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Participatory Varietal Selection, Participatory Plant Breeding, and Varietal Change

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By

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Contents

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Introduction

Participatory varietal selection (PVS) and participatory plant breeding (PPB) are relatively new terms that encompass both old and new concepts and procedures. The difference between PVS and PPB hinges on the degree and timing of farmer involvement in plant breeding. To illustrate the essential features of PVS and PPB we draw on an example of varietal change in Peru. In the mid-1980s, potato breeders in the national program of Peru and the International Potato Program (CIP) jointly decided to evaluate advanced clonal material from a diverse late-blight resistant population in farmers' fields. Three hot spots for late blight were selected in the Department of Huanuco in central Peru. Trials were conducted in farmers' fields under the leadership of Erminia Roncal, the national potato breeder in the Huanuco research station. In return for their support, farmers received one-half of the output of the trials.

Involving farmers directly in the evaluation made sense. The national program's increasingly tight operating budget for agricultural research could be stretched when farmers were not subsidized and when they were responsible for all operations in the test fields. The evaluation took place under farmers' conditions reducing the chances that unwanted surprises would be forthcoming. Lastly, the retained seed provided farmers the opportunity to start multiplying and using any clone that fit their circumstances.

In the final evaluation, six of the most promising clones from six years of on-station selection and three years of testing in farmers' fields figured as entries. All participating farmers selected seedling no. 380389.1. This selection was released nationally as Canchan-INIAA in 1990 (Gastelo et al. 1991). The variety's earliness, late blight resistance, high yield potential, and red flesh color were highlighted in its release description.

By the time Canchan-INIAA was released, dozens of farmers were growing the variety, and a considerable amount of seed had been distributed via the informal seed system. Indeed, farmers' seed was used to release Canchan-INIAA because fields planted by the national potato program for the anticipated release of the variety were severely affected by frost (E. Roncal, personal communication, 1994).

The above description is taken from an impact case study (Fonseca et al., 1996) that was based on early acceptance surveys conducted in 1992 and 1993 in the Huanuco region. The study projected that Canchan-INIAA would be planted on about 10,000 hectares in 2006 and would reach a ceiling level of adoption of 25,000 hectares by 2020 equivalent to about 10% of potato-growing area in Peru. These projections proved to be too conservative as Canchan-INIAA is now planted on 70,000 hectares accounting for about one-fourth of potato area cultivated in Peru (G.Thiele, personal communication, 2006). In spite of a reported breakdown in its resistance to late blight and the lack of renewal of its seed, Canchan-INIAA is still a very popular variety.

The Canchan-INIAA story illustrates several of the essential features of participatory plant breeding. Erminia Roncal may not have known it at the time, but she was engaging in participatory varietal selection when farmers are important actors in selection in the later phases of the plant breeding process. But she was not acting in the spirit of participatory plant breeding (PPB) per se. In the early stages of the varietal generation cycle, late blight resistance was the main criterion for selection pressure. Material that did not have an adequate level of resistance was discarded irrespective of its performance on other traits. The implicit hypothesis or hope was that the very diverse population to which Canchan-INIAA belonged would segregate for traits that farmers wanted, within the set of materials with adequate levels of late blight resistance. Farmer involvement in the on-station research that "designed" Canchan-INIAA was negligible.

In contrast to participatory varietal selection, participatory plant breeding starts with the elicitation of farmer information on desirable traits that in turn leads to the choice of parental material for crossing that is most likely to result in populations that segregate for those desirable traits in farmers' fields for targeted geographic areas and end uses. In several PPB applications, farmers begin selecting material shortly after the cross is made or they may enter later in the process, but they would most assuredly be involved before year 7 as was the case of Canchan-INIAA. Given the success of Canchan-INIAA, it is likely that earliness, market quality combined with a red-skin color, and late-blight-resistance would have belonged to the set of desirable traits to consider in the choice of parents.

Our brief review of participatory varietal selection and participatory plant breeding is organized as follows: (1) rationale, (2) the recent development of PVS and PPB, (3) the practice of PPB, (4) impact, and (5) perspectives and prospects. The literature on PPB (which usually includes participatory varietal selection (PVS)) is a recent and burgeoning one. Several insightful reviews are available. Sperling et al. 2001 presents a taxonomy of participatory plant breeding approaches and characteristics, Morris and Bellon (2004) critically review PPB from an international crop improvement perspective, and Ashby and Lilja (2004) synthesize wide-ranging results related to impact assessment.

The most comprehensive review of farmers' participation in plant breeding is Weltzien et al. 2003 which is based on an inventory of 40 developing-country 'cases' that were active in the 1990s. Formal-led participatory plant breeding was the population of interest in the Weltzien et al. monograph. (Initiatives led by NGOs and by the private sector were not included as the bulk of cases addressed public-sector funded research). Fifteen different aspects of each case were described in an Appendix that is a rich source of material to determine how participatory varietal selection and participatory plant breeding were evolving. The majority of the cases focused on participatory varietal selection or on establishing objectives for a specific plant-breeding program. Eleven of the cases were studied in detail, and this inventory of experience is also the basis for Sperling et al. 2001.

The emerging NGO experience with PPB is also commanding the attention of reviewers. An advocacy and training book based on six case studies of NGO-related PPB was published in 2003 by IDRC (Vernooy 2003). More recently, a comprehensive review has been undertaken of NGO experience (Almekinders and Hardon 2006). Much of that experience takes place within the framework of a farmer field school. NGO applications feature both PVS and PPB. The Almekinders and Hardon review is based on 10 case studies with a regional concentration in Southeast Asia. Special attention is given to the institutionalization of PPB, and the authors point out the difficulties in evaluating the impact of PPB when it is combined with development.

There are several motivations for PPB. This review focuses on PPB efforts that are aimed at generating new varieties that farmers adopt to improve their livelihoods. Enhancing in-situ conservation, expanding genetic diversity, and empowering farmers are not discussed although they may be by-products of production-oriented PPB.

Lastly, a word or two on terminology is warranted. PPB is really a continuum (Morris and Bellon 2004), and the dichotomy between PPV and PPB is not hard and fast (Sperling et al. 2001). PVS is a component process within PPB. All PPB programs use PVS in some form. The contrast to and reference point for participatory plant breeding is usually referred to as conventional breeding, which may sound confrontational. Indeed, one of the main proponents of PPB now refers to it as highly client-oriented breeding and eschews the terms PPB and conventional breeding (Witcombe et al. 2005).

Rationale

Support for PVS and PPB comes from dissatisfaction over the slow pace of varietal change in many agricultural regions in developing countries. The hypothesis is that a more client-oriented breeding approach can accelerate varietal change. Several aspects of the diagnosis of the problem and the potential of the solution are briefly addressed in this section.

Disappointing levels of adoption of modern varieties in 'by-passed' regions

The main rationale for participatory varietal selection and participatory plant breeding in developing-country agriculture is the existence of important cropping systems in marginal regions where the adoption of modern varieties is low or negligible. This widespread perception that the green-revolution varieties have only had an impact on irrigated areas of high production potential is not strictly correct as farmers in large regions of rain-fed agriculture have benefited from varietal change. For instance, improved wheat varieties have penetrated into many so-called marginal production regions in Asia and Latin America (Byerlee 1994). Moreover, not all high potential regions are characterized by a rapid turnover of improved varieties, e.g., in some high-yielding areas of South Asia, farmers still grow varieties that were bred more than 40 years ago.

But, in general, the conventional wisdom of by-passed marginal regions that have not benefited from modern varieties is true. One can document extensive tracts where the uptake of improved varieties is effectively nil, even in countries with strong national agricultural research programs. In India, post-rainy season sorghum is a cropping system that seamlessly fits the description of a by-passed region (Walker and Ryan 1990). The dominant variety in post-rainy season sorghum is still Maldandi (M 35-1), an improved local selection released by the Sholapur research station in 1933 (B.S. Dhillon, personal communication, 2006). Growing a crop under residual moisture in the dry season is a hard environment in which to make progress. And, Maldandi excels on several key traits, such as grain color and size, fodder production, drought tolerance and pest resistance (Dvorak 1987). Still, the absence of progress in stimulating varietal change in a cropping system covering several million hectares in a strong NARS setting is surprising.

For other cropping systems, adoption rates of modern varieties have peaked at levels significantly less than 100% (Jansen et al. 1990). Usually, large locales within a broader recommendation domain are still growing local land races and "first-generation" improved cultivars, whereas other sub-regions in somewhat more favorable environments are benefiting from newer improved varieties. This less-than-full adoption scenario applies to rainy season sorghum in India, which experienced considerable varietal change in the late 1960s and 1970s with introduction of photo-period insensitive, stiff-straw, short-duration hybrids. These high-yielding hybrids were successful, but they were far from universally accepted and could not deter the declining trend in the area of rainy-season sorghum.

Negligible and ceiling rates of adoption imply that farmers' varieties are "old." Weighted average varietal age indexed from the date of release to the present can be a useful measure of the performance of a crop improvement program (Brennan and Byerlee 1991; Walker 1994). Low rates of varietal turnover or replacement highlight the potential for improvement from a change in approach that incorporates elements of PPB (Witcombe et al. 1998). For major field crops, weighted average varietal age exceeding 15-20 years indicates that farmers do not have access to new materials that suit their circumstances; this in turn implies a non-functioning agricultural research system for the commodity under analysis.

Inefficient varietal release and testing procedures

Rigid release requirements and unrepresentative testing conditions lead to mismatches between what is offered by breeders and what is desired by farmers (Witcombe and Virk 1997). For example, in North Africa and the Middle East, barley research typically takes place on stations located in the wheat-growing area (S.Ceccarelli, personal communication, 2006). Barley is grown in dryer zones than wheat; therefore, it becomes a self-fulfilling prophecy that barley in the higher rainfall areas would be effectively served by these stations and that barley in the more arid zones would be neglected. Testing procedures that locate trials in wetter low–lying areas or that use levels of intensification unrepresentative of farmer input use further add to the dissonance between what is offered and what is demanded.

A high incidence of genotype by environment (GxE) interactions also complicates the testing picture in cropping systems cultivated in marginal environments (Ceccarelli et al., 1996). Nowadays, building small research stations in well-identified testing environments within a broader recommendation domain is not an option for most national agricultural research programs. Therefore, other means have to be found to address GxE interactions.

Escapes

Escapes are another indication that plant breeding is not as efficient as it could be. Escapes are usually non-released or rejected varieties because of one or more perceived weaknesses. Mashuri, a high-yielding Malaysian rice variety, is arguably the best-known escape. It was tested in India in the late 1960s, but was not released. Its perceived fatal flaw was susceptibility to lodging. A farmer started to cultivate it in Andhra Pradesh in South India, and today Mashuri is still popular in East India and parts of Nepal and Bangladesh (Tripp 1997).

Escapes may result in more practical impact than released varieties (Walker et al. 2003). In China, Kexin No. 1 has been one of the most widely grown potato varieties since the 1960s. Kexin No. 1 was popularized by a field worker employed by the breeder who made the cross in the 1950s, even though that breeder subsequently discarded this selection (Song BoFu, personal communication, 1997). In recognition of its popularity, Kexin No. 1 was finally released in 1984.

Success of client-oriented plant breeding in developed countries

Several examples that more client-oriented breeding is successful can be found in developed countries. The Netherlands has a long history of incorporating 'professional' and amateur selectors in cultivar generation for their major field crops, particularly in potatoes (Dorst 1954). The Dutch potato-breeding program, arguably the best potato improvement program in the world and the backbone of the Dutch potato seed business that dominates international trade in tuber seed, is a good example of the use of PPB. University and government institutions make the crosses, which are distributed to private breeders for selection on a competitive basis. The best performing materials are released, and the breeders who selected the released varieties receive royalties for their protected property. By the mid-1950s, the number of private potato breeders approached 200, and, of these, 20 were successful in selecting cultivars that appeared on the Dutch List of Varieties (Zingstra 1954). Over time, seed companies have loomed larger in the earlier stages of the potato breeding cycle and in varietal promotion, but private selectors still play an important role in generating varieties.

Dutch bred potato varieties are known for their outstanding market quality and high yield potential. In spite of being bred in small regions of the Netherlands, several of these varieties, such as Desiree, have wide adaptability and are produced globally in many diverse potato-producing regions. But, they usually do not carry high levels of disease resistances particularly to late blight and seed-borne diseases. The assumption is that farmers will repurchase the seed each year; hence, there is no incentive to screen for seed-borne diseases.

A second example comes from Australia where barley is grown in one of the lowest rainfall regimes for crop cultivation in the world. The production environment is not only marginal but also heterogeneous, so much so that barley breeders do the bulk of their selection in farmers fields in spatially disperse locations (S. Ceccarelli, et al. 2004).

Our last example is not as client-oriented as the previous two, but it carries as much weight. Agricultural historians do not analyze the practical effectiveness of plant breeding programs or plant breeders as individuals probably because of inadequate data on varietal adoption over time for the majority of major field crops in most countries. Potatoes are an exception as data on certified seed production is available on an annual basis and most growers plant certified seed each year. This enables researchers to develop adoption profiles over time by variety and plant breeding program (Walker 1994). The 1950s, 1960s, and 1970s were a bad time for most potato breeders in the U.S. and Canada. Varieties were being released, but they were not being adopted. Varietal age was steadily rising, mainly because of the increasing market dominance of high-yield potential regions where Russet Burbank—an 'amazing' clone that Luther Burbank selected from a seed ball in his mother's garden in 1872—could be produced (Davis 1992).

The bright spot in this otherwise bleak picture was the North Dakota State Potato Program, which consistently translated release into adoption beginning with the appearance of its first clone, Norland, in 1956. Excluding releases where the USDA figured as the main release agency, the 14 releases from the North Dakota State Program accounted for more area in growers' fields in the 20th century than the combined total of the 152 releases from all the other public-sector programs including Agriculture Canada (Walker 1994). The truly outstanding performance of the North Dakota program is the counterfactual observation suggesting that progress could still be made in the 1950s, 1960s, and 1970s when the demand and supply conditions appeared to be especially unfavorable for the achievement of practical impact from investments in potato breeding.

Many factors probably contributed to the success of the North Dakota State program, but some indications were given when Robert Johansen, the plant breeder responsible for the program, was presented for Honorary Life Membership in the American Potato Association: "Part of his potato breeding success has been due to the excellent grower relationships he has developed over the years. This has enabled him to get grower input on selections early in their development and also to get adequate seed increases of new releases." (Nelson 1982, p. 441). In an interview on the occasion of his retirement in 1992, Johansen expanded on the reasons for his success: "I take more stock in what growers, processors, and buyers/shippers tell me than what a lot of researchers say. I don't mean to be knocking researchers, but when I send out a variety, I'll ask the grower how it did. He won't lie to me because that is his bread and butter. I've had that philosophy for many years. That's why our program may be a little more successful than some of them. We've gotten the varieties out to growers and have gotten either a positive or negative viewpoint of them." (Ackerson 1992, p. 6). Later in the same article, Johansen says that "probably his biggest reward is when he drives down the highway, identifies some of his varieties and knows that those varieties have helped build communities." (ibid, p. 7).

Interestingly, Robert Johansen carried out his work in the lowest yielding and lowest production potential environment of any of the 10-12 specialized potato-producing regions in North America and Canada. Drought is a frequent visitor to the Red River Valley.

The Recent History of PVS and PPB

The building blocks for participatory variety selection (PVS) were carried out in one form or another under the rubric of (earlier) farming systems research and (later) participatory research in the 1970s and 1980s in several institutional settings. For example, the national program of Guatemala (ICTA) in the late 1970s institutionalized research in researcher-managed, on-farm trials and farmer-managed tests that were designed to elicit farmer information that was used in the design of technology (Hildebrand 1979). But more typically, PVS-related work was not the norm and co-existed with unchanged institutional circumstances. A case in point was the maize breeding program at Pantnagar, one of the leading agricultural universities in India. On-farm research was a prime component of that program, and a routine was developed to enhance the odds that information generated in the on-farm stage would be utilized in decision-making on breeding priorities (Agarwal 1979 and Biggs 1983).

Social scientists also figured prominently in efforts to supply information to breeders on farmers' demand for traits and farmers' early acceptance of elite varieties. Consumer preferences for evident and cryptic quality traits for the ICRISAT-mandated crops were analyzed in the 1970s and 1980s in an attempt to bring market information to bear on plant breeding priorities (von Oppen 1976). Advanced sorghum and pearl millet breeding materials were tested and extensively evaluated with farmers in their fields in West Africa by social scientists prior to varietal release (Matlon 1985).

But, aside from many building blocks pointing to the potential use of PVS, the documentation of explicit farmer participation in varietal development was still scanty in the 1970s and 1980s. Like the case of Canchan-INIAA that was used to introduce this paper, PVS-related efforts were probably more numerous than those reported in the published literature. In other cases, the nature of farmer participation was not well-described although such participation seems to contribute to success. For example, farmers were involved in the generation of what were to become widely adopted improved maize varieties in a multi-decade CIMMYT-associated project in Ghana, but the degree and stage of farmers' involvement was not rigorously reported (Morris and Tripp 1999). Arguably, the best documentation of PVS occurred at CIAT where social scientists identified priority traits for breeding in beans in several participatory research settings. For instance, Sperling et al. (1993) is a widely cited publication that thoroughly described farmers' involvement in the selection of bean varieties in on-station trials in Rwanda.

In the 1980s, the work of D.M. Maruya, a rice breeder improving rain-fed and deep water rice in East India, was arguably the best known example of using farmer participation as an input into a plant breeding program (Maruya et al. 1988). The bulk of that work centered on the testing of experimental varieties with farmers (Weltzien et al. 2003).

Involving farmers in the earlier stages of selection in plant breeding is a more recent development. One of the first applications of PPB took place in the Cauca Valley in Colombia where three farmer breeders worked with breeders in the CIAT bean program. Selections by the farmer breeders provided information on the demand for characteristics across several environments (Kornegay 1996). The term PPB was coined at an IDRC workshop in 1995 and the acronym PVS was also introduced at this event. The first joint use of PPB and PVS in the peer-reviewed literature took place in *Experimental Agriculture* in the following year (Witcombe et al. 1996).

Under the leadership of J.A. Ashby of CIAT, a proposal for a systems-wide initiative on Participatory Research and Gender Analysis (PRGA) was submitted and approved by the CGIAR in 1996. Participatory varietal selection and participatory plant breeding have featured prominently in that program.

Farming systems and participatory research has mainly been 'owned' and practiced by social scientists and agronomists. In contrast, the leadership for and practice of PPB is firmly in the hands of several committed plant breeders supported by researchers in other disciplines mainly social science. Since 1995 about 30 articles relevant to PPB have been published in the plant-breeding journal *Euphytica*. It may be an exaggeration to call PPB a hotbed of intellectual activity, but its dynamism is reflected in a growing and vibrant literature that cuts across theory, method, and application. Teaching materials on the conduct of participatory plant breeding are becoming increasingly available (Christinck et al., 2005).

Prominent in this emerging field is the work of Salvatore Ceccarelli, Eva Weltizen, John Witcombe, and their respective colleagues. All three share a common plant-breeding background: many years devoted to improving drought-tolerant cereals in low-rainfall environments. They also probably shared the same frustrations that contributed to their advocacy for PPB.

To understand PPB, we describe and compare the methods used by the ICARDA Barley Program in Aleppo, Syria, where Salvatore Ceccarelli has worked since the early 1980s and by the CAZS-NR team at the University of Wales at Bangor headed by John Witcombe. These two leading practitioner groups account for more than half of the articles in peer-reviewed journals on participatory plant breeding.

The Practice of PPB

Morris and Bellon (2004) cite and analyze several of the misconceptions about PPB. One way to clear up misconceptions and improve the understanding of PPB is to compare program designs of the leading practitioners.

The Participatory Model of the ICARDA Barley Program

The adoption of PPB by the ICARDA Barley Program was fueled by the overriding concern that, after years of trying with conventional breeding methods, improved varieties were not reaching barley farmers in the dryer arid regions of the Middle East and North Africa. The conversion between 1997 and 2003 from a classical, centralized breeding approach to a decentralized, participatory model was not based on a snap decision (Figure 1). The change was predicated on exploratory research that compared farmers' and breeders' selections in research stations and farmer fields (Ceccarelli et al. 2000 and 2003). This work showed that farmers could handle large populations of entries planted by researchers, develop their own scoring methods, and that they are as efficient as or even more efficient than breeders in selecting the highest-yielding entries in their own fields and in lower rainfall research stations. Breeders were more efficient in selection in higher rainfall research stations, and the selection criteria used by breeders and farmers were roughly the same, although farmers were more likely than breeders to select for specific adaptation. The ICARDA barley breeders concluded that "there was much to gain, and nothing to lose, in implementing a decentralized participatory plant breeding program" (Ceccarelli and Grando 2005, p.1).

The model of participatory plant breeding by the ICARDA Barley Program features four years of on-farm trials and farmer selection (Ceccarelli and Grando 2005; Mangione et al. 2006; Ceccarelli and Grando 2006). Between 1997 and 2004, the ICARDA Barley Program in Syria totally transformed the locus of their operation from 8,000 plots annually planted and evaluated on the research station to 8,000 plots planted and evaluated in farmers' fields. Based on the initial results on barley in Syria, the team has extended their PPB model to six other commodities, including durum and bread wheat, and to nine countries, most of these are in North Africa and the Middle East.

For a self-pollinated crop like barley, a bulk-pedigree method is used with four rounds of farmers' selection (Figure 2). From the year the cross is made, varieties should be eligible for release in years 7-8, which is potentially a significant savings in time compared to the conventional scheme which can take up to 15 years if pedigree selection is practiced or 12 years if bulk selection is followed under Syrian varietal release and testing procedures.

The four rounds of farmer selection are at the heart of the participatory model described in Figure 2. The first year of farmer selection takes place in one unreplicated yield trial per village with about 170 new entries and 30 checks. About one entry in 10 is selected for the next stage when selection pressure decreases from 17 entries to 8 selected in the second year, then to 3 - 4 entries selected in the third year, and then to 1 - 2 entries selected per village in the final stage of farmer selection. The size of the plots in the trial increases at each of the four years of farmer selection, but trials per village are about the same number, between 2 and 4, during the last three years of farmer selection. The number of farmers participating per village is constant at 8 - 10 across the four years of farmer selection.

In Syria, one complete participatory breeding cycle resulted in 19 varieties chosen in the fourth year of farmer selection. Nineteen varieties selected is greater than "the number of lines the Syrian National Program tests at *the beginning* of its on-farm testing which usually ends with one or two recommended varieties across the country" (Ceccarelli and Grando 2006, p. 6).

Selection criteria combine farmers' preferences and breeders' measurements of traits similar to a conventional breeding program. Data on these parameters are analyzed statistically and are discussed at a special meeting when the decision on which lines to advance is taken jointly by farmers and breeders.

Several features of the ICARDA barley-breeding model warrant comment:

- The crosses do not merely combine existing landraces or recommended but yet-to-be-adopted varieties. Wider crosses generating more diversity are preferred. For example, a near relative (*H. spontaneum*) of barley renowned for its drought tolerance figures as one of the parents in the villages in the lower rainfall areas.
- Researchers have primary responsibility for planting and harvesting the trials. Farmers are responsible for everything else and make all the management decisions.
- The statistical analysis is 'state of the art' using spatial analysis of unreplicated or partially replicated trials (Singh et al. 2003).
- In terms of the farmer's time, the cost of participation ranges from two days to two weeks annually depending on the level of participation.
- A back-up set of the selected materials is planted at the research station to assist the selection if pure lines are needed, but, more importantly, to insure against the risk of losing the on-farm trials to drought.

- In the case of drought, the owners of trials are compensated for loss up to expected barley production in a normal year.
- Seed cleaning machinery is supplied to some villages to assist in the rapid multiplication and dissemination of selected varieties following the fourth year of farmer selection.
- Screening for diseases and insect pests can be carried out on-station after the first round of farmer selection.
- The approach is flexible enough to accommodate biotechnological techniques, specifically Marker-Assisted Selection, after the first year of farmer selection. (PPB should be able to provide reliable information on desirable traits that could later be evaluated via Marker-Assisted Selection).

The Participatory Model of CAZS Natural Resources (CAZS-NR)

Since the early 1990s scientists in CAZS-NR at the University of Wales, Bangor, in the United Kingdom have worked in participatory variety selection and participatory plant breeding. (CAZS was an acronym for the Centre for Arid Zone Studies, but the acronym has been dropped because the scientists in the erstwhile CAZS work in many areas outside arid agriculture). For PPB, they have focused on cereals, mostly rice and maize, in marginal regions of South Asia, mainly India, Nepal, and, most recently, Bangladesh. DFID of the U.K. has been the major supporter of the CAZS-NR work. CAZS-NR scientists usually partner with a government organization, often a state agricultural university, and with an NGO, such as the Local Initiatives for Biodiversity, Research, and Development (LI-BIRD) (in Nepal) which has a rich experience in participatory plant breeding.

The CAZS-NR model is more generalized than the ICARDA participatory plant-breeding model. Its PPB projects are characterized by a shared sequential framework. Major elements of that framework are the following:

1. Participatory varietal selection is used as an entry point to better understand the availability of improved cultivars and the value of recommended/existing adapted materials to farmers. PVS also generates information on the suitability of these materials as prospective parents. If PVS results in widespread farmer acceptance of these new but existing materials with significant gains in productivity over customary checks, then the process could stop without investing in breeding.
2. Simultaneous to or with PVS, a rapid appraisal is conducted on farmers' demand for specific traits.
3. Based on the information generated from the participatory varietal selection and the rapid appraisal, goals are set for the plant breeding program and a 'smart' cross is made (for a self-pollinated crop such as rice) to generate a segregating population.

4. The cross is followed by several years of selection either consultatively or collaboratively with farmers, depending on the commodity and the project circumstances.
5. The selected material is multiplied for farmers and is also entered into state trials (in India) or national trials (in Nepal).

Typically, it takes 3-4 years from the time that the cross is made to get material into the hands of farmers for testing (Virk et al. 2005). This gestation period contrasts to about 10 or more years in the most directly relevant comparisons to conventional programs, and a minimum saving of three years is always achieved by concurrent testing on farm and on station.

Generally, PVS in the CAZS-NR collaborative projects often shows that the recommended varieties are not preferred or that they have considerable scope for improvement. Sometimes, PVS by itself is successful and results in rapid varietal change in the project area. The rice variety Kalinga III is a well-documented case for which PVS resulted in accelerated varietal change (Joshi and Witcombe 1996). This variety was released in East India in the state of Orissa in 1983, but was not recommended for release in other states. Kalinga III found a home in farmers' fields in a CAZS-NR-partnered project in eastern Rajastan where it rapidly spread soon after testing (Witcombe et al. 1999).

The CAZR-NR strategy for PPB can be called a low-cross number, large-population size breeding program (Witcombe and Virk 2001). In contrast, most conventional breeding programs generate a high number of crosses each with a small population size. The CAZR-NR strategy of large populations from a small number of crosses stems from both practical—farmers cannot be expected to evaluate the progeny of as many crosses as could be assessed under experimental station conditions—and theoretical considerations (Witcombe and Virk 2001).

Selecting good parents is pivotal to the success of the CAZS-NR approach. One parent is usually a well-adapted improved cultivar; the other is also reasonably well adapted to the specific recommendation domain and shows complementary traits that are demanded in the client population. It is important to note that one parent may contain exotic germplasm. The CAZS-NR team has used maize parents from South America and rice parents from IRRI depending on the needs of the project. In other words, 'smart' crosses does not mean crossing local landraces with local landraces. Because the CAZS-NR team generates a large population for evaluation from one or two crosses (for self-pollinated) crops, the choice of parents is vital but the large population size for selection is just as important.

The crossing program, as in all breeding programs, is a continuous one. Selecting from larger populations of a smaller number of crosses has proven to be a low risk strategy with a high success rate. The CAZS-NR team and their partners are now in the eighth year of a multi-purpose, project-based breeding program that has made a combined total of only 27 crosses for all rice target ecologies and types in Nepal: highland, medium-altitude, lowland, and aromatic (J.R. Witcombe, personal communication, 2006).

Impact

The impact of participatory varietal selection and participatory plant breeding is not easy to assess because, like any other scientific endeavor, insignificant results are seldom reported. But because both PVS and PPB are not very costly activities, documenting positive experiences should be sufficient to tell a persuasive story to make a strong case for PVS and PPB. Success stories of PVS, like the narrative of Canchan-INIAA that was described in the introduction, are often 'buried' in the grey literature or are sometimes not reported because analysts are more likely to focus on the results than on the process of selection. In any case, PVS seems to be increasingly institutionalized in diverse plant breeding agencies in developing countries, and the advantages of using PVS techniques make such good sense that the relevant question is not whether or not PVS should be carried out. But, as Morris and Bellon (2004) implictly pose: How can the quality of PVS applications be improved? Therefore, in this section, we allocate the lion's share of the discussion on impact to PPB and only summarily treat PVS in the next sub-section that briefly describes several success stories of PVS in Sub-Saharan Africa, the region of the world where productivity-enhancing varietal change is most needed.

PVS

Improved bean varieties in East Africa are probably the best-known example of the successful application of PVS which has fueled bean crop improvement in several countries including Rwanda, Tanzania, and Malawi (Weltzien et al. 2003). National program partnerships with CIAT and with USAID's bean-cowpea (Collaborative Research Support Program) CRSP have figured prominently in that work. Common bean has a reputation for narrow ecological and market adaptation; therefore, it is not surprising that PVS can result in highly favorable outcomes.

One of the most economically important uses of PVS that is well-documented in the literature centers on the adaptation of the New Rice For Africa (NERICA) varieties that combine the high productivity of Asian rice with the adaptation and yield stability of African rice (Dalton and Guei 2003). The West African Rice Development Association (WARDA) distributed advanced material from these interspecific crosses for selection in its member countries where participatory techniques were used by men and women farmers in varietal evaluation. Farmers selected from multiple entries in rice gardens (Weltzien et al. 2003). Post-harvest traits loomed large in the farmer assessment and the selection of material for release (Lilja and Ashby 2004). Additional research by Dalton (2004) showed that yield may be given undue importance in breeder's evaluations relative to other traits, such as duration, plant height, grain color, elongation/swelling, and tenderness.

The early-maturing pearl millet variety Okashana 1 is another PVS success story in Sub-Saharan Africa (Bidinger 1998). This ICRISAT-India generated variety was selected by farmers in Namibia in 1987 and was released in 1989. Okashana 1 is cultivated on about 50% of pearl millet area in Namibia and has potential to spill over into other countries in southern Africa (Witcombe and Virk 2001). The success of Okashana 1 has also contributed to the development of a PPB program on pearl millet in Namibia (Weltzien et al. 2003).

Mother and baby trials are a recent innovation that has captured the imagination of researchers in NARS and other research agencies in southern Africa (Snapp 2002). NARS breeders in this region have embraced this on-farm research paradigm that potentially brings them closer to the farmers' environment. Mother and baby trials are still new and may have teething problems in their effective implementation, but they offer an entry point for PVS and a potential platform for PPB. For example, the CAZS-NR group has used mother and baby trials to good effect. They find that the results from the baby trials are the best marker of farmer productivity levels.

PPB

PPB can have a multiplicity of impacts. Many of these are described in the recent review by Ashby and Lilja (2004). Those listed and discussed below are by no means exhaustive and focus on varietal change.

Adoption of PPB products

Generating new varieties for farmers who now cultivate 'old' varieties in marginal environments is the raison d'etre of PPB. Although PPB is still in its early days, practitioners need to show that PPB-generated cultivars are adopted by farmers. Productivity levels in low rainfall environments fluctuate sharply from year-to-year. These fluctuations will swamp the effects of varietal change, giving the impression that nothing significant is happening in the region when, in fact, adoption is robust. Secondary data cannot be relied on to assess the effects of

PPB. Early acceptance and later adoption surveys should feature prominently in the PPB toolkit. In general, the evidence for adoption is variable with several dry holes and undocumented outcomes, but the generation of PPB-related varieties provides grounds for optimism.

In a very short period of time (for plant breeding), the CAZS-NR group has reported five PPB success stories in the peer-reviewed literature (Joshi et al. 2001; Joshi et al. 2002; Virk et al. 2003; Witcombe et al. 2003; and Virk et al. 2005). In India, CAZS-NR and their partners have generated improved rice varieties for the rainfed uplands of eastern India and improved maize varieties for the poverty-ridden Chhotanagpur Plateau of eastern India and for the hill areas of the western state of Gujarat. In Nepal, CAZS-NR and their partners have produced improved rice varieties for the high-altitude hills, several mid-hill districts, and for all 21 terai districts. Early acceptance studies of adoption suggest that all these varieties enjoy bright prospects. Although adoption is still in the early diffusion stage for most of these products, a cost-benefit analysis at this time would almost certainly show a high rate of return on investment and, in some cases, high levels of net present value even for projects that focused on specific adaptation. Very thorough adoption research also documents the rapid spread of Kalinga III, a PVS-related product of CAZS-NR collaboration in the early and mid-1990s (Witcombe et al, 1999).

The ICARDA Barley Team started its work a few years after CAZS-NR, and it has yet to reach the level of adoption performance that the CAZS-NR group has obtained in South Asia. Nonetheless, in the first cycle of crop improvement with PPB (see Figure 2), farmers have selected the following number of PPB-generated barley varieties: 12 in Syria, 1 in Jordan, 5 in Egypt, 3 in Eritrea, and 2 in Yemen where 2 lentil varieties have also been selected. Several of the selections in Syria are already on several thousand hectares. One elite line, Zanbaka, was submitted to the official system of variety release in the early eighties and was rejected. It was then included in the PPB trials and was adopted because it matched farmers' preferences. Zanbaka has now spread from the 'participatory-breeding' villages to about five thousand hectares in Syria in several provinces (Musafa et al. 2006). Recently, a second variety, also rejected by the variety-release committee several years ago is repeating the Zanbaka story of adoption in the PPB trials and is expected to reach 5,000 hectares next year. An ex-ante assessment of the ICARDA Barley Team's PPB investment in Syria shows high economic potential of that work given that barley is cultivated on 800,000 hectares and that results should be rapidly forthcoming (Lilja and Aw-Hasaan 2002). A very early ex-post assessment has been carried out (Musafa et al. 2006).

Conspicuous for its absence is any hard evidence on adoption outcomes in Latin America of PPB-related work. Participatory cassava improvement in the

Northeast Brazil of Brazil is one of the earliest PPB projects in Latin America (Fukuda and Saad, 2001). Clones that are resistant to root rot and that are highly acceptable to farmers have been released, but a recent adoption study concluded that it was too early to mount a survey to assess the level of adoption of those materials (Saad et al., 2005). In Ecuador in 2005, a PVS-related good-processing potato variety I-Fripapa-99 occupied 5,000 hectares in the central part of the country (Montesdeoca et al. 2006). That variety was selected over a three-year period in farmers' fields with producers, consumers, processors, and traders). PROINPA, the semi-autonomous national potato program of Bolivia, has conducted PPB for several years, but PPB-related cultivar adoption as yet does not exceed a few hundred hectares (G. Thiele, personal communication, 2006).

Specific adaptation

Specific adaptation is foremost in participatory plant breeding. In principle, plant breeders should always be able to make progress in a specific locale (N. Simmonds, personal communication 1995). But the generated product may not be transferable to other locales and therefore may only be adopted locally. The CAZS-NR group has provided evidence that varieties bred for specific adaptation may be more transferable than initially thought. One of the varieties bred in the terai has given excellent results in the High Barind Tract of Bangladesh in aus, aman, and even in the irrigated boro seasons (Joshi, et al. 2007). In Nepal, two rice varieties bred for the high hills actually performed relatively better in the mid-hills where rice cultivation is more common (Joshi and Witcombe 2003). Part of the reason for wider than expected adaptation is the shared preferences for traits: aside from yield, farmers usually prize earliness, market quality, and fodder quality and quantity in many cereals.

Net benefits per hectare

Comparing the selected variety and the check variety yields in farmer fields suggest higher net benefits than expected. For the three success stories of the CAZS-NR group in India, the average yield difference of the selected variety was 40% higher than the check (Virk et al, 2005). These relative differences are higher in farmer fields than on research stations. For cereals, these gains are equivalent to about 50-60 U.S. dollars per hectare, assuming a base yield of about one ton.

Costs

PPB has been indicted as costing too much; particularly the operational costs seem high (Ziegler 1996). This critique has motivated cost accounting of PPB and conventional plant breeding. The ICARDA barley team has carried out a very detailed study and arrived at the conclusion that PPB costs 2% more annually than conventional breeding (Mangione et al. 2006). If the speedier delivery of products is factored into the calculation, PPB costs less. In these times of resource scarcity, costs are perceived to be an important issue, but one should not lose sight of the fact that plant breeding is not a costly exercise and that results hinge on the extent of adoption of the program's cultivars. Costs of varietal improvement seldom matter in ex-post cost-benefit analyses. In the CAZR-NR approach, large populations can be grown at very low cost (J.R. Witcombe, personal communication 2006).

Poverty Effects

Practitioners, to their credit, have sited their work in some well-know geographic poverty traps. Marginal production conditions do not always translate into higher levels of poverty relative to other regions (Walker et al. 2006). But the conventional wisdom most likely holds for the regions where PPB practitioners are working. Positive results from PPB resulting in widespread varietal adoption should make a sizable dent in an informative poverty measure such as the squared poverty gap.

Perspectives and Prospects

After ten years of increasing activity, the prospects are bright for participatory plant breeding to make a positive contribution to varietal change in marginal environments. The next ten years are critical to the development of PPB, and they will define the size of that contribution.

Some pleasant surprises have emerged during the first ten years. Research has shown that varieties bred and selected for specific adaptation can perform well in larger niches. Several products of PPB have wider adaptation than expected. Yield gains of 30-50% in farmers' fields, compared to the farmer's variety under the same management, are larger than expected.

The first ten years have also reconfirmed some expectations. Like the green revolution, progress has been faster in cereals than in other commodities although the experience with other crops such as roots, tubers, and pulses in PPB is still scanty. Self-pollinated crops are the ideal candidates for PPB compared with cross-pollinated crops, which require greater effort from farmers in selection and in subsequent seed production.

The target for PPB should still be in geographic poverty traps characterized by low and/or unexploited production potential. Although one success has taken place in one heterogeneous irrigated tract, the PPB varieties, in this case, were competing against cultivars that farmers had adopted in the late 1950s. Very high weighted mean varietal age suggested that PPB could be successful. High varietal age signals the potential demand for PPB. Crops with multiple uses seem to be particularly attractive for PPB projects as conventional breeding tends to focus only on the dominant use.

As with farming systems research, the initial institutionalization of PPB has been slow and perhaps even disappointing to some practitioners. But progress has been made. PPB is starting to figure as a sub-discipline of plant breeding and is beginning to be taught in workshops and university curricula. PPB-related varieties are entering public-sector varietal testing systems. In the next ten years, we should see examples of induced change on formal seed systems and varietal testing and release procedures precipitated by the accommodation of PPB products. (Already institutional change precipitated by these approaches has occurred in Nepal (Joshi et al., 2006).)

We are also beginning to see what production-oriented PPB is and is not. As practiced today, PPB respects the comparative advantage of what a farmer does best and what a breeder does best. Farmers' information is critical on the choice of parents, but farmers are not crossing nor are they directly choosing parents. In the next ten years, we will also have a better appreciation of what works when, where, and why as experience allows researchers to gradually approximate Morris and Bellon's (2004) ideal of efficient participatory plant breeding.

One thing that PPB is not: it is not a substitute for a resource-starved crop improvement program. Like conventional breeding, it requires a stable operating budget that is seasonally unconstrained. Although PPB should be able to deliver results in a shorter period of time than conventional breeding, five to seven years of assured funding are required to generate varieties that have a good chance of farmer acceptance. For many crop improvement programs in the public sector in Sub-Saharan Africa, PPB will suffer from the same resource deficiencies as conventional breeding. Nonetheless, there is ample scope for selected PPB applications in Sub-Saharan Africa (SSA). The absence of experience in SSA is a major gap in PPB's global portfolio. One of the few concerted efforts using PPB in SSA is the improvement of Guinea-race sorghums in Mali (Weltzien et al. 2006a). This work could have wider implications for West Africa because the Guinea-race dominates the region (Weltzien et al., 2006b).

Akin to conventional breeding, PPB requires good plant breeders. The standard for human capital in PPB is as high or even higher for capacity in conventional breeding. Breeders working in PPB have to be creative to come up with flexible yet workable designs tailored to a specific context and to deal with day-to-day tasks that are not routine. (The CAZS-NR group in several of their projects employed an international consultant to perform very specialized work in plant breeding). Given that training in genetics and plant breeding today is severely skewed towards biotechnology, the human capital requirements for PPB could be a cause for concern underscoring the importance for simple generalized designs. Accumulating more contextual information on the spatial, temporal, and commodity adaptation of PPB models and breeding strategies of the CAZS-NR team and the ICARDA barley program is a priority.

Salvatore Ceccarelli tells the story about a presentation he was giving at an international meeting in Morocco in 2005. At the end of his talk on PPB, a young man stood up and observed, "What are you talking about? We are in the 21st century; now we do all this work with Marker-Assisted Selection in the lab. We do it all in the lab!" The young man then stalked out of the conference room. The young man's scenario that all work will be done in the lab may ultimately come to pass but the question is: When? Widely heralded, biotechnology-related transgenic crop varieties that seemed imminent 15 years ago are now projected to take at least 10-15 years or longer to reach smallholder farmers in Africa (Eicher et al. 2006). In this unexpectedly long and increasingly technologically uncertain interim, both conventional plant breeding and highly client-oriented approaches such as PVS and PPB require our support if the aim is to effect varietal change for this generation of poor people and their children.

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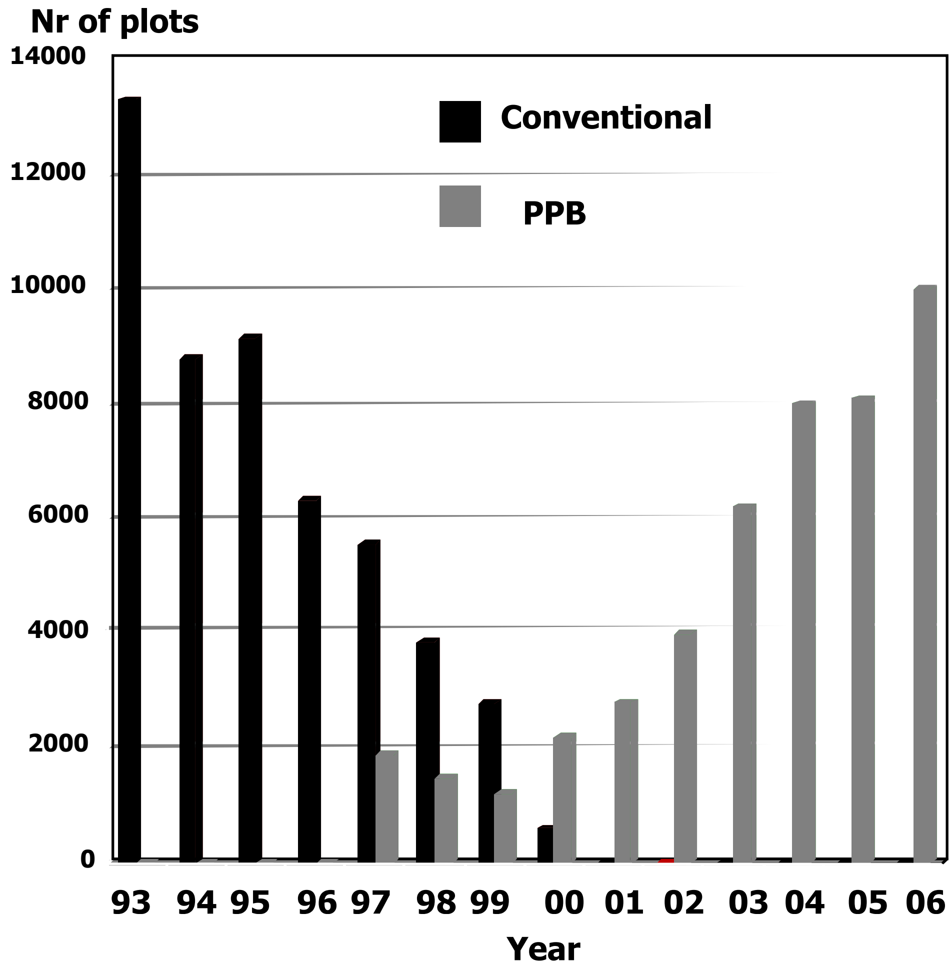

Figure 1. Number of plots of yield trials on and off-station during the transition from conventional to participatory plant breeding.
Source: S. Ceccarelli, ICARDA, 2006.

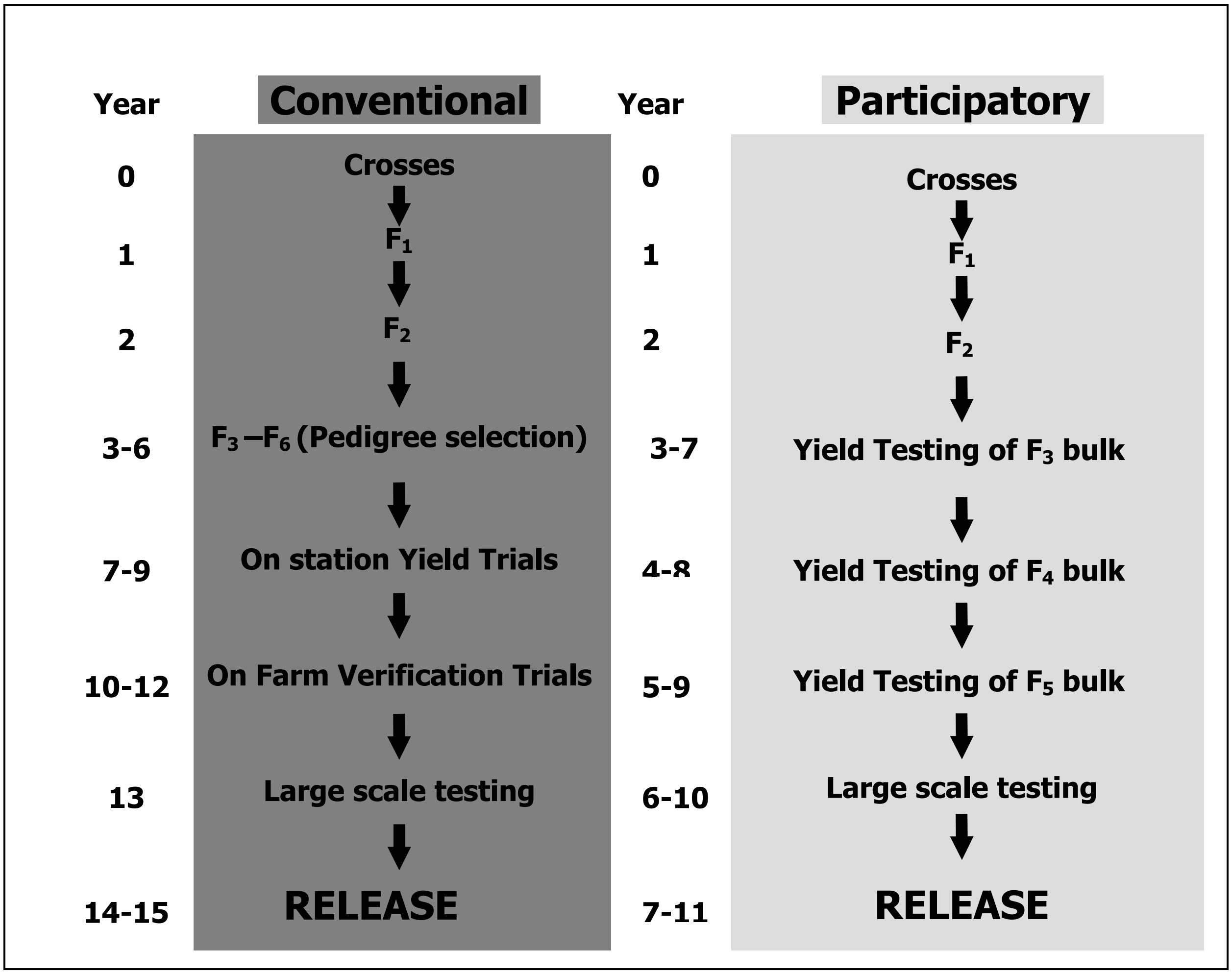

Figure 2. Farmer participation turns the delivery phase of a plant breeding program upside down and makes it demand-driven
Source: S. Ceccerelli, ICARDA, 2006.

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