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"Grassroots Breeding": a Way to Optimise the Use of Local Crop Diversity for the Well-being of People

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Abstract
Effective maintenance of crop diversity within farming systems has been the subject of many studies over the last decade. Although the benefits of agrobiodiversity have been widely recognised and encouraged through global conservation and policy awareness initiatives, its use is constrained due to the limited number plant breeders who can respond to all the needs of the poor farmers. Agrobiodiversity assets that are important for the poor are either being lost or not being used optimally because neither the rural poor nor research and development workers fully appreciate their value and/or manage them well. This loss is often attributed to the green revolution and its assumption that the sophisticated plant breeding, led and controlled by professional breeders, is the best way to address farmers' problem and needs. Consolidating farmer participation in grassroots breeding might: 1) improve farmers' access to a wide range of genetic resources for local innovation, and 2) enhance farmers' knowledge and skills in genetic resources conservation and plant breeding. In this paper, we re-examine if farmer participation does improve the availability, access, quality, conservation and utilization of genetic resources. We put forward a step-by-step plant breeding process, which can enhance the capacity of grassroots institutions and farmers to assess existing diversity, select niche specific plant materials, produce sufficient quality seed, and distribute this within the community. We call this process of local crop development "Grassroots Breeding". Based upon this analysis, together with experience from community-based on-farm management, we conclude that a rethink in current plant breeding approaches is essential if we want to optimise the benefits to poor farmers through the use of genetic diversity at the local level. What are the simple tools that can be used, or are being used, to reach this goal? Such an effort is pertinent given the ever-increasing demands placed on different production systems due to changing climate and farming practices. High levels of on-farm diversity can help mitigate the negative effects of these current trends if communities are empowered for efficient resource use and diversity in agro-ecosystems for improving livelihoods.

Keywords: Agricultural biodiversity, community empowerment, diversity, efficiency, farmer seed systems, grassroots breeding, grassroots institutions, local crop development, participatory plant breeding

Introduction

Many poor farmers in marginal areas have not benefited from the great successes in conservation and crop improvement research for the developing world (Bellon, 2006). This is partly because, in the past, large investment and efforts were made to collect, characterise and store seed for future use but little was done to make quality genotypes accessible and available to needy people (Lantican, 1988;Tay, 1988). The maintenance of crop diversity within *ex situ* and within farming systems (on-farm conservation) has been the subject of substantial work over the last decade (Hodgkin *et al*., 1995; Jarvis *et al.,* 2007). Benefits of these efforts to poor and marginal farmers in developing nations are limited because i) very small proportion of collected accessions are used by plant breeders (Gill, 1989), ii) declining public sector investment in plant breeding (FAO, 2006), iii) over-emphasis of biotechnological tools in plant breeding, iv) declining interest of young scientists in conventional plant breeding (FAO, 2006), and v) lack of innovative and simple plant breeding methods that can be used by local institutions.

Investment (government funded or donor supported) in plant breeding in developing nations has declined. Hence it is important to examine whether this limited investment is being applied in relevant, appropriate and efficient manner. Another factor often cited as being one of the most limiting factors in the use of crop genetic resources to increase crop productivity is the lack of sufficient numbers of well-trained plant breeders (FAO, 2006). Ground level service providers are lacking the capacity to identify and use new and useful sources of variation, whether conserved in the many genebanks around the globe or found in farmers' fields, for traits with current and future use. This paper puts forward a simple plant breeding process that can improve farmers' access to wide range of genetic resources for local innovation, and enhance farmers' knowledge and skills in genetic resources conservation and crop improvement.

Conceptual framework and main assumptions

Landraces constitute much of agrobiodiversity and are the fruits of thousands of years of observations, selection, exchange, and breeding by farmers and communities (Zeven, 1998). There is a growing recognition of the importance of landraces, both as components of sustainable production systems and as sources of genetic variation for modern plant breeding (Teklu and Hammer, 2006). The maintenance and use of highly diverse landraces in local communities suggest that farmers possess traditional knowledge about factors essential for the conservation of landraces and their capacity to develop new varieties (Boster 1985; Salick *et al.,* 1997; Teshome *et al*., 1999). This capacity of farmers and communities can be further fine-tuned and converted into an important tool to assist farmers in enhancing food security, especially in marginal areas (PRGA, 1999). This "fine-tuning" can be achieved through 'grassroots breeding'.

The term grassroots breeding has been used by Berg (1996) in the sense of plant breeding initiated by grassroots movement. Before private seed companies took over the control of breeding work in USA, the American experiment with grassroots breeding was a tremendous agricultural success till 1930. In case of developing countries, there are a hundred million farms in India alone (Swaminathan, 1998), out of which only 15 to 20 percent use seeds from the regular seed trade. The remaining 80 million farms depend on seed supply from other farmers through the informal sector. These figures are similar in most developing countries (Cromwell, 2000; Tripp 2001) and these farms with an informal seed supply constitute the sector where grassroots breeding has its primary attraction. It brings us to marginal areas, women's groups and poor people, who are the main custodians of many neglected and under-researched crops. By targeting such farms with a simple grassroots breeding approach we increase the possibility of benefiting farmers in marginal areas in developing countries. Unfortunately, government and donor agencies emphasis on these simple approaches continued to be neglected.

We re-examine the following commonly held assumptions on access, availability and quality issues of farmer seed system and farmer participation in plant breeding in order to provide immediate benefits to farmers and consumers from the use of available diversity.

Access: A primary requirement for increasing the productivity and use of valuable crops is to increase farmers' access to healthy, viable propagules (seed and vegetative planting materials) of preferred varieties at the right time and under reasonable conditions (von Brocke *et al.,* 2001). Subedi *et al.* (2003) reported that social networks play a key role in determining access to seed and information. Informal seed systems-which are part of social customs and practices- play a central role in the provision of planting materials in developing countries (Tripp, 2001). They largely constitute of self-saved seed, farmer-to-farmer exchanges, and local market purchase, with the formal sector playing a minor role. The value of such informal seed system is also associated with the maintenance of meta-population of on-farm genetic diversity connected by migration (seed flow) and colonization (Hasting and Hartison, 1994).

Access to diversity refers to people having adequate land (natural capital), income (financial capital) or connections (social capital) to purchase or barter for variety (Sperling *et al.,* 2006). In many traditionally managed agro-ecosystems, local populations of domesticated crops maintain a high level of genetic diversity by the function of migration and re-colonization (sink-source) of meta-populations (Hastings and Hartison, 1994). However, farmers often assume that the traditional varieties are usually maintained by someone within the community and that they can obtain them from fellow farmers should they need them (Bellon *et al.,* 2004). Studies have shown that this assumption is often wrong because of the pressures and stresses on traditional seed systems from various commercial and policy forces. The traditional practice of inter-dependence on natural resources in sharing and exchange of germplasm is also changing. Farmers have imperfect access to information about varieties (Tripp, 2001). Access to unique and locally adapted traditional varieties is often poor within the community, even when a sufficient quantity of seed is available (Badstue, 2006), simply because of poor access to information, weak social networks, social exclusion, and weak institutional mechanisms for collective actions. Despite a strong awareness programme, loss of traditional crop varieties continues even in those areas where access to markets, technological interventions, and information is high (Chaudhary *et al.,* 2004). There is a great probability of repeating the classical theory of "the Tragedy of the Commons"[1] if collective action on crop genetic resources is not undertaken (Hardin, 1968).

Availability: The informal seed systems are assumed to be perfect for household seed availability (Almekinders *et al.,* 1994). Availability is defined as whether sufficient seed of appropriate crops is available within reasonable proximity and during the time of planting (Cromwell, 2000). This is not always true in all contexts at all times. Because of eco-geographic variation, lack of sufficient choice of alternatives varieties, and lack of trust, quality, and accessibility of seed available from outside sources, farmers from mountain and marginal ecosystems depend greatly on traditional varieties and informal seed exchange (Badstue, 2006). Therefore, a strong social network for seed flow was found in remote and isolated marginal conditions whereas such networks were relatively weak and small in more accessible and productive areas (e.g. Terai region of Nepal), often involving only 2 to 8 households compared to 30-50 households in middle hills (Subedi *et al.*, 2003). Traditional varieties exchanged in these small social networks are

[1] The **tragedy of the commons** is a class of phenomena that involve a conflict for resources between individual interests and the common good. In this case, a farmer himself grows MV (gets higher yield) assuming that someone else has the landrace (source of genetic diversity for new variety) for when he needs it. If everyone thinks this way then nobody grows the landrace and hence the commons (public value of genetic diversity) will be lost.

vulnerable, and liable to a high degree of loss, for example as seen in the Terai environments (Chaudhary *et al.*, 2004). Therefore, community seed bank of traditional varieties was found to be good practice in Terai part of Nepal as it meets immediate need of farmers (Shrestha *et al.*, 2006).

Quality: Quality of local seed refers to seeds that are acceptable in terms of seed health, and that have specific adaptations and varieties that are socio-culturally acceptable (Cromwell, 2000). It is also commonly assumed by many service providers that quality of landraces are variable and poor in productivity and therefore, should not be promoted by the agricultural extension system (Virk and Witcombe, 2007). Conservationists assume that conservation happens as long as traditional farming systems exists and farmers use local crop diversity and therefore, choice of modern cultivars should be the concern in conservation areas. These contrasting assumptions lead to debate on conservation versus development issues. Rana *et al.,* (2007) however, demonstrated that some landraces are better adapted to specific niches and can even yield better than modern varieties. They also argued that the most practical approach to optimizing the use of existing local crop diversity might be through the identification of a "best-fit' to the environment and management conditions (land types/ farming system/ market).

Table 1. Comparison of grassroots breeding with participatory crop improvement typologies

Typology	Grassroots Breeding	Participatory Variety Selection	Participatory Plant Breeding/ Client-Oriented Breeding
Breeding Strategy	Selection from existing diversity of traditional variety by farmers under target environment	Selection amongst fixed lines by farmers under target environment (Joshi and Witcombe, 1996)	Selection from segregating lines by farmers under target environment (Witcombe et al., 1996; 2006 ; Sthapit et al., 1996)
Breeding Process	1. Need assessment 2. Diversity assessment 3. Selection of preferred traits 4. Multiplication and distribution 5. Monitoring spread	1. Need assessment 2. Search 3. Experimentation 4. Wider dissemination	1. Goal setting 2. Creating variability 3. Selection of segregating lines under TPE 4. Testing varieties 5. Seed supply 6. Monitoring spread
Institutional role	Grassroots	NGO, Department of Agriculture, National Agricultural Research Station	NGO, NARS, CGIAR

Considering some of the assumptions debated in the literature, we can strengthen farmer seed system and farmer innovation in local crop development to improve farmers access to wide range of agricultural biodiversity for local innovation, and to enhance farmers' knowledge and skills in genetic resource management and plant breeding so that we could optimise the use of local crop diversity for the well-being of people. In reality, there will never be enough plant breeders to develop specific varieties for specific situations in specific crops, particularly minor and underutilised species. So what is needed is a simple approach that can be employed by large number of researchers, extension workers, NGOs, and local institutions and maximizes the use of useful diversity (Berg *et al*., 1991; Hardon and de Boef, 1993). This will improve the cost-effectiveness and efficiency of plant breeding where investment in plant breeding and institutional capacity to address all circumstances is limited.

Grassroots breeding

The grassroots breeding focuses on two basic plant breeding steps: 1) participatory pre-breeding efforts (locating, assessing, multiplying and making germplasm available) with the objective of immediate use and 2) enhancing germplasm through simple selection, healthy seed production, and deployment of seed by social seed networks. The term 'grassroots' is coined to reflect two key elements: firstly, it involves very grassroots (basic) type of plant breeding, and secondly, activities can be led by farmers and grassroots institutions (Table 1). The term 'grassroots breeding' is coined to capture a simple plant breeding approach that strengthens the organizational and selection skills of farmers and communities in plant breeding, seed production and marketing strategy. Some elements of grassroots breeding have already been emphasized in the literature in the name of 'Informal Research and Development' (Joshi and Sthapit, 1990; Joshi and Witcombe, 2002), 'Local Crop Development' (Hardon and de Boef, 1993), 'Farmer Breeding' (Sperling *et al.,* 2001), 'Diversity Field Fora' (Huvio and Sidibe, 2003) and 'Diversity Kits' (Sthapit *et al*., 2006). Bellon (2006) emphasizes those alternative methods, which build and improve on farmers' local germplasm and practices, merit attention so that they can benefit poor farmers, especially in marginal areas, and particularly when formal breeding approaches are unavailable.

Process of grassroots breeding

Building upon the previous PPB experiences, a simple six-step process of grassroots breeding was found to be effective in community-based management of agricultural biodiversity (Figure 1). Since most of the poor live in rural areas and depend on agriculture and forests, a key asset they maintain and control is a diversity of crops, varieties, animal breeds, and forest species—the components of agricultural biodiversity, which are available in their habitats. The process of grassroots breeding could easily be applied with a wide range of local biodiversity for their livelihoods and well-being. This requires holistic perspective from the eyes of farmers, but current institutional set up could easily be constraints for such institutional innovation.

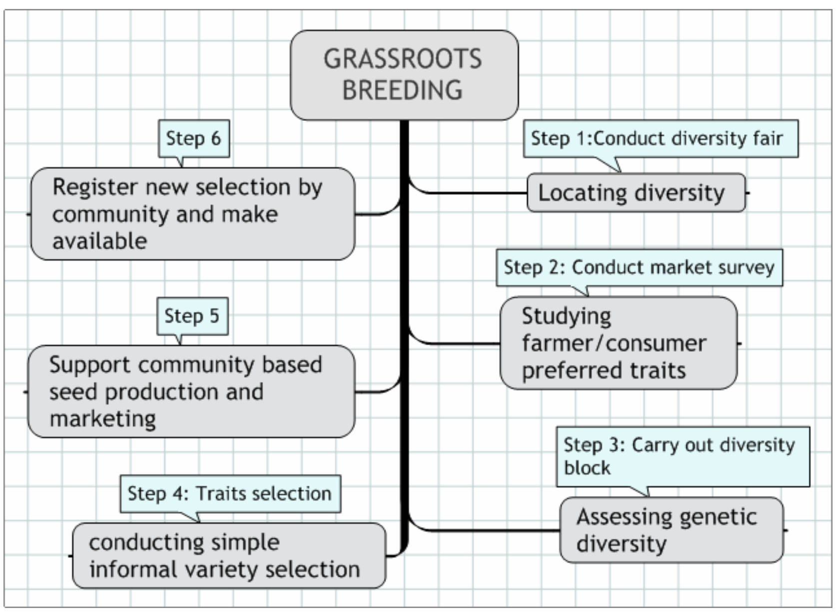

Figure 1. Process of grassroots plant breeding

Table 1 shows comparative differences between three typology of participatory plant breeding (PPB)[2]. In case of plants, this concept is an inclusive term referring to all preliminary steps of a participatory plant breeding effort, beginning with setting the breeding goals which define the

[2] Over 15 years of PPB practice, we know now that grassroots breeding (GB), participatory variety selection (PVS) and participatory plant breeding (PPB) are not so clearly delineated for most non-plant breeders. We have used this description of GB, PVS and PPB under the rubric of PPB so that distinct steps of plant breeding process are highlighted and value of such steps are recognized according to institutional capacity of the plant breeding programme.

traits of interest to be selected from existing local crop diversity, and ending with the on-farm testing, multiplication and distribution of seed to farmers (PRGA, 1999; Sperling *et al.,* 2001). In the context of broad definition of PPB, the grassroots breeding can be a preliminary step of participatory plant breeding process. However, it is important to distinguish the process because it will encourage plant breeders to look into the existing local crop diversity in the farming system and but also and set appropriate breeding goals, strategy and breeding tools (a suite of tools from grassroots to marker-assisted breeding). The process not only includes enhancement of existing diversity but also requires involving the process of seed multiplication, distribution and monitoring of diversity as resources for underutilised and minor crops are limited.

Table 2. Contextual framework of the farmer's seed system and relevance of grassroots breeding

Material + Information	Context A	Context B	Context C	Context D	Context E	Context F	Context G
Access	√	√	√	x	X	x	x
Availability	√	√	x	√	X	x	x
Quality	√	X	√	√	√	x	x
Diversity	x	√	√	√	√	√	x
Relevance:							
Grassroots breeding	*Not Needed*	*Needed*	*Needed*	*Needed*	*Needed*	*Needed*	*Needed*
PVS	*Needed*	*Needed*	*Needed*	*Needed*	*Needed*	*Needed*	*Needed*
PPB	*Needed*	*Not Needed*	*Not Needed*	*Needed*	*Needed*	*Needed*	*Needed*

The importance of grassroots breeding may vary with the goal of the exercise and the context it takes place in. Grassroots breeding may not be appropriate in all circumstances and for all crop species. Grassroots breeding is important in those circumstances where farmer access to seed, seed availability, and seed quality are major problems. A range of hypothetical context is presented in Table 2 to use matrix as a decision tool depending upon farmer's access to seed, seed availability, quality and diversity. GB might not be required in those areas where modern varieties have already replaced traditional biodiversity and/or where advanced plant breeding has already incorporated useful genes into commercial modern cultivars. In this situation PVS and PPB might be more appropriate to enhance varietal diversity and minimize pests and diseases by increasing intraspecific diversity (Witcombe *et al.*, 2001). The success of future breeding lies in how systematic grassroots breeding efforts are carried out by community-based organisations and local actors.

Advantages and disadvantages of grassroots breeding

Grassroots breeding offers a number of potential advantages compared to both conventional and participatory crop improvement methods:

1. Empowerment of grassroots institutions and communities in genetic resource conservation and use
2. Immediate benefits to communities by improved access to rare germplasm and associated knowledge
3. Wider impact on marginal and poor farmers because of better understanding of underutilised and neglected diversity for local and specific adaptation along with preference of culturally valued traits
4. Promotion of on-farm management of local crop diversity through enhanced capacity of grassroots institutions and farmers in diversity assessment and use
5. Encouragement with local innovation in plant breeding and setting breeding goals to overcome weakness of local varieties

6. Opportunities to generate income and support livelihoods through collective actions in seed production and the marketing of unique and rare varieties

However, there can be some problems as well. If new genetic diversity is not carefully used, a particular area might end up with sister selections and a narrowed genetic base. Therefore, caution needs to be exercised in making the right choice of parents. Secondly, this approach can lead to diverse types of the same product, which may not have the same value in the market due to the demand for uniform material.

Case studies

We are mindful that the suitability of local crop development (grassroots breeding) is determined by farming circumstances, plant breeding capacity and availability of options (Table 2). Nonetheless, it has been noted that by making selection criteria more relevant to local needs, participatory breeding can reach poor farmers who have not yet benefited from modern varieties (Kornegay *et al*., 1996; Sperling *et al*., 1993; Vernooy, 2003). With grassroots breeding, this can be further focused on traditional diversity, which has been neglected by the practitioners of participatory approaches. This approach allows farmers and researchers to understand the value of local diversity before modern varieties are imposed. There are many scattered experiences that illustrate the identification of locally adapted germplasm and the use of it either directly or as the basis for breeding new varieties and this can benefit the poorest of the poor farmers. We cite herein three case studies from on-farm management project of Nepal to demonstrate usefulness of these practices that use available local diversity.

Improved access to unique cultivars and information: Sthapit *et al.,* (2006) reported that a good quality sponge gourd variety (e.g. *Basune ghiraula*, literally, aromatic sponge gourd) was grown by few households in Begnas village of Nepal and its existence and seed availability was unknown to most others until a diversity fair was organised and locally multiplied seeds were distributed to other farmers. Currently, the variety is grown by 120 households compared to a single household in 1998. Many such examples were found in traditional local cereal and vegetable crops that need special focus. In one of the on-farm conservation sites in the Bara district of Nepal, it was found that a certain rice landrace was maintained in a large area by one household because the variety is adapted to the "*ghol*[3]" area the farmer possessed. The variety has a specific adaptation with potential to be used in a specific niche outside the community. Realizing that this type of area is also widespread throughout the Terai regions of Nepal, local NGOs have multiplied the seed of locally adapted varieties and deployed them through diversity kits in order to maximize the use of existing diversity (Gyawali *et al.,* 2005). This is just few examples from rice crop where local innovation has the potential to be translated into larger benefit through better delivery mechanisms.

Improved availability germplasm and associated knowledge:

Of 941 household of Begnas VDC, at one household in Bhagara, Mr Khim Bahadur Gurung was maintaining local taro cv. *Rato panchamukhe pidalu*. This variety is valued for low acridity and excellent cooking quality. Corm of this variety is excellent for curry in combination with fish, meat and *masaura* (vegetable nuggets). The above ground parts are used for multiple uses. The availability and access of this germplasm is enhanced by sharing information. Five women farmers from Majhthar women group village collectively multiplied seed as a part of income generation in 2003. At present this unique variety is grown by 11 farmers in three villages and

[3] A kind of rice ecosystems in which fields are perpetually water logged. Only few local varieties are adapted to such conditions (Rana, 2004).

being distributed by farmer-to-farm exchange and sale. In high production potential Bara site of Nepal, out of 33 rice landraces inventoried in 1998, the number decreased to 14, landraces growers decreased to 32 from 68% and total area occupied by rice landraces decreased to 3 from 17 % in 2003 despite the implementation of on-farm conservation programme (Shrestha *et al.*, 2006). This alarming situation was capitalized by the project staff to encourage farmers of Kachorwa to establish community seed bank and to minimize rapid disappearance of the landrace from the community. Shrestha *et al*., (2006) have reported that access of local varieties increased by 38-48% amongst poorest group of women farmers by establishing community seed bank in the village. The availability of local varieties increases from 11 to 23 landraces amongst 40 to 87 farmers within a three years period.

Improved local materials and marketing:

Gyawali *et al*., (2006) have already demonstrated a successful example of grassroots breeding in rice in Nepal. From 338 seed samples of *Jethobudho* rice landrace collected in 1999 from the seven geographic regions, diversity was assessed for consumer-preferred post harvest traits during the 2000 and 2001 seasons. Significant variations in market traits were found in the studied populations. In 2006, six most preferred populations of Jethobudho rice were selected for quality traits and variety was released by the National Seed Board of Nepal under the name of "*Pokhareli Jethobudho"* in 2006. Community based seed producer groups multiply foundation and truthfully label seeds and market through extension, private and NGOs outlets to generate income. In Begnas viilage resource poor households grew *Mansara* landrace despite its poor taste, low yield and poor market because of it excellent adaptation to 'poor' rice fields where no other rice varieties perform well. With community participation, local *Mansara* cultivar is selected and improved for its eating quality and productivity –through the process of participatory plant breeding.

Scaling up

The most significant contributions made by grassroots breeding will be on the scale of operations. It is relatively easy to scale up this good practice as it requires fewer resources than participatory variety selection or participatory plant breeding. The GB model is developed expressly to focus on the constraints of accessing materials and knowledge to improve them by strengthening local institutions. These kinds of activity could be integral part of majority of community development initiative. The process will provide immediate benefits to farmers and consumers from the use of available diversity. This approach will strengthen local crop development in which the role of farmers and the community in the on-farm conservation of local crop diversity is enhanced.

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