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PARTICIPATORY PLANT BREEDING ACHIEVEMENTS IN CUBA

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INTRODUCTION

Two agricultural models are distinguished in the contemporary world: the agroecological and the conventional ones, both of them presenting seed systems with clearly defined typologies. The first model is based on using low energetic inputs (fossil fuel, agrochemicals) where specific adaptation of varieties, aimed at optimizing yield, plays an important role (1). As to the second model, it is characterized by the use of high energetic inputs, seeking varieties with wide geographical adaptation for optimizing yield (2).

It is interesting the way in which growers who deal with ecological and conventional agriculture talk about sustainable models (sustainability seems to be a wide concept, as well as suitable for all circumstances). This specific article deals with implemented alternatives in Cuba in terms of crop breeding, amidst of a dramatic change from a high chemical input agriculture, with strong subsidy rates, to a low energetic input agriculture with growers’ participation. The present work intends to show that decentralized and participatory methods can promote diversity, yield and growers’ empowering.

Why is participatory plant breeding applied in Cuba?

After the triumph of the Cuban Revolution in 1959, and with the objective of transforming Cuban fields, three priorities were established within the government’s policy: a) supplying food needs of the Cuban population; b) creating exportable funds for buying raw material and developing an industrial agriculture; and c) eliminating poverty along the country (3).

In order to achieve such goals, Cuban agriculture became one of the most industrialized models in Latin America (4). A centralized crop breeding system was implemented in Cuba (1, 5) in correspondence with this model, as well as supported by imported agrochemical and energetic inputs from the socialist block. Through this model, the practice of several activities was strengthened; among them introducing foreign germplasm, generating genetic diversity through hybridization, inducing mutation, and somaclonal variation (6).

The impact of large seed transnational organizations was not noticeable in Cuba and national breeding programs played an important role by providing seed enterprises with improved seeds from the main nutritious crops. Formal systems of important basic nutritious crops, such as cassava, bean, maize and rice, presented great national development and were linked to international breeding programs, which were carried out by international public institutions such as CIAT, CIP and CIMMYT. Likewise, the work of some national scientific institutions in Cuba was notable in terms of rescuing, preserving and using phylogenetic resources (7).

Even though formal seed systems (8) were able to select, introduce, generate and evaluate genetic material through its various experimental stations, universities and research centers, such systems presented difficulties in promoting improved varieties. Top-down generation and technological transfer prevailed as a system for promoting varieties. For instance, as part of the variety releasing process, after eight to ten years of selection and experimentation in research stations, each variety had to be approved by the scientific board of the institute, and then submitted to an evaluation carried out by a board of experts, made up of researchers, professors and directors of production enterprises. Only after their approval the variety could be sent to the vice minister of various crops. He should inform different provincial delegates about the approval, who would later give the information to the municipal ones. This process goes on until growers get to know about such approval (9). National seed enterprise, together with its corresponding nets, is in charge of multiplying and distributing the new approved material massively.

Top-down technological promotion system demanded varieties with general adaptation, which should reach high yields in great geographic areas. So, a sort of recognition was given to breeders who were able to introduce a variety in large regions of Cuba (1). Whenever a breeder was able to spread a variety of an important crop throughout the country, he felt proud of himself, as well as of his respective institution.

Agrochemical and energetic input crisis

When the socialist block collapsed in Eastern Europe, the supply of inputs and fossil fuel to Cuba was reduced (4). Facing the new situation, the centralized seed breeding system reduced its production significantly. Many of the concepts acquired by the model of industrial agriculture were changed in practice, as a result of the crisis (1). The environment was not appropriate for many of the conceived...
varieties for a high input agriculture, since there was lack of fertilizers, irrigation fuels and chemical pesticides for controlling pests and diseases. Big enterprises, which depended on seeds coming from the formal breeding system, experimented a drastic yield reduction, whereas many of the private or cooperative sectors, which were immersed in the dynamics of informal seed systems, kept their yield and even increased production amidst of the input crisis.

The fact that some individual growers were able to keep and increase yield, during the period of national agrochemical input deficit, caught the attention of the Cuban scientist community. So, a team of researchers began to study the informal seed systems for a better understanding of their dynamics and interaction with formal system (10).

**Participatory plant breeding (PPB) as a decentralized and participatory model of crop breeding**

Amidst of the massive implementation of alternative technologies as a response to the economical crisis, the development of a complementary breeding system was suggested, which should be able to respond to the new and different demands of the agricultural Cuban context that was characterized by:

- minimal use of agrochemicals
- strengthening diversity of environments and cultural practices (polyculture was noticeably strengthened)
- a conventional breeding system with restricted capacity of supplying growers’ heterogeneous demands
- a considerable increase in cropping areas, as well as an exponential development of urban agriculture and «popular rice movement»
- using huge areas, which were previously planted with sugarcane, for producing grain and garden crops, due to the economical collapse of the Cuban sugar industry.

It is precisely in this context that participatory plant breeding, a system which involves growers in selecting, preserving, multiplying and exchanging improved seeds, is created.

**Which are the distinctive features of participatory plant breeding in Cuba?**

With the objective of presenting a clearer view of the PPB model, the centralized conventional breeding model developed in Cuba during the 80’s, and the decentralized participatory plant breeding model are shown in Figures 1 and 2, respectively.

Different from the centralized model, PPB considers that a down-top process should be followed for selecting, multiplying, preserving and spreading seeds. In this sense, PPB takes individual farmers as a base, in addition to APCs (Agricultural Production Cooperatives), farmer experimentation groups or clubs, among other entities, which should spread varieties of high interest throughout the community, starting from the introduction of genetic diversity, through a process known as «chain reaction». Afterwards, exchange among the genetic conglomerates of each community, locality, or municipality, becomes gradually relevant. This way, local seed systems are strengthened through collections preserved in germplasm banks and managed by growers, as well as through segregating populations and released varieties from conventional programs.

![Diagram](https://via.placeholder.com/150)

**Figura 1. Centralized systems of extension and breeding**

**Research-development stages in participatory plant breeding**

After a lineal analysis of the basic research-development procedure, developed in the PPB project, the following stages could be found:

**a) Diagnosis:** It is suggested to know the agroecological and socioeconomic environment of the target communities (11, 12). The following questions should be answered: Which are the phytogenetic resources of the area in which PPB will be applied?; which is the direction of growers' seed management system?; how are the exchange relationships?; how is the relationship between the seed system managed by growers and the formal breeding one?; who are the leading farmers in the community?, etc. Through the diagnosis, in essence, farmers can be typified according to the socioeconomic and biophysical characterization of production systems. It also provides key arguments for determining places in which PPB could be applied within the community. Starting from this stage, farmers feel actively involved in the systematic task of knowing the community.

**b) Collection of local phytogenetic resources:** The collection of phytogenetic resources offered the possibility of knowing diversity managed by local systems, as well as enabling an easier access of such resources to the community, to the formal breeding systems and other farmer communities.

**c) Development of diversity fairs:** Diversity fairs constitute an alternative through which either breeders or farmers themselves provide access to genetic diversity coming from formal and informal seed systems. With this purpose, a field is seeded with all varieties presenting potential adaptation to the communities and growers select material of their interest (1, 13, 14).
to introducing genetic diversity with high adaptation to the community, these fairs have become an important strategy for preserving threatened material, as well as a way of amplifying the spectrum of growers’ demands.

d) Farmer experimentation: After selecting the material, and with the objective of analyzing response of such material under specific conditions in their farms, growers develop experiments, evaluate varieties and exchange seeds and experience, through workshops in the communities.

Results of the decentralized and participatory plant breeding project

Among the most relevant results of the project during diagnosis stage are the discoveries made in growers’ seed systems. In the case of bean, which is a self-pollinated crop, growers reported an increase in disease attacks. At the same time, the number of varieties, at the community level, reduced in the last ten years. However, maize, which is an outbred crop, seemed to be resistant during the last ten years (12). Likewise, it was interesting to see how “criollo” of variety maize from La Palma community presented a common feature: cobs full of grains with good husk cover. However, even presenting distinctive phenotypic features, this variety seems to present wide genetic diversity that is associated with growers’ management techniques (15). Dynamic management of genetic diversity seems to be directly related to profitability of seed systems, as well as to pest and disease attack, which was confirmed by the experience obtained in La Cuenca de Papaloapan, Mexico.

Enabling an easier access to genetic diversity

One of the most useful tools of PPB in Cuba, has been growers’ access to diversity through diversity fairs (1, 13, 14). The fact that growers select varieties according to their own criteria has allowed them to take a great diversity of varieties to their farms for further experimentation, leading to a considerable increase in effective genetic diversity (17), which is observed in Table I.

The exponential increase in diversity on growers’ farms is evident. This has amplified growers’ options and generated a demand of local diversity as a way of supplying their needs. The increase in diversity on farms by applying PPB has strengthened the knowledge of growers in terms of experimentation and has generated new educational alternatives, such as the Agricultural Farmer University.

Before the participatory plant breeding project, I only knew black, red and white bean varieties. However, there is plenty of varieties within each color now.

1Opinion of research growers from La Palma (Pinar del Río), San Antonio de los Baños and Batabanó (Havana).
Selection schemes in PPB. “Felo” study case

In the case of Felo, a grower belonging to “Gilberto León” Agriculture Production Cooperative (APC) in San Antonio de los Baños, Havana, facing with the poor supply of improved seeds with good response to the conditions of deficit of fertilizers and pests for controlling maize moth (Spodoptera frugiperda), he began a program for selecting a basic or variety population with good adaptation to pest and chemical fertilizer deficit. The scheme is described in Figure 3.

Professional breeders gave nine growers access to maize diversity; only one grower was able to develop a maize population. The remaining ones could not even preserve their seeds, due to lack of conditions. Actually, the practice of preserving seeds from harvest to harvest no longer existed. For more than 15 years, these growers depended on the formal seed sector, which provided them with improved seeds every season.

Table I. Increase of genetic diversity by farmers applying participatory plant breeding

<table>
<thead>
<tr>
<th>Place</th>
<th>Average bean-growing area at the main sowing season</th>
<th>Total number of varieties managed by research growers before PPB</th>
<th>Total number of varieties managed by research growers after PPB</th>
</tr>
</thead>
<tbody>
<tr>
<td>La Palma (sample of nine growers)</td>
<td>&lt; 0.6 ha</td>
<td>5-6</td>
<td>70</td>
</tr>
<tr>
<td>“Gilberto León” and “Jorge Dimitrov”</td>
<td>&gt; 13 ha</td>
<td>2-3</td>
<td>34</td>
</tr>
<tr>
<td>Cooperatives (two research growers), Havana</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 3. Selection scheme used by Felo
The genetic pool from maize population belonging to Felo, who had practiced selection during seed fairs, was provided by different sources and was conformed by: a commercial variety from the formal seed sector, five half-sib families of a landrace from «La Palma» (Pinar del Río) and four half-sib families of a landrace from «Catalina de Güines» (Havana). Afterwards, the same grower mixed the material and selected the best 1500-2000 plants in the field, according to cob size, cob height in the plant and husk cover for three cycles. Then, during a seed fair arranged by his cooperative, this population was mixed and seeded among 38 landraces and commercial varieties, preserved by the gene bank of INIFAT (Fundamental Research Institute on Tropical Agriculture), 56 half-sib families from non-improved species, preserved by the National Institute of Agricultural Sciences (INCA), four commercial varieties and a male parent of a popular hybrid.

Afterwards, the total population was named Felo and two mass selection cycles were developed. Currently, the so-called Felo variety is under seed multiplying process, selection goes on, and such variety is well accepted across the municipality.

Genetic advance through selection in farmer experimentation

In conventional breeding programs, one of the best indicators for determining the impact of selection consists of estimating genetic advance through selection (18), which is described as follows:

\[ S = h^2 \times DS \]

where:
- \( h^2 \): heritability
- \( DS \): selection differential
- \( S \): selection

In the case of PPB, such estimation has been applied to each grower who has selected varieties during diversity fairs (Table II).

It is evident that populations selected by most of the growers who participated in diversity fairs, have superior mean yield estimates than the ones of all present varieties in the field. This indicates that PPB effect is not only seen through the increase in diversity, but also yield.

In recent workshops, growers reported a significant increase in yield after four cycles of participatory selection, as well as an exponential increase in the number of areas intended for seeding maize and bean.

Farmer experimentation faces genotype-environment interaction

Genotype-environment interaction is a broadly proved and reported phenomenon in most of the conventional breeding programs. However, in practice, this effect becomes a strong restriction for centralized systems, which promote the release of varieties with wide geographical adaptation.

To the same extent that the use of agrochemical inputs reduces, yield variations caused by both the environment and management practices, become much more noticeable (8, 17). In this sense, PPB has corroborated the intensity of genotype-environment interaction in the current agricultural context of Cuba, and has given important space to specific variety adaptation. The fact that growers select varieties with higher specific adaptation, taking into account their socioeconomic and biophysical needs, leads to higher energetic efficiency, as well as to higher profitability in economical terms (Table III).

A grower states the following: I can take more diversity of products to the market, as well as try to improve the financial strategy of the cooperative.

Table II. Genetic advance through selection, recorded on a yield estimation applied to growers who have participated in diversity fairs

<table>
<thead>
<tr>
<th>Crops (number of varieties per crop)</th>
<th>Farmers who select</th>
<th>Number of growers with positive genetic advance</th>
<th>Number of growers who achieved no genetic advance</th>
<th>Effectiveness percentage*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize-54</td>
<td>84</td>
<td>76</td>
<td>8</td>
<td>90.5</td>
</tr>
<tr>
<td>Bean-54</td>
<td>68</td>
<td>59</td>
<td>9</td>
<td>86.7</td>
</tr>
<tr>
<td>Rice-80</td>
<td>41</td>
<td>32</td>
<td>9</td>
<td>78</td>
</tr>
</tbody>
</table>

*It is estimated according to percentage of growers achieving a positive advance through selection

Table III. Economical and energetic impact of PPB in pumpkin, Batabanó, Havana (6)

<table>
<thead>
<tr>
<th>Indicators (average estimation)</th>
<th>Varieties from a centralized breeding system and sown under low input conditions</th>
<th>Varieties selected by growers who practice PPB and sown in growers’ own farms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimate of energetic wastes</td>
<td>Fertilization: 679,000</td>
<td>Fertilization: 42,000</td>
</tr>
<tr>
<td></td>
<td>Irrigation: 10,160,000</td>
<td>Irrigation: 3,697,200</td>
</tr>
<tr>
<td></td>
<td>Pesticides: 6,160,000</td>
<td>Pesticides: 88,000</td>
</tr>
<tr>
<td></td>
<td>Total: 16,999,000</td>
<td>Total: 3,827,200</td>
</tr>
<tr>
<td>Total incomes (16 cents kg⁻¹)</td>
<td>240</td>
<td>1080</td>
</tr>
<tr>
<td>Profits ha⁻¹ (Cuban pesos)</td>
<td>-462*</td>
<td>372</td>
</tr>
<tr>
<td>Benefit/cost relationship</td>
<td>0.34:1</td>
<td>1.5:1</td>
</tr>
</tbody>
</table>

*Loss
Finally, farmer experimentation constitutes an alternative that, under current conditions, should be taken into account by individual growers and those belonging to Agricultural Production Cooperatives. It is suitable for environments with high yield potential and for the ones which are more heterogeneous.

In general sense, it has been seen that, after introducing PPB, the functions of seed systems are concentrated in each farm belonging to grower participant’s. Each farm has an area for testing varieties, other for multiplying seeds of promising varieties, and a larger area intended for both self-consumption and selling grains to the market. Official seed commercialization is not an effect of PPB yet. Up to the present, financial profits focus on increasing harvest yield, using the same amount of agrochemical inputs or lower ones.

**Growers’ empowering as a response of their participation when taking decisions**

The term «empowering» is commonly heard in development agencies nowadays. In the concrete case of PPB in Cuba, empowering is understood as the growers’ acquired ability for designing, implementing and controlling their seed systems, in order to increase individual and social well-being.

Likewise, the term «participation» presents different concepts (19, 20). Through the project of Participatory Plant Breeding as a complementary strategy in Cuba, growers are the ones who select varieties within their production units, and play the most important role when taking decisions on the varietal strategy. The breeder participants provide an easier management of diversity, as well as training for growers and the other people involved, improving their ability for designing, implementing and evaluating their own initiatives.

It has been proved that the empowering manifested in communities where participatory plant breeding is applied presents a direct relationship with the access to genetic diversity and growers’ opportunity of taking decisions concerning varietal strategy, as a way of strengthening local seed systems, according to the current Cuban agricultural context.

In practice, PPB project has become an incipient platform for designing, implementing and evaluating phylogenetic resources, favoring well-being of the participants. Likewise, such project has brought about growers’ recognition as protagonists in the process of breeding and preserving varieties.

Results of participatory plant breeding have allowed focusing again on breeding of bean, maize and rice crops, according to growers’ diverse socioeconomic and biophysical situations. In brief, PPB has made a call to reflection on the importance of seeing growers as direct clients of the work on breeding, under Cuban current conditions. PPB has been an interesting school for the participants, in the task of considering alternatives for strengthening collaboration between breeders and growers which, therefore, helps to strengthen local seed systems.

At the same time, PPB has made it easy to revitalize plant breeding as a science in Cuba, identifying and refocusing the role of participants, as well as finding innovative methods for breeding, which respond to the Cuban current agricultural context. There is no doubt about the fact that decentralized and participatory plant breeding seems to be an interesting choice of development, which should be considered by the ones involved in taking decisions regarding national policies, and also constitutes a potential example of efficiency of breeding systems using minimal energetic inputs.

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