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Exploitation of genetic diversity through participatory plant breeding

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Abstract
Agrobiodiversity is the substrate of plant improvement. Genetic diversity remains extremely important not only to individual farmers and farming communities but also to scientists and breeding institutions and humanity as a whole. With the advancement of green revolution, locally adopted populations from the farmers' field have been replaced with few modern varieties leads towards uniformity. These products have been effective for farming systems sufficiently similar to those on experiment station but not adopted when genotype by environment interactions (GEI) is large. Participatory plant breeding (PPB) is extremely advantageous in those geographic areas where conventional breeding efforts have been less successful and failed to leave a positive impact on farmers' conditions. PPB is an approach to overcome the limitations of conventional breeding by offering farmers the possibility to select, in their own environment, which varieties suit better their needs and conditions. PPB exploits the potential gains of breeding for specific adaptation through decentralized selection and is the ultimate conceptual consequence of a positive interpretation of genotype x environment interactions. PPB can be resorted to for multiple uses like increasing productivity, preserving diversity and benefits for specific end-users. In order to be a sustainable approach to plant breeding, PPB needs to become a permanent feature of plant breeding programmes, addressing crops grown in agriculturally difficult and climatically challenging environments.

Keywords: Participatory plant breeding, diversity, decentralized selection

Introduction
The Green Revolution and subsequent phases of agriculture and rural development increased yields of a number of crops in developing countries. These arose through the development and spread of modern high-yielding crop varieties and new agricultural practices [1-7]. Despite the benefits of these breeding efforts, modern plant breeding and the seed industry that evolved around it, turned out to have some negative effects as well, especially on the level of agrobiodiversity. For decades now, agricultural development has become almost synonymous with farming system intensification, monocropping, and high-input/high-output production systems. As a result, concurrent with farming system intensification, many traditional crops and varieties have been abandoned and lost by farmers. Conventional plant breeding is mainly directed at increasing yield in more favourable environments. While broad adaptability is a major objective, there are many more marginal environments in which improved varieties do not express their increased yield potential or do not satisfy other user requirements. The diffusion of modern varieties into less favorable agro-ecological zones was slow and more limited [8-9]. In the more extreme environments, genotype x environment interaction starts to play a major role. It involves adaptation to both the physical environment (climate, soil, abiotic/biotic stresses) and the socioeconomic environment (economic status, user concerns, consumer preferences, markets, etc.). It has become apparent that these off-springs (new varieties) of the non-participatory, non-interactive breeding products did not satisfy the needs of farmers in more marginal agricultural environments. This suggests the need for participatory plant breeding. It can be consideredas a type of evolutionary plant breeding because of its beneficial effects on biodiversity [10].

Participatory Plant Breeding (PPB)
PPB is a combination of two words namely Participation and Plant breeding, participation means "an act of taking part in an event or activity" or a "multi-dimensional, dynamic process of contributing, influencing, sharing, or redistributing power and of control, resources, benefits, knowledge, and skills to be gained through beneficiaries' involvement in decision-making."

While plant breeding is a science for improvement of genetic makeup of crop plants using different tools and techniques for the human welfare [11]. The term PPB first used in a 1995 workshop, hosted by Canada's International Development Research Center (IDRC) [12-13]. 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. It is also known as Collaborative Plant Breeding (CPB) [14], Farmer Participatory Breeding (FPB) [15], Decentralized Participatory Plant Breeding, and Participatory Crop Improvement (PCI) [16]. PCI is also categorized into two areas. First is Participatory Varietal Selection (PVS), where farmers are only involved in selecting pre-existing varieties or stabilized materials and second is Participatory plant breeding that involves the creation of new varieties in breeding programmes by collaboration with breeders and farmers. The involvement of farmers in PPB will depend on the crop and availability of resources, which they have. It may be either consultative i.e. consultation with farmers should be at every stage starting from the breeding objectives to finished product, or collaborative i.e. farmers grow the variable PPB material in their own fields and select the best plants from it. The participation of farmers in plant breeding programs facilitates the inclusion of target traits they consider important in the selection criteria, and it also makes it possible to take advantage of their technical skills in evaluating plant materials [17]. Participatory Plant Breeding (PPB) was developed as part of the response to an alarming erosion of Plant Genetic Resources (PGRs), particularly the loss of traditional varieties in farmers' fields as well as to breed varieties adapted for low-input agro-ecosystems with the increase rate of adoption of cultivars by small farmers [18].

Participatory Plant Breeding v/s Conventional Plant Breeding

Formal breeding programmes can be briefly described as a centralized sequential process in which breeders collect germplasm, evaluate it under carefully controlled experimental stations, and make crosses among superior materials. The large amount of genetic variability continuously created is then drastically reduced through selection for varying number of years, which depends on the crop, the methodology and the type of variety to be produced; and eventually obtain as a final product a new variety, which in several countries must be distinct, uniform and stable for its seed to be legally commercialized. The process has been effective for farming systems sufficiently similar to those on experiment stations [17] but not adapted when GxE interactions are large. In addition to this formal breeding tends to focus on "broad adaptability" — the capacity of a plant to produce a high average yield over a wide range of growing environments and years. Therefore, candidate genetic material that yields well in one growing zone, but less in another, is quickly eliminated from the breeder's gene pool [19].

Participatory Plant breeding is seen by several scientists as a way to overcome the limitations of conventional breeding by offering farmers the possibility to select, in their own environment, which varieties suit better their needs and conditions [27, 21, 10]. Participatory plant breeding exploits the potential gains of breeding for specific adaptation through decentralized selection, defined as selection in the target environment, and is the ultimate conceptual consequence of a positive interpretation of genotype x environment interactions.

Unlike conventional plant breeding focused on selecting genotypes with 'broad adaptability,' PPB can develop varieties specifically adapted to local environments. This 'specific adaptability' confers important advantages for organic farming also. Performing the selection cycles in the agro-systems where the varieties will be cultivated makes it possible to identify advantageous genotype-by-environment (G x E) interactions that would be discarded in conventional breeding [10]. The process in PPB is similar to a conventional breeding program with three main differences, namely a) testing and selection take place on-farm rather than on-station, b) key decisions are taken jointly by farmers and breeder, and c) the process can be independently implemented in a large number of locations.

Role of farmers' as Breeder in Participatory Plant Breeding

The farmers contribute the main role in PPB programme

a. Farmers contribute knowledge and information based on their experiences to orient the breeding programme according to their preferences for specific crop traits. By this the reorientation of the breeding programmes in terms of selection strategy, and different choices of germplasm used for breeding.
b. Farmers' contribute genetic material: Farmers can contribute genetic materials to breeding programmes, particularly PPB programs focusing on adaptation to specific stresses, production systems, or niches, Specific quality traits or crops for which not much breeding has been done rely strongly on farmers contribution of their own genetic materials to a joint breeding effort. Farmers genetic materials can be used in different ways. In a few cases with cross pollinated crops, farmers deliberately create new variability by facilitating outcrossing between highly diverse types of varieties, often their landraces and an introduced modern variety. These outcrosses often reveal enormous genetic variation and many new combinations of traits. In several cases, farmers have contributed landraces as parents for crossing, or for targeted improvement efforts. Farmers; genetic material often broaden the genetic base of the participatory breeding programme considerably. The material derived and disseminated from these efforts may represent the wider range of diversity than the products of services efforts, and sometimes contributes to the conservation of the landrace materials in the local farming system. The impacts that were observed or expected from using farmers; genetic materials have been mostly related to biodiversity enhancement or the conservation of the local germplasm in the farming community, and as enhanced productivity in specific production systems.
c. Farmers are actually involved in the breeding process and selection process. They manage trials on their own land with management of nutrients. It increases the research efficiency through providing appropriate testing condition.

Impact of Participatory Plant Breeding on Biodiversity

Agrobiodiversity is the substrate of plant improvement. Genetic diversity remains extremely important not only to individual farmers and farming communities but also to scientists and breeding institutions and humanity as a whole.

Diversity assists both farmers and breeders to select and breed for better crops and varieties to satisfy present and future demands in production and consumer preferences. The use of plant genetic diversity is essential for ensuring an adequate and stable supply of diverse food crops as well as for enhancing their nutritional quality. The total genetic diversity in a crop gene pool is the result of i) natural processes unaided by humans (wild relatives of crops); ii) crop evolution, selection and adaptation in farming systems in highly variable and often marginal environments and iii) formal breeding to create new genetic combinations according to predetermined criteria [12].

In formal breeding programmes, the generated genetic variability is drastically reduced through selection during a varying number of years and few surviving lines are spread among farmers as a final product. These products have been effective for farming systems sufficiently similar to those on experiment station but not adopted when genotype by environment interactions (GEI) is large [22]. Thus far, modern plant breeding has been unable to generate sufficient benefits for many small and resource-poor farmers because of above mentioned reasons. The low adoption of modern plant varieties in large areas of small-scale agriculture has both baffled and challenged scientists, development workers, governments, and others with a stake in agricultural progress and in the fight against poverty.

PPB can impact positively on biodiversity because, being a highly decentralized process, it produces different varieties which have been selected in different areas in each country in response to different environmental constraints and users' needs. Crop varieties favored by "traditional" smallholder farmers often have multiple uses e.g. young leaves as vegetables and dried stalks for fodder, in addition to grain. Currently, this approach is being used to develop new varieties adapted to organic farms [23], which need specific ideotypes [24].

In addition, these varieties are often not homogenous, i.e. they are still genetically variable – in contrast to the majority of varieties produced by conventional breeding in which all the plants are genetically identical. Local adaptation helps to limit genetic erosion and consequently avoid major risks due to varietal homogeneity at the territorial scale [16]. The continuous flow of new genetic materials, which favours a rapid turnover of the varieties, thus increasing agrobiodiversity in time [25]

Pros and Cons of Participatory Plant Breeding

Identification and selection of materials through farmers' collaboration presumably will increase adoption rates of the developed varieties. PPB can lead to crops that not only perform well in their intended environments, but are available more quickly and are more readily adopted. PPB can strengthen farmer seed systems, defined as the ways in which farmers produce, select, save and acquire seeds. Encouraging and supporting on-farm seed production by farmers is seen as one approach to sustainable seed delivery because it gives farmers betters access to quality seed of their choice. PPB can be inclusive of women and, importantly, account for their tastes and preferences that often differ from those of their male counterparts. As farmers' participation increases, they must invest increasing amounts of time, energy, and resources; they must also provide increasing amounts of intellectual input and draw on increasingly sophisticated analytical skills. Generated biodiversity by PPB is an ecological barrier to the spreading of pests, but on the other end, the assessment of the impact of PPP programmes is difficult in terms of area planted with the varieties generated by the program, or bythe number of farmers growing them, or by the percent share of the seed market in thecase of private breeding companies [26].

Conclusion

Participatory plant breeding is a process of bringing farmers into contact with professional breeders, thereby raising the farmers' awareness of what science can offer them. This has an empowerment effect which is evident in the enhanced quality of farmers' participation over time. PPB is extremely advantageous in those geographic areas where classical breeding efforts have been less successful and failed to leave a positive impact on farmers' conditions. PPB can be resorted to for multiple uses like increasing productivity, preserving diversity and benefits for specific end-users. However, most of the goals are not mutually compatible leading to trade-offs when any one option is giving priority. Despite the advantages of participatory approaches it has certain limitations when compared to the conventional breeding methodologies especially the cost that is sometimes exorbitant and also slow adoption rate for larger area. The major obstacle to mainstreaming PPB is the centralized seed systems, through which measuring the impact of PPB program is a challenging task. Thus, it is important that one should have total clarity regarding the objective of Participatory research as to whether it is being used for improving the efficiency of agricultural research or merely being used as a tool for empowering farmers or partners organizations. In order to be a sustainable approach to plant breeding, PPB needs to become a permanent feature of plant breeding programmes, addressing crops grown in agriculturally difficult and climatically challenging environments.

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