CHAPTER 22

Participatory seed diffusion: experiences from the field

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22.1 CONVENTIONAL SEED PRODUCTION SYSTEMS IN CUBA

During the golden years of the eastern Socialist countries, a centralized plant-breeding model was a standard component of the high-input agriculture practised in Cuba, and particularly for the country's cash crops (Begemman, Oetmann and Esquivel, 2000). Foreign varieties, hybrids, landraces and varieties obtained by mutation were the principal sources of genetic variation used for varietal development in Cuban plant breeding programmes (Ríos, 1999). At the end of the 10–12 year period typically spent in varietal development for a specific crop, the breeding programmes usually released only one or two varieties for the entire country, therefore assuming a geographically wide adaptation. Wide geographical adaptation characteristics were encouraged by policy-makers, with most Cuban governmental organizations providing incentives to scientists involved in releasing a variety for use over a large area.

Ambitious plant breeding programmes were developed in the 1980s for sugar cane, roots and tubers, rice, tobacco, coffee, horticultural crops, pastures, grains, fibres and some fruit trees, undertaken by fifteen research institutes and their corresponding networks of experimental stations that spread over the island (Begemman, Oetmann and Esquivel, 2000).

As a part of the varietal release process, each new variety had to pass through a series of steps. The research institutes sent their results to the Scientific Forum (*Consejo Cientifico*) at the national level. This Forum checked their scientific validity and, if approved, they sent them on to an Expert Group (*Grupo expertos*), which consisted of researchers, teachers and production directors. If this group approved the results, they were then sent to the Vice-Minister of Mixed Crops (*Vice-Ministro Cultivos Varios*). This Minister would send the results to the provincial delegations, which would incorporate them into their production plans, so that producers were obliged to adopt them. This procedure took a top-down approach without consulting the producers. Some researchers did visit farms, but still the research agenda came from the decisions of the researchers (Trinks and Miedema, 1999).

Some plant materials collected in Cuba with useful characteristics, such as disease resistance, short growing cycles and good food qualities, were not used by the formal plant breeding sector due to their low yields under high-input conditions (Castiñeiras, 1992).

Following the disintegration of the USSR in 1989, the Cuban agricultural sector had to cope with a drastic reduction in input and trade support, shifting gradually towards more self-sufficient and rational forms of production.

Many remarkable technical and social transformations occurred as a response to this challenge. In the 1980s, Cuba had carried out 87 percent of its external trade under preferential price agreements, imported 95 percent of its fertilizer and herbicide requirements, and owned one tractor for every 125 ha of farm land. After the collapse of the socialist block, foreign purchase capacity was reduced from US$ 8.1 billion in 1989 to US$ 1.7 billion in 1993. This greatly affected the country's ability to buy agricultural inputs (Funes, 1997).

To address the crisis, the Cuban government implemented changes in all sectors to reduce the negative impact on the national economy. During the early 1990s, severe social and economic changes were made in order to maintain the social guarantees of the government while simultaneously reconstructing the Cuban economy (Enriquez, 2000; Rosset and Benjamin, 1993). Cuba thus undertook one of the most dramatic changes in farming systems, having to move from being the highest agrochemical consumer in Latin America, to very-low-input agriculture in less than three years (Funes, 2002).

However, the plant breeding sector has been slower to adapt. Even though the professional plant breeders faced a difficult economic situation and researchers had few incentives, they pursued top-down approaches and adopted rigid reductionist perspectives. Within this existing system, the solution was not as simple as technology substitution. Due to the financial crisis, research institutions faced various constraints, such as lack of access to, or maintenance of, important genetic resource collections; energy blackouts; incapability to refresh seeds; and a decrease in the number of international programmes that had formerly supported Cuban research institutions in the 1990s. The national seed supply system urgently needed to expand, but lacked the financial resources to do so. In the 1990s, its seed production capacity for maize and bean had fallen by 50 percent (Ríos and Wright, 1999).

Through the informal system, the production of seeds of the basic staples of the Cuban diet became a major issue in many parts of the country. These genetic resources had provided a basis for plant breeders to select commercial genotypes during the industrial agriculture period. However, relatively little attention has been paid to this informal seed management system and much genetic variability had already been eroded (Esquivel and Hammer, 1992). Usually, the maintenance of genetic diversity was considered very close to environmental protection, with an altruistic rather than profit-making approach. The public plant breeding sector in Cuba and other Latin American regions considered agro-biodiversity management and plant improvement as an exclusive activity of professional researchers.

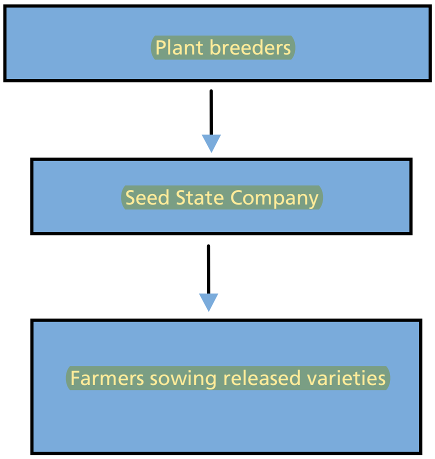
Making use of the space opened up by the economic crisis, a participatory seed dissemination programme emerged, inspired by some former work with pumpkins (Ríos, Soleri and Cleveland, 2002), and aiming to develop participatory seed production, improvement and distribution practices. This programme uses a variety of tools, including seed fairs and participatory variety selection, as strategies for seed diversification to improve the yield and genetic diversity in Cuba.

22.2 CHANGES IN THE PARADIGM: TOWARDS PARTICIPATORY SEED DIFFUSION

In principle, the Participatory Seed Diffusion (PSD) concept emerged in Cuba to integrate diversity seed fairs with farmer experimentation. A seed diversity fair is an approach where plant breeders, farmers and extension agents have access to diversity in one or more crops. Varieties from formal and informal seed systems are sown under the usual cultural practices of the target environment. Stakeholders have the possibility to make selections in the field. They do not know the seed sources of the varieties in the plot. After the farmers have taken and experimented with selected seeds on their own farms, discussions on varietal performance take place within the communities between farmers and researchers. This discussion is considered the start of the farmer experimentation period.

The two models – the centralized, conventional breeding model developed in

FIGURE 22.1
The centralized seed diffusion model in Cuba



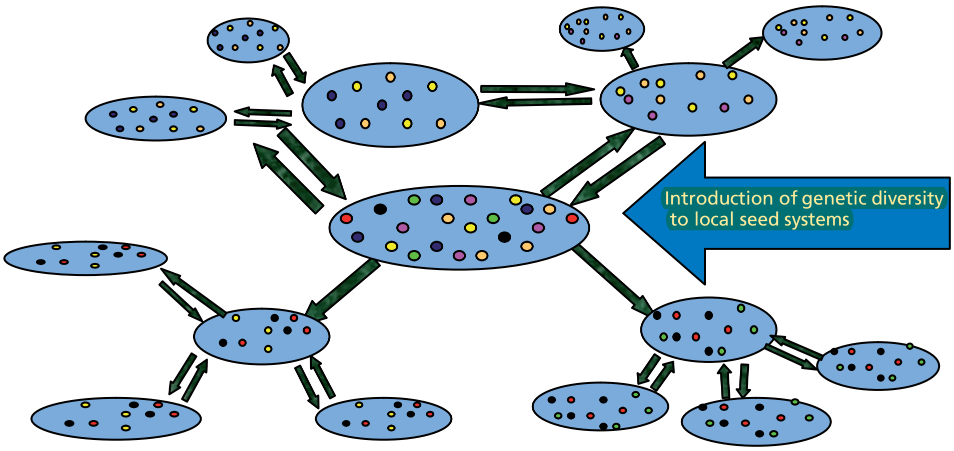
Cuba during the 1980s, versus the decentralized, participatory plant breeding model – are shown in Figures 22.1 and 22.2, respectively.

In contrast to the centralized model, PSD is based on the individual farmer, through Agricultural Production Cooperatives, farmer experimenters, and groups or clubs, among other entities, which test and spread throughout the community varieties of high interest. Starting with the introduction of genetic diversity, through a process called chain reaction (Ríos, 2003), a diversity nucleus is built up that provides genetic diversity to others, and that grows exponentially through farmer participation. Once farmers see the favourable effects of experimenting with genetic diversity, they organize themselves into farmer research groups. Each diversity nucleus promotes knowledge, social organization and entrepreneurial centres characterized by intensive genetic flows and continued discussion around local innovation.

22.3 THE DIVERSITY SEED FAIR

The first diversity seed fair was held at the National Institute for Agricultural Science (INCA) in 1999, as an approach for disseminating maize seeds suitable for low-input agriculture (Ríos and Wright, 1999).

FIGURE 22.2
Participatory Seed Diffusion promoting a "Diversity Chain Reaction"



Source: Ríos, 2003a.

There, professional breeders provided farmers with access to diversity from the formal and informal seed systems, and the seeds were sown under relatively low input conditions (Ríos and Wright, 1999).

Some months before the first diversity seed fair, two breeders undertook maize seed collection missions to a farming community in the province of Pinar del Rio, and to Santa Catalina in Havana province. A selection was made for hardiness under low-input conditions, and 66 landraces (entries) were collected, including 10 from the focus communities in Havana province. In addition, four commercial varieties were supplied from research institutes. These were planted in December on an experimental plot at INCA. Each of the 70 lines was sown in three rows, and wide border strips were sown with a mixture of different lines.

Because of lack of financial resources, the experimental plot received only one irrigation treatment and no fertilizer or pest control inputs. Eighteen farmers from regions of high-input production, along with formal-sector maize breeders, social scientists from the National Agricultural Research System (NARS), and representatives from the National Small-Farmer Association and the former Cuban Association of Organic Agriculture (ACAO) attended the first seed diversity fair.

The farmers were taken to inspect the maize experimental plot and to examine cobs of all the maize lines from this plot, with each farmer selecting five preferred lines. Seeds from these lines would later be given to the farmers for experimentation. Short questionnaires were used to gather information on the farmer's evaluation of each line chosen, and the results were discussed. The main problems associated with seed management and use were low seed quality, low seed availability, and the incidence of pests and diseases. Availability of training and extension, exchange of seeds, and input availability were considered less problematic.

TABLE 22.1

Selection criteria for maize varieties, accepted as important by farmer participants

Criterion	Percent of farmer acceptance
Plant yield	87.5
Plant height	87.5
Positioning of leaves	62.5
Number of leaves	60.0
Leaf colour	45.5
Leaf size	41.3
Stalk width	76.3
Number of cobs	57.5
Ear colour	32.5
Ear size	40.0
Susceptibility to lodging	31.3
Cob weight	50.0
Cob height	40.0
Cob fullness	40.0
Husk colour	28.7
Cob diameter	37.5
Cob husk cover	55.0
Cob size	42.5
Cob shape	55.0
Insect damage	35.0
Cob length	45.0

Source: Ríos and Wright, 1999.

In the field, farmers rapidly selected from the large number of lines on offer. They showed an immediate preference for the mixed varietal border stands as these showed a better response to low input conditions than the mono-varietal rows. The importance of each of their selection criteria is shown in Table 22.1.

In the selection, 80 percent of the farmers identified different preference criteria for each of the five lines they had selected. Participants observed better results from mixed-variety rather than single-variety planting, which led researchers to conclude that they would have to overcome contradictions in the practice of maintaining varieties through strict isolation, as demanded by the formal system.

It became clear that farmers looked not only at yield, but also valued aspects such as plant height, stalk size, number of cobs, and number and position of leaves. This is an indication of the need for alternative breeding objectives.

Selection criteria chosen for maize varieties indicated that farmers, in general, did not practice seed saving. In fact, during the discussion period, several of them asked how to save seeds.

The general reception given to this new participatory approach was positive, given that farmers were historically accustomed to a more top-down management procedure. Farmers had rapidly and easily selected between the 70 lines on show, and a very large range of new seed lines had been extended to them. The plant breeders who started to work in PSD felt that this diversity indicated the need to refocus seed management so that yields and cob quality could be improved under low input conditions (Ceccarelli and Grando, 2002; Ríos, 2003; Acosta *et al*., 2003; Martínez and Ríos, 2003b). Stimulating the flow of genetic resource variability has shown the potential available for increasing yield performance on trial plots for farmer acceptance.

22.4 FARMER ACCESS TO GENETIC DIVERSITY

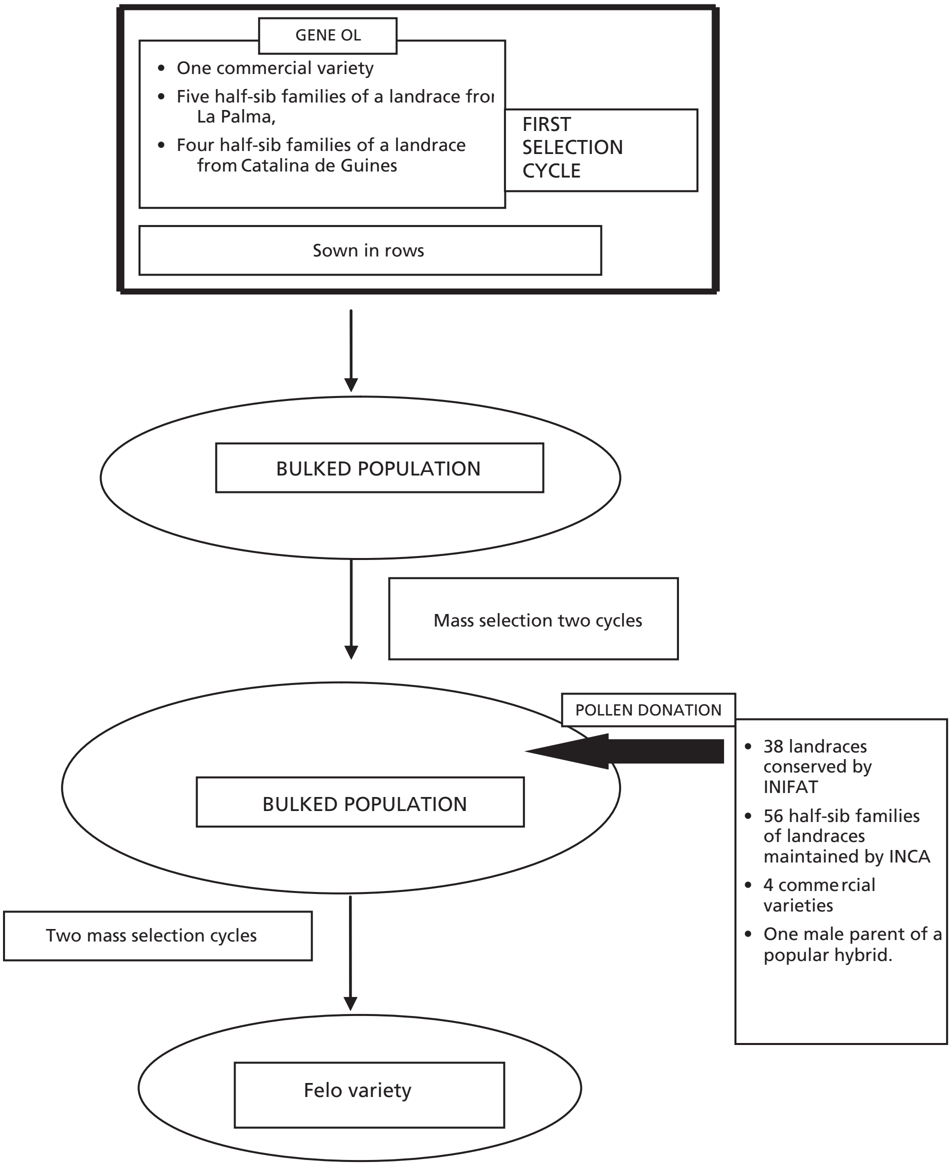
22.4.1 Cross-pollinated crops: the example of maize

Three months after the Diversity Seed Fair, the farmers' capacity to develop maize populations was assessed among nine farmers working on three cooperatives and one private farmer; all ten had attended the maize seed fair. Three of these farmers were unable to maintain their seeds because they lacked the conditions required for conservation from season to season, having relied for more than fifteen years on the formal seed sector, which supplied improved seeds every season.

The gene pool of the maize population of one Havana farmer who selected from the seed fair was found to be composed of different seed origins: one commercial variety from the formal seed sector, five half-sib families of a landrace from La Palma (a neighbouring province), and four half-sib families of a landrace from Catalina de Guines (a neighbouring municipality of the same province) (Figure 22.3). Later the same farmer bulked all materials and selected in the field the best 1500–2000 plants according to cob size, plant cob height and husk covering, during three cycles. Afterwards, at a seed fair prepared by his cooperative, this bulked population was sown along with 38 landraces conserved by the Fundamental Research Institute (INIFAT) gene bank, 56 half sib families of landraces maintained by INCA, four commercial varieties and a male parent of a popular hybrid (Ortiz *et al*., 2006, 2007).

Subsequently, the bulked population was named Felo (the nickname of the local farmer breeder) and two mass selection cycles were done. Gradually, this new seed pool, under farmer management, increased maize production and diffusion amongst cooperatives, and the area intercropped with maize increased over the years (Table 22.2). Maize rose from being one of the most neglected crops in the cooperative to the third important profitable crop (Ortiz *et al*., 2003a). Currently, this population, cv. Felo, is under seed multiplication and continued selection, having gained recognition from all the

FIGURE 22.3
Maize selection scheme used by Felo – a farmer in Cuba



Source: Ríos, 2003a.

municipality stakeholders, and has been registered as an official variety in Cuba.

Usually, the conventional model of breeding cross-pollinated crops entails recombining in the first stage of the breeding programme, and once breeders identify a certain population with desired characteristics, this population is maintained in isolation (Ríos, 2003). The interesting fact learned through the Felo experience was

TABLE 22.2
Maize production in Cooperative Gilberto Leon, Havana, Cuba

Year	1999	2000	2001	2002	2003	2004
Maize area (ha)	36	52	65	72	96	120
Maize area of seeds improved by farmers (ha)	0	10	65	72	96	120
Intercropping (ha)			25	50	60	

Source: Ortiz *et al.*, 2003a.

TABLE 22.3
Origins of bean varieties grown at seed diversity fair

	Commercial varieties	Genetic diversity conserved in gene bank	Accessions collected in the participant communities (Landraces)	Total
Black beans	17	30	16	63
Red beans	16	15	8	39
White beans	4	14	4	22
Total	37	59	28	124

Source: Lamin, 2005.

the possibility of improving yields by disseminating seed diversity. Each genetic pool built up by farmers could probably be continuously recombined, choosing for yield improvement as well as other important traits holding cultural or market values.

According to the first results of PSD in Cuba, seed diversity fairs should become a recombination process whereby farmers can have access to genetic diversity at community level. In this sense, farmer experimentation can play two roles, first in continuously providing the best progeny to the diversity gene pool at community level. and second in providing farmers with the opportunity to select the best recombined family in a certain cycle in the field. Thus, PSD in a cross-pollinated crop such as maize seemed to be a simple method where the recurrent selection principle can be applied (Maldonado *et al.*, 2006).

22.4.2 Self-pollinated crops: the example of beans

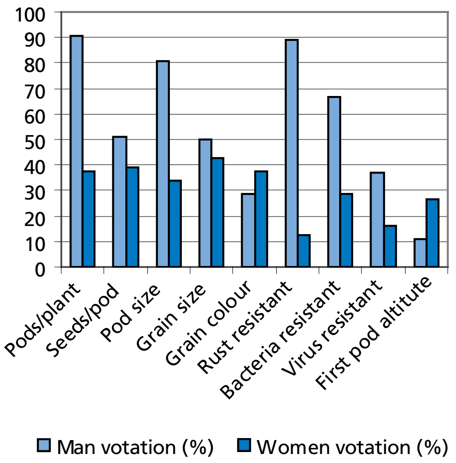
In the case of common bean, a self-pollinated crop, PSD in Cuba has been working mainly with released varieties and landraces, using a non-segregating population. Farmers could access up to 124 varieties of bean from different sources (Table 22.3) grown under low-input conditions at the INCA Experimental Station. Each variety was sown in a small plot, where participants could select up to five varieties to be taken home and tested on their farms under their prevailing production circumstances.

After more than half of the varieties had reached the stage of physiological ripening, a meeting was held with the farmers.

In the case of bean, farmer participants came from different biophysical and socio-economic contexts. Both marginal and industrial farming systems were represented by 42 farmers, as well as some NARS scientists, members of NGOs, functionaries and technicians of the Ministry of Agriculture.

The bean seed diversity fair was attended by male and female farmers. It was planned to carry out varietal selection for women and men separately (Verde *et al.*, 2003). A questionnaire was used in order to see

FIGURE 22.4
Differences in plant selection according to gender focus



whether there were differences in selection criteria according to gender. At the same time, 60 varieties were cooked and participants were grouped in small teams of 3 men and 3 women to evaluate 10 varieties each, with an extra questionnaire on cooking qualities to be completed by participants. Team members facilitated the processes of understanding and filling in questionnaires by participants.

Male farmers voted for varieties with high yield and associated characters, such as number of pods per plant, pod size and disease resistance. In contrast, female participants voted for varieties with large pods, grain size, shape and grain colour. Female farmers' criteria seemed to be more closely related to culinary properties than those of the males (Figure 22.4)

Most farmer participants associated grain colour with variety, and because of this it was interesting for farmers to see agro-morphological differences within colour in the first bean diversity fair; they commented on the degree of variability of disease resistance within the same colour (Miranda, 2005).

At the beginning, the selection exercise was run on an individual basis; however, some farmers collectively decided to chose a wide range, as they wanted to test a range of varieties in their region. They were keen on organizing a seed diversity fair exercise in their own communities. During the selection exercise in the field, the team noted that none of the farmer participants had previously had the opportunity to gain access to genetic diversity.

In the cooking test, males noted that more than 80 percent of the varieties tested had good quality, whereas females showed more rigour in testing beans for cooking quality (Table 22.4).

After the bean seed selection, the project focused on supporting experimenter farmer networks as had been initiated for maize. In the case of bean, the mission was to compare and release varieties according to the farmers' traditional farming systems. Workshops on experimental designs were held at community level. Experimenter farmers' networks started to grow at community level, the reaction of farmers

TABLE 22.4
Gender comparison of cooking quality in common bean

	Male (n = 100)			Female (n = 80)		
	Good	Medium	Bad	Good	Medium	Bad
Flavour	80	13	7	63.7	26.3	10
Softness	95	3	2	73.8	21.3	5

Source: Verde *et al.*, 2003.

confronted with bean diversity was overwhelming, and nobody expected genetic diversity to be of such importance to farmers.

In fact, the main interest of farmers in maize and bean was to be able to select amongst the wide range of varieties according their own criteria. Numerous varieties conserved in the gene bank showed good performance even though some had been lost off the official varieties list. The spirit of experimentation, the opportunity for more such productive options, and the gender differences detected in the first participatory seed selection exercises in Cuba, inspired farmers, scientists and others stakeholders to further explore PSD in Cuba and abroad. Consequently, a Mexican and Cuban team started to collect seeds from different sources, promote diversity seed fairs and farmer experimentation in their local context.

22.5 COLLECTION OF SEED DIVERSITY

A collecting mission was carried out as a multidisciplinary effort. Teams composed of scientists from INCA and local stakeholders, in Cuba and Mexico, collected beans, maize and rice landraces in different provinces and municipalities (Table 22.5).

In terms of the results of these diversity collection missions (Ríos *et al.*, 2006), the teams in Cuba, La Cuenca del Papaloapan and Chiapas reported potential interesting material for certain breeding programmes. In general terms, the farmers donated their seeds freely. In the case of Mexico, the phenotypic diversity of collected seeds of maize was enough to organize different plots in both Chiapas and La Cuenca de Papaloapan. In Cuba, an important bean collection was donated by the Fundamental Research Institute in Tropical Agriculture (INIFAT), and rice germplasm was donated by the Rice Research Institute (IIR), in addition to collected material.

For maize, most of the diversity collected in Mexico came from local seed systems, with 8 lines provided by CIMMYT. In Cuba, most collected maize came from local seed systems, with only four commercial varieties coming from professional breeders. In every case, each maize, bean and rice accession collected per family farm was considered as a variety. In comparison with maize and bean, only very narrow rice diversity was found in the field (Moreno *et al.*, 2003).

In Cuba, several public organizations were very open to providing materials for seed diversity fairs, and these have been considered an important support to the PSD process. The main problem in Cuba was the resistance of conventional plant breeders to facilitate segregating populations.

In Mexico, it was extremely difficult to break the barriers for access to public germplasm for developing seed diversity fairs at community level. At the same time, the reaction of some public plant breeders was conservative.

22.6 FARMER'S ACCESS TO GENETIC VARIABILITY

The genetic diversity conserved in conventional gene banks, accessions collected during the collecting mission undertaken by the project, and commercial varieties donated by breeders of bean, maize and rice, were sown in 2001 in Cuba at farm level. In La Cuenca del Papaloapan (a catchment covering the tropical area of Oaxaca and Veracruz states), Mexico, two seed diversity fairs were held for maize and bean, and rice plots were attempted but it was not possible to obtain a harvest (Table 22.6).

TABLE 22.5
Characteristics of collection missions

Crop	Region	Number of accessions	Number of farmer donors	Number of municipalities involved	Number of communities involved
Maize (*Zea mays* L.)	Cuenca del Papaloapan	204		11	43
	Chiapas Highland	368	221	20	66
	Cuba	254	82	25	65
Beans (*Phaseolus vulgaris* L. & *P. coccineus* L.)	Cuenca del Papaloapan	52	48	8	20
	Chiapas Highland	201	125	19	40
	Cuba	150[(1)]	—	—	—
Rice (*Oryza sativa*)	Cuenca del Papaloapan	8	2	3	4
	Chiapas Highland	3	2	2	2
	Cuba	16	15	2	8

Notes: (1) 60 accessions were donated by INIFAT gene bank.

TABLE 22.6
Location and number of varieties grown in seed diversity fairs in the 2002–2003 period in Mexico and Cuba

Diversity plot location	Crops and no. of varieties per location	Farmers selecting varieties	Altitude (masl)	Experimental field plot topography
Chenalho, Chiapas, México	Maize: 84 Beans: 75	37 in maize; beans could be harvested owing to high rainfall regime.	1500	Heterogeneous
Comitán, Chiapas, México	Maize: 139 Beans: 74	No growth because of drought.	1600	Homogenous
San Cristobal de Las Casas	Maize: 95 Beans: 68	49	2120	Homogenous
Ejido Valle Nacional, Municipality Santa Maria de Jacatepec	Maize: 131	163	40	Homogenous
Doroteo Arango Municipality Acatlan de Perez Figueroa	Maize: 97	100	54	Homogenous
San José de las Lajas. La Habana, Cuba	Beans: 70	42	132	Homogenous
San Antonio de los Baños, La Habana, Cuba	Beans: 97	35	150	Homogenous
La Palma, Pinar del Río, Cuba	Beans: 53	81	60–80	Heterogeneous
Los Palacios	Rice: 80	41	60	Homogenous

Source: Ríos *et al*., 2006.

In Chiapas, four experimental plots were cultivated with collected genetic diversity: at Villa Flores Agriculture University in the lowland, and the other three in the highlands of Chiapas at La Albarrada (San Cristobal de Las Casas Municipality), Yabteclum (Chenalo Municipality), and Comitan (Comitan Municipality). In the case of Mexico, most of the maize diversity grown in the different places was mainly donated by farmers. Consideration was made of the altitude where the seed was collected, in order to avoid mis-adaptation.

All cultivation of the diversity plots was undertaken according to the traditional practices of the participant communities, except in Chiapas lowlands and Cuenca del Papaloapan, where a half-technical package was applied. Each accession collected was considered a variety. In all diversity plots, farmers were allowed to choose five or six varieties to take home.

22.7 PARTICIPATORY PLANT BREEDING AND SEED PRODUCTION

In both Mexico and Cuba, the facilitation of farmers' genetic diversity through seed diversity fairs increased the early reaction obtained from the first two seed diversity fairs carried out in Cuban communities. In Chiapas highlands, only one seed diversity fair was held, the other three did not reach harvest due to drought or flood.

In every place where seed diversity fairs were held, farmers showed great interest in introducing greater genetic diversity into their own farm system (Table 22.7).

In Mexico, participants appreciated that some traditional varieties were grown in seed diversity fairs. In this way, traditional varieties which had almost become extinct were chosen and multiplied by participants.

After farmers took seeds to be grown on their farms, different workshops were conducted to discuss selection methods at community level and experimental design principles. In La Cuenca del Papaloapan, the follow-up process in maize was focused in two communities: Doroteo Arango and Vega del Sol.

In Doroteo Arango, after one selection cycle working with professional breeders, the farmers had to move off their land because of conflicts of land tenure, and so their maize breeding programme was completely halted as all the farmers' efforts had to be oriented toward land recovery.

In the other community, Vega del Sol, germination of distributed seeds was poor with farmers losing all the varieties selected at the fair, so then the farmers and professional breeders decided to start a new collection mission in their communities. They collected 91 accessions in neighbourhood communities, setting up four experimental plots, one per colour.

After three years of mass selection, farmer participants had sown 17 ha of land with four maize gene pools: white, yellow, red and black, choosing the best cob each cycle. Farmers from the community started to make some negotiations with tortilla

TABLE 22.7
Genetic diversity chosen by farmer participants in the seed diversity fairs

Place	Crop	No. of participants	No. of varieties grown in seed diversity fair (b)	Chosen diversity (a)	Percent effective diversity (a/b × 100)
San Cristobal de las Casas	Maize	51	84	51	60
La Palma, Pinar del Rio	Beans	74	52	47	90.4
Ejido Valle Nacional, Municipality Santa Maria de Jacatepec.	Maize	163	131	91	69.5
Doroteo Arango Municipality Acatlan de Perez Figueroa	Maize	100	97	70	72.2
San José de las Lajas	Beans	42	70	46	65.7
San Antonio de los Baños	Maize	35	97	47	48.5
Los Palacios, Pinar del Río	Rice	41	80	60	75

Source: Ríos, 2005.

companies to provide maize for specialized markets.

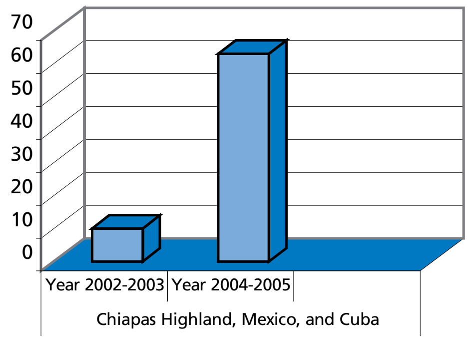
The General Farmers and Workers Union (UGOCP), which was coordinating PSD in La Cuenca del Papaloapan, had since the 1980s lead an Agrarian Reform, and its members were facing strong conflicts over land tenure. Once the farmers had land, UGOCP needed different approaches for enhancing rural development more independent from external resources. Indeed, involving farmers in plant breeding meant a new, more civil approach and orientation for UGOCP for the enhancement of local innovation and participation in making agriculture more sustainable.

PSD was an attractive initiative not only for farmers but also for technicians, researchers, functionaries, politicians and policy-makers, who learnt about the opportunities offered by genetic diversity for cropping systems using less agrochemicals, and about their and its relationship with indigenous knowledge. In practice, PSD showed to be a concrete approach for improving farming systems with interesting entrepreneurial opportunities.

In Chiapas and Cuba, the process developed so fast that the number of seed diversity fairs increased exponentially in rural and urban areas (Figure 22.5). Simultaneously, the number of different crops grown increased from 1 in 2001 to 18 in 2004.

In the particular case of Cuba, PSD in the period 2003 to 2008 increased from three communities in the western part of the country to a national group of practitioners. This means that training programmes could be designed and implemented with the participation of local stakeholder to strengthen local seed systems. Master in Sciences projects and PhD programmes have been implemented in the communities, with local universities starting to integrate their research work with farmer experimenter networks.

FIGURE 22.5
Number of farmer's experimental plots in Cuba and Chiapas



Source: Ríos, 2005

In rice cultivated under high and low potential environments in Cuba, farmers grew different varieties selected in seed diversity fairs. Interesting evidence has been reported by Moreno *et al.* (2005) and Lopez *et al.* (2005), who proved that varieties unpopular in seed diversity fairs had been officially promoted by the conventional seed system. In fact, PSD was adopted by the Popular Rice Movement as a national strategy to enhance rice genetic diversity to fulfil the different biophysical and socio-economic demands of popular rice growers in Cuba (Aleman, 2005, *Arroz con amor se paga*, video).

In Chiapas, Mexico, the process was initially introduced by UGOCP, and afterwards, the Development Secretary of Chiapas Highlands and the Indigenous People's Secretary of Chiapas endorsed the PSD approach as a key alternative for enhancing indigenous culture in the current social life of Chiapas State. During the scale-out process, two main reactions emerged: one where farmers were willing to start experimenting with varieties as never before to rescue maize and bean landraces in Chiapas; the other where economic support was requested to grow experimental plots. The second reaction appeared to be conditioned by other rural programmes, which supported subsidies for food production in the region. Some farmer leaders in favour of the second reaction decided to pull out of PSD.

In Cuba and Mexico, according to the perceptions of the participants, yields have improved in crops under the farmer experimentation process, and farmers were able to diversify and disseminate varieties to the rest of the communities after three years of testing (Lamin, 2005).

In general terms, the amount of seed produced by farmers increased exponentially in the participating communities.

22.8 DECENTRALIZED SEED PRODUCTION SYSTEM

After four working years, the research team noted some differences in seed production concepts between PSD and conventional plant breeding. In PSD, a defining characteristic is the integration within the household or community of genetic resource conservation, plant breeding, seed production, crop production and food consumption. In contrast, in conventional plant breeding, these functions are institutionalized, specialized and separated (Ríos, 2003; Cleveland *et al.*, 2005). Therefore, most of the farmers working with PSD test genetic diversity and subsequently multiply their best options to fill different demands from the family, neighbourhood and local market.

In marginal and industrial environments, the tendency was to retain as much diversity as possible. The reaction of some farmers from marginal environments in keeping diversity was: "We need to keep various options because who knows how hard is the next season" (A. Alda, pers. comm.; Mohamed, pers. comm.). Through PSD, farmers reinforce seed production to be exchanged for experimenting next crop season or simply for culinary testing, and they use seeds for promotion or in barter for other products. In some cases, farmers who never grew seeds are selling seeds to farmers or to the state seed company. Unfortunately, the team has no details of the volume of seeds sold through PSD.

Actually the official scheme of releasing certified seeds to be adopted by farmers has partially broken down. In PSD, as in other participatory plant breeding methods, farmers adopted varieties by experimentation, and released their best options once disseminated varieties were certified (Ceccarelli, 2005, pers. comm.). In this sense, the seed production process in centralized plant breeding, with no participatory element, officially starts when improved varieties are multiplied and certified for dissemination. In PSD, because farmers are participating in the process of selection from the beginning and they are continuously accessing genetic diversity, seed production is an integral element of the process through which farmers decide the varieties or crops that have to be multiplied and disseminated.

Currently, four agrobiodiversity centres have been built by collaborative efforts between farmers and professionals scientists in Cuba, to promote diversity through diversity seed fairs, farmer experimentation and seed production by farmer decision. Primary diversity centres are farms with capacity to introduce, test and disseminate genetic diversity.

The speed at which PSD has spread in Cuba and Mexico has caused an interesting conflict: on the one hand, the legislation does not allow free national seed flow because seeds are not certified, and on the other hand, national food security depends on informal seed production in both countries. Therefore discussions to reconcile the differences are taking place in both Cuba and Mexico.

22.9 FARMERS' GENETIC GAINS

As yields were increasing in the communities, a discussion emerged in different communities implementing PSD about the real influences of farmer selection on yield response. In fact, the team and scientific community looked for hard evidence on farmer selection efficiency.

In conventional breeding programmes, one of the common indicators for determining the impact of selection consists of estimating genetic advance through selection (Falconer, 1960), which is described as follows:

$$S = h^2 \times DS$$

where: S = selection advance; h^2 = heritability and DS = selection differential, as discussed in detail in Chapter 2.

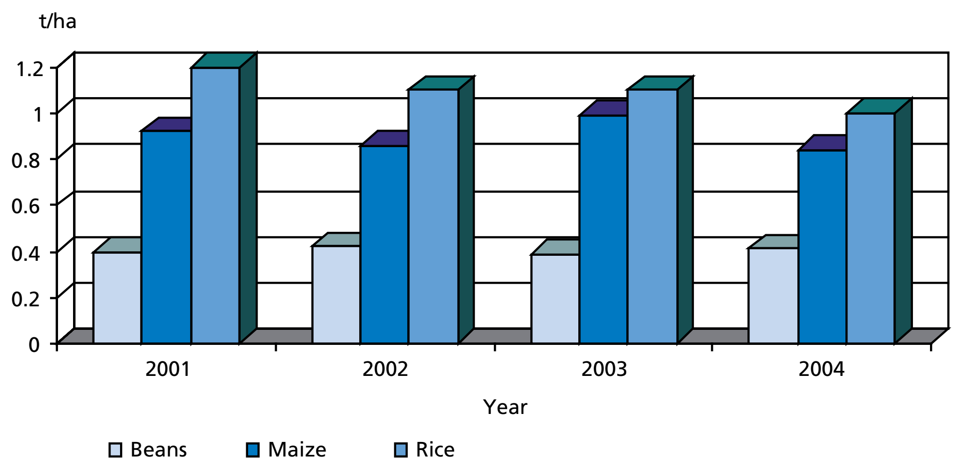
In the case of PSD, such estimation has been applied to each grower who has selected varieties during diversity fairs (Figure 22.6).

Indeed, the differential selection reached by farmers gave evidence of their capacity for obtaining superior materials amongst certain populations. The results strongly imply that farmers participating in plant selection and seed diffusion could collaborate in simultaneously increasing yields and diversity. In practice, access to diversity in the form of released varieties and segregating populations could provide an interesting fit at local level (see Rosas, Gallardo and Jimenez (2006) for segregating populations).

Other interesting evidence is the case of pumpkin breeding (Table 22.8). The farmers who choose gene pools on farm, according to their criteria, had more efficient use of energy for producing food and more profitable crops

Conventional pumpkin breeding in Cuba provides an example of the possible negative economic effects when varieties

FIGURE 22.6
Average selection differential attained by farmers in 18 bean, 10 maize and 6 rice seed diversity fairs in Cuba



Source: Ortiz *et al*., 2005.

TABLE 22.8
Economic impact of pumpkin breeding under low input conditions

Indicators (calculated as averages)	Varieties bred under high input conditions sown in low input conditions	Varieties bred and sown under low input conditions
Cost per ha under low input conditions (Cuban pesos)	702.3	708.3
Fruit yield (t/ha)	1.5	6.7
Total income (@ 0.16 Cuban pesos per kg)	240	1080
Net income per ha (Cuban pesos)	-462(1)	372
Benefit:cost ratio	0.34:1	1.5:1

NOTES: (1) average net loss.
Source: Ríos *et al*., 2002.

TABLE 22.9
Socio-economic and biophysical contexts of scaled-out Participatory Seed Diffusion

	Indigenous culture	Farmer literacy	Research-development policy priority	Production potential
Republic of Cuba	Low	High	Public sector	High-Low
Cuenca del Papaloapan	High	Low	Private sector	High
Highland Chiapas State	High	Low	Private sector	Low

are selected in an environment not representative of the target area. The occurrence of a cross-over response (Ceccarelli *et al*., 1994; Ceccarelli and Grando, 2002) suggests the importance of having a realistic view about who will be using the products of plant breeding.

The experience described in this chapter attempts to maximize the role of local multi-sectoral efforts, including international, national and local stakeholders, through promoting the generation of benefits at local level by using PSD.

22.10 SCALING UP PARTICIPATORY APPROACHES

As a result of the outcome of the two breeding cycles in Cuba, the team and other partners decided to expand the pilot experience from the western part of Cuba in the form of a PSD programme for the central and western parts of Cuba, and to the Highland of Chiapas and La Cuenca del Papaloapan, Mexico. The working team was eager to know how PSDs, emerging from the western part of Cuba, could be practically adapted to other Cuban zones and abroad, with different biophysical and socio-economic contexts (Table 22.9).

What did we scale out? Chiefly we scaled out:

- The diagnostic phase, looking for local genetic diversity, intervention entry points and enabling institutional environments, for a change of paradigm.
- Seed diversity fairs in maize, bean and rice, to stimulate varietal demand and enhance farmer participation in generating benefits.

It was very effective to discuss the idea of PSD with a wide range of stakeholder participants; in fact, a constructive reaction was received from government, civil society and farmers. They built up the different teams and planned the activities, and immediately started to work. Local organizations were extremely cooperative in supporting the process.

The teams' main work objectives were to understand the seed flows, leadership relations and reaction of local policy-makers in terms of supporting the idea. In parallel, and as a key activity, teams collected genetic diversity from the formal and informal seed sector, mainly of maize and beans.

In addition, Cuba had a Popular Rice Movement which was highly suited to the application of PSD. The Popular Rice Movement is a people's movement to produce rice under low input conditions for self-consumption and markets within Cuba. This movement aiming at producing the main staple food emerged in the 1990s in response to the collapse of conventional rice production handled by the large state farms. Farmers were then allowed to plant rice everywhere, and the government made the land available for this (Moreno *et al*., 2005).

In terms of farming approaches, in Cuba, farmers were experiencing a 'special period' due to the collapse of the Socialist Block in the late 1980s (Ríos, 2003), which in general terms meant that they had very limited access to agrochemicals and improved seeds of basic grains. In Chiapas, in contrast, upland farmers had no choice but to grow their crops in a marginal environment. In comparison, La Cuenca del Papaloapan was a high-potential environment and had received enormous agricultural investment in the 1980s for maximizing yields according to Green Revolution philosophy. In 2001, however, farmers in this region had, for various reasons, lost a major part of the official financial support.

According to the diagnosis phase carried out before the PSD intervention, farmers who have more diversity and dynamic seed exchanges in maize had more profits, in both Cuba and Mexico. The experimentation capacity of farmers seemed to be an important element for successful family business under restricted financial conditions (Ríos, Soleri and Cleveland, 2002).

In maize, a cross-pollinated crop, there were significant agromorphological differences between farmer-collected accessions, even though the local maize population had the same name: criollo, pintico, amarillo, negrito, blanco, etc. One hypothesis is that such diversity made it possible to improve certain complex characteristics, such as yield, through farmer participation (Acosta *et al*., 2003; Martinez, 2005). In the case of beans, a self-pollinated crop, few bean types existed in industrial farming systems, and in certain lowlands of Chiapas farmers decided to stop growing beans due to disease attacks, whereas in the upland it was possible to collect different types of beans to be intercropped with maize.

In general terms, with beans, farmers perceived increased disease susceptibility and loss of genetic diversity over the previous decade. Limited access to new genetic diversity from either the formal or informal seed sectors was evident. Some morphological differences were found to be limiting genetic diversity within grain colour of farmers' beans prior to the PSD intervention (Miranda, 2005).

Finally, the team's work showed that the situation for Cuba and Mexico was common in terms of limited access to financial resources to buy seeds and agrochemicals for the production of basic grains. In the particular case of Mexico, stakeholders felt threatened by the USA policy of selling cereals at very low prices. In fact, the limited economic situation faced by Cuba, in relation to Green Revolution concepts, was not exclusive; other regions were suffering from similar problems and local innovation was emerging as a response for overcoming obstacles to producing food.

22.11 EXTERNAL COSTS OF PARTICIPATORY APPROACHES

Apparently PSD seemed to be an attractive process for local stakeholders; however, after four years of PSD implementation, one important question emerged: What will happen once PSD is no longer financially supported by external donors?

One of the key discussion points about public innovation systems in agriculture is in regard to financial support. NARS have been losing funds, and the international core budget of the CGIAR centres has fallen over the last 14 years (CGIAR, 1990–2004). As a consequence, both national and international institutes have been forced to be more innovative in their activities in poor regions.

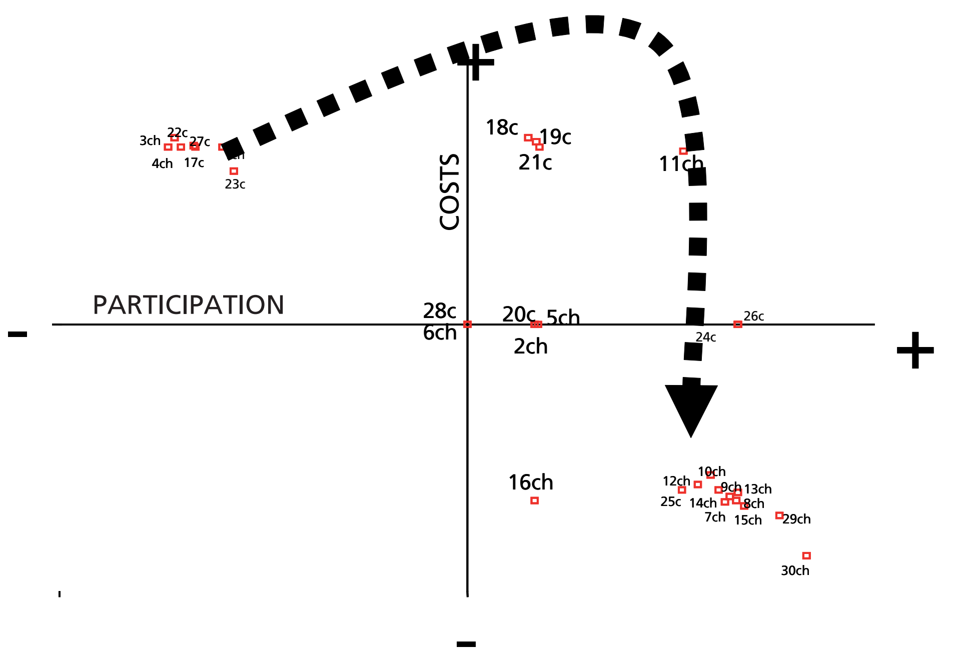
Taking this into account, the team estimated the external cost tendency and its relationship with the participatory approach in PSD.

An analysis of participation and external costs was carried out for all the maize and bean seed diversity fairs organized in Cuba and Chiapas over the last four years. To reach a better understanding of the relationship between participation and external costs, a graph (Figure 22.7) represents the two components plotted.

In the x component, participation was represented by different categories as follows:

- *Very high*: Farmers organized seed diversity fairs on their farms with varieties and technologies brought by themselves, they were able to involve communities in undertaking participatory approaches.
- *High*: Farmers organized seed diversity fairs on their farms with technologies

FIGURE 22.7
Participation versus external cost of participatory diffusion of bean and maize seeds in Cuba and Mexico



and varieties brought by professional researchers, farmers, NGOs, private companies, etc. Farmers were able to involve communities in undertaking participatory approaches.
- *Medium*: Farmers organized seed diversity fairs on public property, and seeds and technologies were supplied by farmers and professional researchers; farmers were partially able to call on participants for undertaking participatory approaches.
- *Low*: Public or private institutions organized seed diversity fairs on experimental stations, and researchers, extension agents, public or private functionaries took decisions. Farmers could not involve other farmers in undertaking participatory approaches.

The y axis was represented by three categories of external costs as follows:
- *High*: The expenses for food, participant transportation and implementation of diversity plots was covered by the project.
- *Medium*: The food expenses and participant transportation was paid for by the project. The expenses of implementing diversity plot was covered by communities.
- *Low*: The implementation of experimental plots, food and transportation was covered by the communities.

Figure 22.7 shows how the external cost decreases with an increase in participation over the four years of project implementation. The results show that external costs could be reduced gradually when local stakeholders adopt participatory methodologies, and the recognition of farmer knowledge as well as the economic benefits of farmer experimentation seems to be an important incentive for developing PSD. Farmers decided to incorporate trials as organic components of their farming systems.

The PSD in Chiapas was largely focused on the highlands, with farming systems on sloping areas, and with farmers having very low literacy levels. However, most of the characteristics represented by the high participation and low external support in Figure 22.7 belonged to the seed diversity fairs developed in that region.

The results confirmed the hypothesis that local innovations are not strictly related to literacy levels. Even though farmers had a high literacy level in Cuba, the relationship between professional scientists and farmers was weak before the collapse of the socialist countries, and it was currently taking some time to establish a new relationship. It has been a difficult process to convince the professional scientists to consider farmer participation as a scientific element of their profession.

In general terms, the agricultural education systems did not consider farmers as collaborators or partners of research work, scientific services or policy-making, and decisions in agriculture had a very strong top-down character. However, research institutes and development organizations have worked directly in different ways to quickly adopt participatory plant breeding methodology, even though the concept was not well documented. Personal influences of researchers have played a critical role in scaling-out PSD (Chaveco *et al*., 2006).

22.12 CONCLUDING REMARKS

Usually, the route of plant genetic resources collected in communities ends at research institution gene banks, to be used in conventional plant breeding programmes (Almekinders *et al*., 2000). The experiences discussed in this chapter provide evidence of how material from collecting missions could be tested, multiplied, improved and disseminated by farmers and local stakeholders. In practice, PSD maintains landraces by using farmer experimentation. Traditional varieties were re-evaluated within local and national contexts.

Due to the progress of seed diversity fairs and farmer experimentation, farmers in Cuba and Mexico started to add diversity to their farming systems with additional species. They were able to organize seed diversity fairs, simple experimental designs on-farm, and diffuse diversity among themselves, in their communities and to professional scientists. Farmers were able to produce seeds to be distributed.

Interesting combinations of cropping systems with new and old crops and new technologies emerged from the collaborative efforts. Currently, two instances have emerged so far: hundreds of concentrate formulas for animal feeds were built up from the collaborative efforts promoting agrobiodiversity enhancement and farmer participation (Ponce and Rodriguez, 2005, pers. comm.).

Recently in Chiapas, technical education is being organized with farmers using more than 30 seed diversity fairs, and the University of Villa Flores is implementing some maize breeding protocols in different regions of Chiapas State (Espinosa, 2005; Aguilar, 2005, pers. comm.).

Professional scientists actually doubted the capacity of farmers to simultaneously manage four or five trials of different crops, but finally they realized that farmers had a more profound conception of their farming system than had been imagined by professional scientists.

Conventional plant breeding has an enormous capacity for diversity generation in major crops. Moreover, powerful selection methods for fixing important genes into certain populations are undertaken by international and national research centres. However, the explicit aim of reaching wide geographical areas is a limiting factor when developing capacity for seed diffusion in diverse biophysical and socio-economic contexts. In this sense, organizing farmers into local innovation groups can maximize local, national and international efforts.

To consider only conventional research and development organizations as partners in plant breeding could be underestimating other strong forces for driving demand and having positive impact in rural and urban areas. Public and private innovation initiatives need to involve farmers and other local stakeholders as a key forces for agricultural benefit.

In fact, the PSD has been a continuous learning process in action. The professional breeder participants become more efficient in their interventions, and farmers more precise in their experimental systems, so it is crucial to enhance collaboration between farmers and scientist-technicians for generating and sharing benefits at community level. The action of the project has been able to influence the inclusion of the PSD concept into the education curriculum, nurturing new, critical students capable of combining biological and social sciences in Cuba and Mexico.

The institutional participants noted that involving farmers in the process of plant selection helped to recognize the enormous value of diversity generated by national and international centres as well as the genetic diversity managed by farmers. Before PSD, national scientists had few collaborators and limited impact from their work. However, currently and because of the increasing demand for genetic diversity, they have hundreds of collaborators multiplying local, national and international efforts in diffusing genetic diversity.

Currently, the public research institutions are suffering from severe financial restrictions; they are strongly influenced by external budget changes, which are very vulnerable to socio-economic or political changes. The field experience described in this chapter provides a clue that genetic diversity could lead to a viable, small, economic initiative for many local stakeholders.

New institutional arrangements for enhancing collaborative efforts between scientists and farmers seem to be an important issue in reaching a better understanding of local seed systems and agrobiodiversity incentives (Vernooy, 2003) as 'development cells' for national and international development.

It is quite clear that the experience accumulated from PSD in Cuba and Mexico shows that innovation in agriculture is not exclusively a business for professional scientists, but that by involving local stakeholders and farmers the impact of plant breeding in different contexts might increase. PSD has been able to revive the professional plant breeding role and farmer knowledge in a current context. Perhaps the results obtained by the collaboration of farmers and scientists, and the difficult economic situation faced by national and international public plant breeding, could facilitate new approaches towards more diverse, productive, socially and economically fair plant breeding in future years.

The economic and energy efficiency of selecting varieties under real environmental conditions, and farmers' attitudes to experimentation, become important arguments to convince policy-makers to apply PSD as a transformative tool in agriculture. Officially, PSD has been focused as a method to encourage public welfare and re-evaluate public institutions in Cuba. At the same time, the organizations leading PSD in Mexico are focusing on more entrepreneurial tendencies to show how people marginalized by top-down approaches can be recognized as innovators and potential local managers of plant genetic resources. In practice, both country cases are dealing with their own contexts. However, both countries are enhancing diversity, farmer participation and new technological and institutional arrangements towards more integrated food production.

ACKNOWLEDGEMENTS

The author is grateful to Ronnie from the International Development Research Centre (IRDC); Lisse and Richard from the Canadian International Development Agency (CIDA); Olivier and Rodolfo from Swiss Development Cooperation for their advice and funding. Special gratitude to Jose Roberto from INCA for patience, enthusiasm and friendly discussions of the idea and implementation of the project. Thanks to Juan and Reynel from SEPI (Indigenous People's Secretary of Chiapas), Victor and Margarito from UGOCP (General Farmers and Workers Union), as well as Arturo from SDR (Development Secretary of Chiapas Highlands), who believed in PSD as a tool to induce some changes in Mexico. Deep thanks to all my researchers, technicians and farmers from Cuba and Mexico: actually, they were the real concept makers of Participatory Seed Diffusion. Thanks to Nathaniel and Julia for their draft discussion and spelling support.

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