Participatory Plant Breeding: Farmers as Breeders
Digvijay Kumar Bhargay* and H. P. Meena¹

*Ph.D. Scholar, Division of Genetics, Indian Agricultural Research Institute, New Delhi-12
¹Scientist (Plant Breeding), Directorate of Oilseeds Research, Rajendranagar, Hyderabad-500030

*Email of corresponding author: harimohit2010@gmail.com

Participatory plant breeding (PPB) is a strategy for plant breeding with its own set of methodologies that applies in situations where the demand for specific varietal traits among producers, traders, industries and consumers is poorly understood and difficult to diagnose with conventional market research methods. In this article we discussed about who can participate in plant breeding, why PPB came in force in developing countries, roles of farmers in PPB, advantages and disadvantages of PPB over conventional breeding, possible outcome and successful story of PPB in India and other countries.

Participatory Plant Breeding (PPB)
Broadly, participatory plant breeding (PPB) is the development of a plant breeding program in collaboration between breeders and farmers, marketers, processors, consumers, and policy makers (food security, health and nutrition, employment). It is also known as Collaborative Plant Breeding (CPB) (Soleri et al., 1999) Farmer Participatory Breeding (FPB) (Courteois et al., 2001), Decentralized Participatory Plant Breeding, and Participatory Crop Improvement (PCI) (Witcombe et al., 1996). In the context of plant breeding in the developing world, PPB is breeding that involves close farmer-researcher collaboration to bring about plant genetic improvement within a species. PPB is a strategy for plant breeding with its own set of methodologies that applies in situations where the demand for specific varietal traits among producers, traders, industries and consumers is poorly understood and difficult to diagnose with conventional market research methods. PPB is a complement to conventional breeding approaches. Participatory plant breeding is seen by several scientists as a way to overcome the limitations of conventional breeding by offering farmers the possibility to decide which varieties suit better their needs and conditions without exposing the household to any risk during the selection progress. A number of PPB varieties have been already released for many crops e.g, rice, maize, sorghum, barley, etc.

Why Term Participatory
It is termed "participatory" because users can have a research role in all major stages of the breeding and selection process. Such 'users' become co-researchers as they can: help set overall goals, determine specific breeding priorities, make crosses, screen germplasm entries in the pre-adaptive phases of research, take charge of adaptive testing and lead the subsequent seed multiplication and diffusion process (Sperling et al., 2001).
Who Participate in PPB
In PPB, professional plant breeders and researchers from various disciplines collaborate with farmers and other stakeholders in the food chain to produce locally-adapted varieties that meet farmers’ needs, priorities, and market opportunities (Johnson et al., 2004; Ceccarelli and Grando, 2007).

Why PPB came in force in developing countries
Researchers breed exotic hybrids in the laboratory that are successful only under ideal conditions and that require just the right inputs of water, fertilizer, and pesticides to maximize yields. For many farmers such conditions simply don’t exist, and as a result they obtain poor results from high-tech seeds offered by the formal research system. Because of that reason PPB came in force in developing countries. Another reason is the limited success of CPB in meeting the need of smallholder subsistence farmers in less favourable environments of the developing world led to the emergence of participatory approaches, focusing on farmer preferences and involvement to encourage rapid adoption and diffusion of new varieties.

What Are the Goals Do PPB?
1. Increase production and profitability of crop production through the development and enhanced adoption of suitable, usually improved, varieties.
2. Provide benefits to a specific type of user, or to deliberately address the needs of a broader range of users.
3. Build farmer skills to enhance farmer selection and seed production efforts.

PPB Encourages Two Kinds of Participation
1. Functional Participation
   • Plant breeders can direct their research according to the needs of the specific groups of farmers (women, men, rich and poor). The physical and economic resource bases of different people necessitate tailored research approaches.
   • Farmers can assure plant breeders that they are assessing tradeoffs among traits correctly.
   • On-farm research assures that varieties will produce well under “real life” conditions. On-farm research can be managed by the researcher, by the farmer, or by both.
   • PPB ensures greater success of adoption of innovation by the farmers.

2. Empowering Participation
   • Increasing farmer knowledge and skills so that farmers can participate more fully in the collaborative breeding efforts and be better at their own, personal efforts.

What Activities can PPB Include?
Participatory plant breeding includes many activities like (i) identifying breeding objectives, (ii) generating genetic variability, (iii) selecting within variable populations to develop experimental
varieties, (iv) evaluating experimental varieties, (v) variety release, (vi) popularization of release varieties, and (vii) seed production.

**Stage of Farmers Participation:** Farmer participation can usefully occur at various times, depending on the crop, parent materials, target region, researcher capacity to assimilate farmer criteria, farmer capacity to handle different types of materials, traits of interest, and scale of the breeding program/number of materials to be screened.

**Roles of farmers in PPB:** The possible roles of farmers in participatory plant breeding are described (i) provide technical leadership, (ii) provide key social organizational leadership, (iii) information-giving role, (iv) trainer/skill builder role, (v) field laborer role, (vi) input supply role: provide land for 'realistic' bio-physical sites, and (vii) provide landrace or farmer material used for further breeding work.

![Diagram showing the process differences between Conventional Plant Breeding (CPB) and Participatory Plant Breeding (PPB).](image)

**Figure 1.** In Conventional Plant Breeding (CPB) new varieties are released before knowing whether the farmers like them or not and the process is typically supply-driven. In Participatory Plant Breeding (PPB) the delivery phase is turned upside down because the process is driven by the initial adoption by farmers at the end of a full cycle of selection and is therefore demand-driven. (Source: Ceccarelli and Grando, 2007).
Table 1. The distinguishing features of Formal (PB) and Participatory (PPB) Breeding

<table>
<thead>
<tr>
<th>S. No.</th>
<th>PB</th>
<th>PPB</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Favorable robust environment</td>
<td>Heterogeneous fragile environment</td>
</tr>
<tr>
<td>2</td>
<td>Assured inputs</td>
<td>Low / inadequate inputs</td>
</tr>
<tr>
<td>3</td>
<td>Can be cost-intensive</td>
<td>Has to be cost-effective</td>
</tr>
<tr>
<td>4</td>
<td>Aims at widely applicable impact [Wide horizon]</td>
<td>Has to focus on site-specific methods [Narrow horizon]</td>
</tr>
<tr>
<td>5</td>
<td>Can work on high-tech mode</td>
<td>Learn to scale-up downstream technology</td>
</tr>
<tr>
<td>6</td>
<td>Can invest high technical skill</td>
<td>Constrained to farmer preference</td>
</tr>
<tr>
<td>7</td>
<td>Unrestrained options base [Narrow genetic base]</td>
<td>Wide options to utilize site diversity both intra- and inter-specific [Broad genetic base]</td>
</tr>
<tr>
<td>8</td>
<td>Can rest on an innovative theoretical</td>
<td>Has to be practical with popular acceptance</td>
</tr>
<tr>
<td>9</td>
<td>High productivity is the usual target</td>
<td>Sustainability of production (though moderate) and local preference are targets</td>
</tr>
<tr>
<td>10</td>
<td>Generates new varieties and identifies growing targets [Exploiting G x E]</td>
<td>Site-specific varieties imperative [Utilizing G x E]</td>
</tr>
</tbody>
</table>

Table 2. Number of varieties selected and adopted by farmers in the PPB programs in 5 countries.

<table>
<thead>
<tr>
<th>Country</th>
<th>Crop (s)</th>
<th>Varieties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Syria</td>
<td>Barley</td>
<td>19</td>
</tr>
<tr>
<td>Jordan</td>
<td>Barley</td>
<td>1 (submitted)</td>
</tr>
<tr>
<td>Egypt</td>
<td>Barley</td>
<td>5</td>
</tr>
<tr>
<td>Eritrea</td>
<td>Barley</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Barley</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Lentil</td>
<td>2</td>
</tr>
</tbody>
</table>

PPB produces varieties that are

1. **Targeted**: because they are focused on the right farmers;
2. **Relevant**: because they respond to the real needs, concerns and preferences of farmers; and
3. **Appropriate**: because they can be adopted and used under the conditions in which farmers live and farm.

Possible Outcomes/Benefits of PPB

1. **Production gains**: yield increases; increases in stability of yield; faster uptake; wider diffusion; and higher market value of products.
2. **Biodiversity enhancement**: communities have wider access to germplasm; wider access to related knowledge; and increased inter- and intra varietal diversity.
3. **Cost-efficiencies and effectiveness**: fewer research dead-ends; more opportunities for costsharing in research; and less expensive means of diffusing varieties. Effective meeting of
user needs: higher degree of farmer satisfaction; broader range of users reached, including marginal farmers; and promotion of group learning through farm walks.

Advantages of Participatory Over Conventional Breeding Methods

- At least one parent in any cross is well adapted to the local environment.
- Genotypes x environment interactions are used positively because breeding is done in the target environment.
- The impact of genotype x year interaction is probably reduced because local parental materials have adapted to local year-to-year variations.
- Only a few crosses are made, so large F$_2$ and F$_3$ populations can be grown to increase the likelihood of selecting desirable segregants.

Collaborative Work in India

Collaborative arrangements for PPB programmes are in place with three universities in Madhya Pradesh, Rajasthan and Gujarat. These programmes include six crops: maize, rice, horsegram, black gram, niger and sunn hemp. In India the participatory rice varietal improvement program going on at IRRI in collaboration with NARS in eastern India (Courtois et al., 2000). Other than India many other countries where the participatory breeding program is implemented and crop details are given in Table 3.

Table 3. Countries where the participatory breeding program is implemented and program details.

<table>
<thead>
<tr>
<th>Country</th>
<th>Crop(s)</th>
<th>Locations</th>
<th>Trials</th>
<th>Plots</th>
</tr>
</thead>
<tbody>
<tr>
<td>Syria</td>
<td>Barley</td>
<td>24</td>
<td>176</td>
<td>10020</td>
</tr>
<tr>
<td></td>
<td>Wheat</td>
<td>6</td>
<td>42</td>
<td>710</td>
</tr>
<tr>
<td>Jordan</td>
<td>Barley, Wheat, Chickpea</td>
<td>9</td>
<td>21</td>
<td>2798</td>
</tr>
<tr>
<td>Egypt</td>
<td>Barley</td>
<td>6</td>
<td>20</td>
<td>460</td>
</tr>
<tr>
<td>Eritrea</td>
<td>Barley, Wheat, Chickpea, Lentil, Faba bean</td>
<td>7</td>
<td>36</td>
<td>1475</td>
</tr>
<tr>
<td>Algeria</td>
<td>Barley</td>
<td>5</td>
<td>5</td>
<td>500</td>
</tr>
<tr>
<td></td>
<td>Durum Wheat</td>
<td>2</td>
<td>2</td>
<td>200</td>
</tr>
<tr>
<td>Iran</td>
<td>Barley</td>
<td>2</td>
<td>7</td>
<td>700</td>
</tr>
<tr>
<td></td>
<td>Bread Wheat</td>
<td>2</td>
<td>2</td>
<td>200</td>
</tr>
</tbody>
</table>

Achievements of PPB in India

In Gujarat three varieties of maize have been developed by PPB. GDRM-187 was one of these three promising varieties (Witcombe et al., 2003). It was bred as an extra-early maturity maize variety (matures earlier than the earliest local varieties by about seven days). When farmers tested it in participatory varietal selection (PVS) trials, they liked the qualities of GDRM-187. It was very
popular and high yielding in their fields over two seasons. It produces fewer barren plants and larger cobs, which, unlike local varieties, are filled to the tip. Farmers also noticed that the husk completely and tightly enclosed the cobs, thus reducing insect attack. The new maize varieties GM-6 developed through client oriented breeding in India (Witcombe et al., 2003). New varieties of rice, Ashoka-200F and Ashoka-228 bred by client oriented breeding (COB) in Eastern India by Virk et al., (2003). Farmers in a remote area of India, where soils are highly degraded and production is subsistence oriented, could identify varieties of several major crops that provided them with new options, more food, and greater stability of production (Witcombe and Joshi, 1996). The documentation of adoption of the rice variety “Kalinga III” is a good example of the spread of a variety identified through farmers’ participation in variety testing.

**Current Achievements of PPB in China**
A number of varieties have been developed and released through PPB in Guangxi, southwest China from 2000 to 2011 (Yiching and Jingsong, 2011). Here the researchers again utilized the farmer’s knowledge and experience to develop these varieties.

1. **Xin Mo 1 (OPV)** --The 1st PPB variety is Xin Mo 1, which derived from the cross of farmer improved Tuxpeno 1 (as female line, from Wenteng village) and Jiahe white (as male line, from Zicheng village) in 2002. It is an open-pollinated variety (OPV).

2. **Zhong Mo 1 (OPV)** --The 2nd one is Zhong Mo 1, which derived from a cross of Xin Mo 1, Suwan 1 and Amarinto 966 (as male line) in 2004. Since Xin Mo1 is in white color, PPB farmers discussed with breeders and would like to improve it into a yellow color, which has high commercial value. This was the motivation for breeding out Zhong Mo 1.

3. **Zhong Mo 2 (OPV)** --The 3rd one is Zhong Mo 2, which derived from a cross between Xin Mo 1 and Amarinto 9 in 2006. It had the same breeding objective as Zhong Mo 1, just trying to improve the eating quality.

**Achievements of PPB in USA**
Improved Tuxpeno 1 -- an open-pollinated variety (OPV), was introduced by CIMMYT in 1997, and improved by Pan Peiyin (female, farmer) from Wentan village, Wuming County.

**Achievements of PPB in Uganda**
NASPOT-11 is a recently sweet potato cultivar, bred by participatory plant breeding (PPB) in Uganda (Gibson et al., 2011). It is already grown extensively by farmers who call it Tomulabula.

**Achievements of PPB in Uganda**
Fourteen varieties were selected by farmers for drought tolerance in rice including Nerica1, Duorado, IR79913-B-176-B-4, CT16333 (1)-CA-20-M, CT16333 (1)-CA-22-M, CT16333 (2)-CA-18-M, CT16313-CA-19-M, WAB964-B-3A 1.2, CT16317-CA-4-M, CT16307-CA-14-M, CT16337-CA-12-M, CT16345-CA-3-M, WAB 905-B-4A 1.1 and WAB 450-B-136-HB - NERICA9; but only nine of them were successfully used due to hybridization incompatibility in Kenya (Kimani et al., 2011).
Achievements of PPB in Nepal
Because farmers were involved in the selection in segregating generations, a rice variety (*Oryza sativa*) was bred that combined the high level of Farmer Participation and Formal-Led Participatory Plant Breeding Programs chilling tolerance of landrace rice varieties of the Nepal mountains with the increased productivity from modern varieties. So for the first time the farmers in these hilly regions could benefit from a plant breeding effort targeting their region (Sthapit et al., 1996).

Achievements of PPB in Brazil
Another example is the case of Bean (*Phaseolus vulgaris* L.) breeding in Brazil which became successful through involving farmers in breeding a variety that combined disease resistance (*Macrophomina and Fusarium wilt*) with the preferred seed coat color, drought adaptation, and yield characteristics for the dry zone of northeastern Brazil (Zimmermann, 1995).

Achievements of PPB in Zimbabwe
Maize variety ZM-421 was developed by PPB from the International Centre for Maize and Wheat Improvement (CIMMYT), Zimbabwe.

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.

Conclusion
Participatory plant breeding in the context of plant breeding in the developing world, PPB is breeding that involves close farmer-researcher collaboration to bring about plant genetic improvement within a species. It is seen by several scientists as a way to overcome the limitations of conventional breeding by offering farmers the possibility to decide which varieties suit better their needs and conditions without exposing the household to any risk during the selection progress. PPB programmes in India is going on with collaboration of three universities in Madhya Pradesh, Rajasthan and Gujarat on six crops: maize, rice, horsegram, black gram, niger and sunn hemp. There are many achievements of PPB in India and abroad.

References


Yiching S and Jingsong L. 2011. The role of biodiversity, traditional knowledge and participatory plant breeding in climate change adaptation in Karst mountain areas in SW China. *Biocultural Heritage.*