledge', 'local knowledge' and 'traditional knowledge' often have conflicting meanings, and these meanings differ among researchers (Ellen and Harris, 2000). We use the terms 'indigenous knowledge' (IK) and farmers' knowledge (FK) to refer to the knowledge of people who are not in the modern, global scientific system. We understand that what is often referred to as IK is not 'indigenous' in the more restricted sense of arising from only local sources (Cleveland and Murray, 1997; Dove, 2000), but use the term in a general way to emphasize the contrast of relatively more local IK with relatively more general (at least in a geographical sense) modern, scientific knowledge (SK).

Disagreement over terminology has not prevented new efforts by social and natural scientists to understand the potential contribution of IK to sustainable development, and new efforts by local peoples and their supporters to try to capture more of the power of SK to serve their own goals.

Small-scale farmers whose well-being and way of life are threatened by globalization, opportunistically make use of the possibilities offered by other aspects of globalization to improve their situation (Cleveland, 1998), or simply to be able to remain farmers. Therefore, local groups may define ‘indigenous’ or ‘traditional’ agriculture in ways that include industrial agriculture technologies, in part because this serves their larger goal of maintaining their physical and cultural identity; *they localize global SK*. Local communities are increasingly taking the initiative, or working with national and international non-governmental organizations, to gain more control over the process of improving IK (e.g. Millar *et al.*, 2001). For example, Zuni indigenous farmers have learned how to use global positioning system (GPS) technology to map their family farm fields, and this became an important force for resolving land disputes that have impeded the revitalization of indigenous agriculture (Cleveland *et al.*, 1995).

Scientists who perceive negative impacts on the natural environment and on society of the application of SK are also interested in *globalizing IK* for increasing sustainability. Biological scientists have supported this integration in agriculture, advocating ‘the development of more ecologically designed agricultural systems that reintegrate features of traditional agricultural knowledge and add new ecological knowledge’ (Matson *et al.*, 1997: 508). Interest in cataloguing IK in terms of SK concepts to facilitate its use in more locally appropriate, participatory development has reached the mainstream, though it is often criticized for detaching IK from its local contexts and thus rendering it useless (Sillitoe, 1998). The status of IK as a complement to SK in promoting more sustainable development is still far from certain, and it is difficult to separate empirical evidence from its political contexts (Ellen and Harris, 2000).

As a result, local farmers, project workers, agricultural scientists, social scientists and development policy makers are increasingly asking (implicitly and explicitly), ‘Is it possible for scientists and local peoples to collaborate to reach common development goals?’ Could the answer be ‘No, this idea is just a politically correct fad, doomed to failure because the social and biophysical environments, knowledge and goals of the two groups are so different’? But what if they aren’t so different? Perhaps we should first ask, ‘In what ways are scientists’ and farmers’ environments, knowledge and goals similar, as well as different? What are the reasons for differences and similarities?’ Approached in this way the answer to questions about the possibility of collaboration might not necessarily always be ‘No’. It might also be ‘Yes, scientists and local peoples can collaborate to reach common development goals.’ Then questions need to be asked about collaboration. ‘What form would collaboration take? How would the relative value of local and scientific knowledge be determined for a given situation, and what methods could be used for integrating them? How would scientists and local people talk to each other? Would scientists or local people be in charge?'

This book addresses these questions for the important case of plant breeding. Different chapters deal with very different situations, and focus on different components of the plant breeding system of farmers, of plant breeders or of both. Most are written from the perspective of plant breeders and/or social scientists, although some also take the perspective (through the lens of outsiders) of farmers. The authors of the chapters also have different methodological approaches and theoretical orientations, and are working with data from different and, to some extent, unique situations. Yet the authors of each chapter reflect on their own knowledge and practice, and that of the farmers and scientists they work with, have the plant breeding system as a whole as a reference, and strive to make their methods and assumptions explicit. The chapters provide valuable insights on the importance of understanding the dynamics of farmer and scientist knowledge in assessing the possibilities for collaboration.

We asked the authors to describe the way in which working with farmers, their crop varieties and growing environments has led them to reinterpretations of conventional plant breeding or social theory and to new insights, methods and practices, and to be as explicit as possible about their understanding of farmers' and scientists' knowledge and practice. These requests made of the authors reflect an important assumption on which this book is based: through rigorous empirical research, theory building, self-reflection and cross disciplinary communication, we can gain greater understanding of the details of, and causes for, both general patterns and unique situations, both similarities and differences between farmers and scientific plant breeders, and thus of the possibilities for collaboration between them.

In the remainder of this introduction we discuss the separation between farmer and scientist plant breeding, a broad definition of the plant breeding system, and the current move to bring farmers and scientists more closely together in plant breeding.

The Development of Plant Breeding and the Separation of Farmers and Scientists

Since the first domestications of wild plants about 12,000 years ago, farmer plant breeders have been responsible for the development of thousands of crop varieties in hundreds of species (Harlan, 1992). Plant breeding as a specialized activity began about 200 years ago in industrial countries (Simmonds, 1979). Modern professional plant breeding developed in the early part of the 20th century based on

Darwin's theory of evolution through selection and the genetic mechanisms of evolution, together with the basic mechanisms of inheritance and expression of the phenotype (via genotype × environment interaction, G × E) discovered by Mendel in 1865 and rediscovered and elaborated by others in the first decades of the 20th century (Simmonds, 1979; Allard, 1999; Duvick, Chapter 8, this volume). For example, Johannsen demonstrated that quantitative traits followed the same principles of inheritance that Mendel demonstrated for qualitative traits; Nilsson-Ehle and East showed that many different genes could affect one character; Turesson found that different genotypes of a species are adapted to a specific range of environmental variables; and Fisher and associates demonstrated that the inheritance of quantitative characters could be analysed statistically (Hill *et al.*, 1998; Allard, 1999).

The crop varieties developed by plant breeders and farmers are often considered to be contrasting, although this is a simplification to which there are exceptions (Evans, 1993; Frankel *et al.*, 1995; Fischer, 1996). The emphasis of most scientific, professional plant breeders (hereafter simply 'plant breeders') has typically been on developing a relatively small number of genetically more uniform *modern varieties* (MVs), adapted to geographically wide, *optimal* (relatively low stress and uniform) growing environments, with high yield and yield stability in these environments. *Farmers' varieties* (FVs) are characterized by narrow geographical adaptation to *marginal* (relatively high stress and variable) growing environments, and high yield stability in those environments from year to year. We use the term FVs here to include landraces, traditional varieties selected by farmers, MVs adapted to farmers' environments by farmer and natural selection, and progeny from crosses between landraces and MVs (sometimes referred to as 'creolized' varieties or 'degenerate' MVs).

Plant breeding by scientists has become increasingly separated from plant breeding by farmers (Simmonds, 1979), as have seed supply systems (Cromwell *et al.*, 1993). Schneider documents the process of decreasing collaboration between wheat farmers and wheat breeders in Switzerland, and suggests political, institutional and technological reasons for this change (Schneider, Chapter 7, this volume). The distance between scientific and farmer plant breeding is especially great in the case of small-scale farmers planting in marginal growing environments with limited access to external inputs, as documented by many of the chapters in this book. In some industrial societies communication between conventional commercial farmers and plant breeders is still important, for example between large-scale maize farmers in the central United States and commercial maize breeders (Duvick, Chapter 8, this volume).

The Plant Breeding System

The process of formal plant breeding begins with the initial decision about breeding goals and plans, and concludes with the release of a new variety and its subsequent dissemination to farmers (Weltzien *et al.*, 2000). In between are four basic steps: (i) creation of a large amount of genetic diversity through choosing parent germplasm, hybridization (crossing) and recombination in filial generations; (ii) selection of individual plants and populations initially in a limited range of *selection environments*; (iii) evaluation of the 'best' populations resulting from selection across a wider range of *test environments*; and (iv) the choice of varieties for release in the *target environments* on the basis of their potential to out-perform (out-yield) the existing varieties (Simmonds, 1979; Stoskopf *et al.*, 1993).

Selection vs. choice

To understand plant breeding systems it is important to differentiate between *choice* of populations or varieties, which does not change the genetic make-up of these units, and the *selection* of plants from within populations or varieties, with the potential to change the genetic make-up of these units, and result in new varieties (Cleveland *et al.*, 2000). While this distinction is commonly made in the participatory plant breeding literature (e.g. Witcombe *et al.*, 1996), the terms 'choice' and 'selection' are often not explicitly defined, and may sometimes be used interchangeably.

The *choice* of germplasm (populations and varieties) determines the genetic diversity available within a crop, both as a basis for selection (by farmers and breeders), and for production (by farmers). Farmers and plant breeders make choices between varieties and populations, especially (for plant breeders) in the initial stages of the selection process when choosing germplasm for making crosses, and in the final stages when choosing among populations/varieties generated from those crosses for further testing (Hallauer and Miranda, 1988), planting (farmers) or release (plant breeders). Farmers' choices when saving seed for planting, in seed procurement and in allocating different varieties to different growing environments also affect the genetic diversity of their repertoires of crops and crop varieties, and determine the diversity on which future selection will be based.

Artificial *selection* of plants by farmers and breeders within segregating plant populations can change the genetic make-up of the population and lead to the development of new varieties. Artificial selection is both *indirect*, a result of the environments created in farmers' and plant breeders' fields and store rooms, and *direct*, a result of human selection of planting material. Direct artificial selection can be both *conscious* (based on explicit criteria), the result of decisions to select for certain traits, and *unconscious* (based on implicit criteria), when no conscious decision is made about the trait selected for, as when large seeds are automatically selected because they are easier to handle (Harlan, 1992). There is some confusion over terms in the literature; indirect artificial selection is sometimes defined as 'natural' selection (Simmonds, 1979: 14–15), as the same as conscious selection (Allard, 1999: 19, 26), or as entirely 'unconscious' selection (Poehlman and Sleper, 1995: 9).

Broadening the definition of plant breeding

While the standard definition of plant breeding emphasizes its biological aspects, it is obvious that the human element is critical, and needs to be explicitly addressed when collaboration between scientists and farmers is a goal. Therefore, the plant breeding system (Fig. 1.1) can be more broadly defined to include not only

- the *biophysical* components of crop populations and growing environments; and

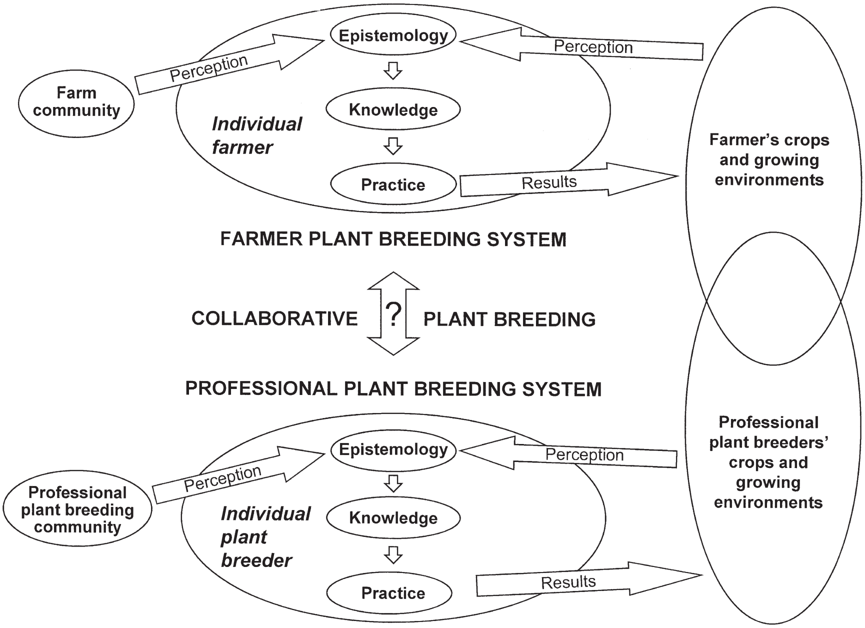

Fig. 1.1. The plant breeding system.

- the *practice* of choice and selection between and within crop populations;

but also

- the *social* and *institutional* components (communities of farmers and plant breeders, including social structure, economic and power relations, behaviours and oral/written expressions of knowledge);
- the *knowledge* of individual farmers and plant breeders about their crop populations and growing environments (both conscious and unconscious, including intuition, values, empirical data, theory); and
- *epistemology*, the way knowledge is acquired through the processing of physical stimuli from the outside (affected by sensory perception, brain structure and function, language, technology, practice and pre-existing knowledge).

The chapters in this book consider the plant breeding system in this broad perspective, though each chapter focuses on a limited portion of it.

The biological basis of plant breeding

The elementary biological model on which plant breeding is based, and as presented in the standard textbooks, is universally accepted among plant breeders (e.g. Simmonds, 1979; Falconer and Mackay, 1996). First, variation in population phenotype (V_P) on which choice and selection are based is determined by genetic variation (V_G), environmental variation (V_E), and variation in genotype × environment (G × E) interaction ($V_{G \times E}$), thus $V_P = V_G + V_E + V_{G \times E}$. Broad sense heritability (H) is the proportion of V_P due to genetic variance (V_G/V_P), while narrow sense heritability (h^2) is the proportion of V_P due to additive genetic variance (V_A/V_P), that is, the proportion of V_G directly transmissible from parents to progeny, and therefore of primary interest to breeders.

Second, response to selection (R) is the difference for the traits measured between the mean of the whole population from which the parents were selected and the mean of the next generation that is produced by planting those selected seeds under the same conditions. R is the product of two different factors, h^2 and S ($R = h^2S$), where S is the selection differential, the difference between the mean of the selected group and the mean of whole original population selected from. Expression of S in standard deviation units (the standardized selection differential; Falconer and Mackay, 1996) permits comparison of selections among populations with different amounts or types of variation. The results of selecting for a given trait improve as the proportion of V_P contributed by V_G (especially V_A) increases.

The biological relationships described in these simple equations underlie plant breeders' understanding of even the most complex phenomena that they encounter (Cooper and Hammer, 1996; DeLacy *et al.*, 1996). For example, two highly respected English-language plant breeding texts state that the relationship between genotype and phenotype is 'perhaps the most basic concept of genetics and plant breeding' (Allard, 1999: 48), and of $R = h^2S$, that 'If there were such a thing as a fundamental equation in plant breeding this would be it' (Simmonds, 1979: 100).

The social and individual bases of plant breeding

Much of the current discussion about the nature of knowledge is polarized between objectivist and constructivist camps (e.g. Hull, 1988; Harding, 1998). The assumption at the *constructivist* end of the spectrum is that knowledge is dominated by social forces, including power relationships, and is historically and culturally particular; that is, the process that mediates the acquisition of knowledge (epistemology) is dominated by pre-existing knowledge, including values, acquired through participation in a particular institutional or social setting, often mediated by the social control of technology and information. The assumption at the *objectivist* end of the spectrum is that more and more universal and accurate knowledge of biophysical reality is a valid goal; that is, epistemology is dominated by scientific methods capable of discriminating and eliminating social influences and of ascertaining the true nature of the world outside the individual mind.

In an objectivist approach to plant breeding, science is often seen as increasing the amount and accuracy of objective knowledge about plants and their environments solely through testing of theory-based hypotheses, and applying this knowledge to produce new, more desirable crop varieties. Plant breeders consider themselves to be 'applied evolutionists' (Simmonds, 1979: 27; Allard, 1999: 49) and textbooks document the progressive, science-based development of the profession, which increasingly differentiates their SK from the IK of farmers.

In a constructivist approach, the development, application and results of plant breeding science, including the kinds of crop varieties developed, are often seen to be primarily the result of macro political or economic variables, foremost among them industrial modernism. This is the approach of most social scientists who research or discuss plant breeding. From this viewpoint, the SK of plant breeding unobjectively adopts the values of modernism, yet is imperialistic in its claims to universality, and focused on transforming the climate and environment to fit a predetermined 'ideal plant type', in contrast to IK, which is seen as much more complete and sophisticated in terms of objective reality (e.g. Scott, 1998).

From the viewpoint of the more extreme positions that dominate the 'science' wars (Gould, 2000), IK and SK sometimes seem to be mutually exclusive, providing no rationale or capacity for collaboration between them. However, the real challenge lies not in promoting ideologically based conclusions about IK and SK, but in understanding the complexities that determine knowledge and practice in general, and in a particular situation, in order to support change in a socially desirable direction. (Of course, determining what is socially desirable is itself part of the problem.) It demands, to the extent possible, separating conclusions based on values, for example that local communities should have control over their FVs, from conclusions that can be tested by empirical research, for example that local communities are conserving crop genetic diversity.

As an alternative to objectivist and constructivist views, a 'holistic' model of knowledge assumes that both farmer and scientist knowledge of plant breeding are the result of objective observations of reality and social construction, and both may be composed of empirical data, theory and values (Fig. 1.1; see also Soleri *et al.*, Chapter 2, this volume). This approach is being discussed more and more as an alternative to dichotomous, essentializing definitions of indigenous and scientific knowledge in the social sciences (Bernard, 1998; Schweizer, 1998) and in social studies of science (e.g. Hull, 1988; Harding, 1998; Gould, 2000). Plant breeders may also recognize that their theoretical understanding of plants is limited by the lack of required experimental data, and of the technologies and resources necessary to gather them (Simmonds, 1979; Anderson and Hazell, 1989; Duvick, Chapter 8, this volume), although they do not often consider the extent to which their knowledge may be socially constructed.

The Move to Reunite Farmer and Scientific Plant Breeding

Participatory plant breeding (PPB) proposes to reverse the historical trend of separation between farmers and plant breeders, bringing them together in the process of developing new crop varieties or improving existing ones. In some ways it is a relatively new approach to crop improvement. While PPB is only a very small part of plant breeding as a whole, it has become a popular component of international agricultural development during the last several years, and the main focus of several global-level international development initiatives (Eyzaguirre and Iwanaga, 1996; Witcombe *et al.*, 1996; McGuire *et al.*, 1999), including the Community Biodiversity Development and Conservation programme (CLADES *et al.*, 1994; http://www.cbdcprogram.org/frame.htm) and the PPB component of the CGIAR's System Wide Programme on Participatory Research and Gender Analysis (SWP PRGA) (CGIAR, 1997; http://www.prgaprogram.org/).

Interest in PPB comes from a convergence of the movement towards sustainable agriculture in professional plant breeding, genetic resources conservation and traditionally based agriculture (Cleveland *et al.*, 1994), and towards participatory research and development (Friis-Hansen and Sthapit, 2000). Frossard (Chapter 6, this volume) describes one of the most prominent examples of farmer-initiated PPB in his chapter on MASIPAG in the Philippines. Several chapters in this book are by plant breeders who describe the motivation for beginning to work with farmers in Syria (Ceccarelli and Grando, Chapter 12), Nepal (Joshi *et al.*, Chapter 10), Cuba (Ríos Labrada *et al.*, Chapter 9) and Zimbabwe (Bänziger and de Meyer, Chapter 11).

Increasing environmental sustainability

Agriculture and plant breeding, like most human activities, are facing unprecedented challenges at both local and global levels. It is widely agreed that human impact on the Earth's ecosystems threatens the current patterns of biological and sociocultural diversity, and this has focused attention on achieving more sustainable human–environment interaction (Vitousek *et al.*, 1997), including agriculture (Matson *et al.*, 1997). At the same time, the demand for food is increasing, while past approaches to increasing food production are often considered to be inadequate (Evans, 1997; Mann, 1999).

Modern, professional plant breeding (in concert with agronomy) has been extremely successful in meeting increasing demands from a growing human population (Evans, 1993, 1998). However, the benefits of modern plant breeding have not reached many of the limited-resource farming communities that characterize much of the developing world, as documented in many of the chapters of this volume (see McGuire, Chapter 5; Frossard, Chapter 6; Zimmerer, Chapter 4). For example, only about 40% of low-input maize production in the developing world is planted to MVs (Heisey and Edmeades, 1999). The reasons for the failure of modern plant breeding to benefit many farmers include the conventional belief that improving productivity of higher input systems is a more effective way to increase food production and people's well-being than is attention to farmers in marginal environments (Heisey and Edmeades, 1999), or perhaps a failure to understand marginal environments and the farmers who make a living there (Ceccarelli *et al.*, 1994; Bänziger and de Meyer, Chapter 11; Ceccarelli and Grando, Chapter 12; Joshi *et al.*, Chapter 10, this volume). Modern, industrial agriculture also faces the challenge of developing varieties that are adapted to growing environments with fewer external inputs, including artificial fertilizers and pesticides, and irrigation (Duvick, 1992). Cuba's response to forced and dramatic reductions of agricultural inputs in 1989 (Ríos Labrada *et al.*, Chapter 9, this volume) is seen by many as an example of what other industrial agricultural systems will face in the future.

At the same time, the success of modern agriculture has threatened the genetic base on which both modern and traditional agriculture depend, the replacement of many FVs with fewer MVs, and the movement of many farmers in marginal environments out of farming. The FVs grown by farmers contain rich but largely unknown genetic resources that will be essential for developing more sustainable crop varieties of both MVs and FVs (Qualset *et al.*, 1997; Brown, 1999) and, just as importantly, may be critical for even modest FV success in many extant traditionally based systems (Soleri and Smith, 1995).

For all of these reasons, there has been increasing awareness among plant breeders of the need to:

- increase yields and yield stability in marginal environments, both (i) those that have been high-yielding, but where inputs are being reduced to reduce production costs and negative environmental impacts; and (ii) those of many of the world's farmers who have not adopted MVs, but whose FVs have inadequate yields;
- conserve the base of genetic diversity on which all plant breeding depends, and which is threatened by the loss of FVs as the area planted to FVs and the number of farmers growing them declines (Fischer, 1996; Qualset *et al.*, 1997; Heisey and Edmeades, 1999).

From the perspective of an increasing number of scientists, plant breeding with farmers is a way to both increase yields and other desirable production components in marginal environments, while at the same time supporting *in situ* conservation of crop genetic diversity (Witcombe *et al.*, 1996; Qualset *et al.*, 1997; Brown, 1999; Weltzien *et al.*, 2000; Ceccarelli and Grando, Chapter 12; Joshi *et al.*, Chapter 10; Ríos Labrada *et al.*, Chapter 9; Smale, Chapter 3, this volume).

Increasing social and economic sustainability

As with other areas of development, a major incentive for scientists to work with farmers has been the value of IK for increasing environmental sustainability. However, recognition of the claims by indigenous peoples of rights to natural resources, to manage their own development, and to their IK, implies the need to increase the social and economic sustainability of agriculture as well (Cleveland and Murray, 1997). Several chapters in this book demonstrate the importance for plant breeding of understanding the knowledge and practice of farmers, and the social and political systems within which they are embedded (Chapters 2, 4, 5, 6, 7, 9, this volume).

An important method for achieving this has been ‘participatory’ research and development although, deciding what ‘participation’ means in terms of valuing IK, of recognition of rights in IK, and who is to be in control of development has been contentious. Since PPB is still relatively new, there is a wide range of understandings of what it entails, and a wide range of activities in PPB projects (Friis-Hansen and Sthapit, 2000).

Much of PPB to date has emphasized the participation of farmers in plant breeders’ work. An important reason for this is that most of this work has been initiated by ‘foresighted individuals working at otherwise conventional research stations’ with objectives therefore focused on developing new products rather than on the process of farmer plant breeding (Friis-Hansen and Sthapit, 2000: 19). Another major reason for not using farmers’ plant breeding experience and theory more extensively in PPB may be that very little is known about them by outsiders, either in farmers’ own terms, or in terms of the theory of scientific plant breeding (Brown, 1999; Cleveland *et al.*, 2000). Other ways of characterizing participation in plant breeding include a widely used quantitative taxonomy based on the amount of effort borne by farmers (Biggs, 1989; see Joshi *et al.*, Chapter 10; and Soleri *et al.*, Chapter 2, this volume, for more discussion).

Comparing the economic sustainability of PPB with more conventional approaches can be complex and requires evaluation of the ‘participatory’ aspect as well as, but separate from, other substantial deviations from the conventional model such as decentralization (Ceccarelli *et al.*, 2000). Ríos Labrada *et al.* (Chapter 9, this volume) include a basic economic comparison of some aspects of two plant breeding methods in Cuba. Benefit/cost analyses of PPB and other types of plant breeding may yield very different results, and will be an important contribution to understanding the basis of PPB, but this area of research is just beginning to be explored (Simmonds, 1990; Heisey *et al.*, 1997). Smale’s chapter in this volume (Chapter 3) is the first attempt by an economist, based on her very extensive empirical and theoretical work with both farmers and plant breeders, to lay out a framework for the economic research in this area.

We have suggested *collaborative plant breeding* (CPB) as an alternative to PPB to emphasize two points that we believe to be critical for the intercultural (farmers and scientists) and interdisciplinary (social and biophysical sciences) nature of collaboration between farmers and plant breeders (Cleveland and Soleri, 1997).

1. The knowledge and practice of both farmers and breeders are important, neither should be assumed to be 'better' a priori; their relative merits in terms of contribution to CPB need to be empirically assessed in each situation. At a more fundamental level, successful collaboration requires mutual respect that is based on an understanding of differences and similarities.
2. Positive biological and social results in CPB are not necessarily correlated with the amount of physical effort invested by farmers. For example, introgression of alleles conferring disease tolerance into FVs may require very little if any physical work on the part of farmers, yet have major benefits for them.

The term PPB, however, is still used by most, and some may prefer it to CPB because 'collaboration' suggests to them an emphasis on social as opposed to biological goals. There are also other terms that overlap to a greater or lesser extent with CPB, such as 'decentralized breeding', 'farmer crop improvement', 'joint breedership' and these are used for the most part interchangeably (Weltzien *et al.*, 2000: 7), including in most chapters of this book. However, some authors and practitioners imply specific meanings with their use of terms (see Joshi *et al.*, Chapter 10 and Soleri *et al.*, Chapter 2, this volume, for examples). Clearly the actual terminology is in many cases irrelevant, but the assumptions that have become associated with terms do require examination. We believe that the use and discussion of different terms is an important part of the process of clarifying what 'collaboration' or 'participation' means, and what they imply in terms of goals.

Conclusion

Successfully meeting the challenges for environmental, social and economic sustainability of food production that we face in a globalized 21st century will undoubtedly require new strategies. Based on past experience it seems likely that an important component of these will be new understandings of diverse perspectives and identification and pursuit of shared goals. Increased collaboration between scientific plant breeders and farmers could be vital for achieving those understandings and realizing those goals. However, this may require rethinking past approaches, and more work on the theoretical basis, practical implications and potential contributions of collaboration. An essential ingredient, we believe, will be greater understanding of the knowledge and practice of both farmers and plant breeders, and of the differences and similarities between them. This book is a contribution to that end.

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