FARMERS AND PLANT GENETIC RESOURCES

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Contents

Summary

This article provides an overview of the major topics relating to farmers and plant genetic resources (see *Agricultural Biotechnology*). Farmers value these resources for biological, social, and economic reasons. To a large extent they depend on genetic and

crop diversity for survival. Because of this, farmers have an intricate knowledge of plant genetic resources and use a variety of strategies to manage them to suit their needs. These strategies include: varietal choice, varietal management (recombinations and introductions of new materials), seed selection, storage, exchange and purchase, and breeding and experimentation (see *Conventional Plant Breeding for Higher Yield and Pest Resistance; Plant Breeding and Molecular Farming*). The formal research system has identified some of these strategies as promising entry points or levers by which they can support resource-poor farmers to enhance their livelihoods and to conserve the world's biological resources (see *Biotechnology and Agrobiodiversity*). Three distinct approaches of working together with farmers on plant genetic resources are discussed: participatory plant breeding, support to informal seed systems, and *in situ* conservation. Developments are also summarized: the use of biotechnology techniques to meet small farmers' needs and the novel intellectual property rights that emerge from explicit collaboration between scientists and farmers (see *Inventions, Patents, and Morality*).

1. Introduction

The importance of plant genetic resources (PGR) to humanity stems from their use as a source of genetic material to develop crops and medicinal plants fundamental to the world population's nutrition and health. These resources also fulfill vital ecosystem functions related to soil structure, nutrient cycles, hydrological flows, agroecosystem stability, and defense against pests and diseases. The diversity of plant genetic resources is threatened by a complex of factors, *inter alia*, poverty, economic development, and market integration. Farmers around the world have historically been and continue to be the stewards of most of these resources, maintaining, refining, and trading them to suit their needs. As such, farmers, including the poor, are key actors in the conservation and enhancement of plant genetic resources.

This article provides an overview of a topic of extreme importance to millions in the developing world and to the citizens and consumers of the industrialized world: the interaction of farmers (resource-poor farmers) and plant genetic resources. The first section explains why plant genetic resources are so important to farmers biologically, socially, and economically. The second part shows how farmers manage and use these resources to perform a wide array of activities. The third section elucidates how the formal system can and has begun to support enhanced PGR use with farmers and what have been the impacts so far. This section covers participatory plant breeding (PPB), support to informal seed systems, and *in situ* conservation. Finally, the fourth section addresses two developments in the field: biotechnology-assisted PPB and novel intellectual property issues that emerge as scientists work more closely with farmers.

2. Why Plant Genetic Resources (PGR) Are Important to Farmers

Plant genetic resources (PGR) are more than crops and food for resource-poor farmers. They are fundamentally a means for survival and a "currency" with which to negotiate the "purchase" of other essential goods and services, be it through barter with other farmers or in the market. Many resource-poor farmers live in marginal areas—localities characterized by difficult growing conditions, geographical remoteness, little or no integration to markets, and often negligible attention from formal agricultural research and extension systems. Dependence on a single crop species or variety in these conditions can be disastrous. Seen in this way, the importance of *a diversity* of plant genetic resources to farmers is evident (see *Biodiversity: Structure and Function*).

Biologically, a diversity of crops and species ensures farmers a certain degree of stability in their harvests from year to year and from season to season. If one crop or variety fails because of biotic or abiotic stress, others may not. At the community level agrobiodiversity (see *Fundamentals of Biodiversity*) ensures that seed can be obtained from neighbors if one farmer loses his/her seed or if seed needs to be renewed. Different varieties will be adaptable to different microclimates and soil types—a heterogeneity characteristic of marginal areas. Harvests can be staggered so that when one crop's harvest is consumed, another's may still be in stock, and yet another may be in the field ready for reaping. Diversity also ensures that an array of essential nutrients and micronutrients are available. By maintaining biological diversity in their fields, farmers reduce their risks and assure their food security.

Socially, a diversity of crops and species with different growing cycles allows farmers to spread their labor demands to different members of the household and over periods of time in the year. Certain crops and species are used in local rituals and festivals and can be preferred by one ethnic/social group or another. In Mkulula, Tanzania, for example, Friis Hansen found that the number of sorghum varieties maintained by different ethnic groups varied according to their historical subsistence strategies. Social institutions and norms may determine which groups in a society have access and control over particular crops and varieties. In a maize-cultivating community in Mexico, Louette found that land tenure and access had a strong bearing on farmers' seed sources and consequently on the number of varieties that they planted. Barter or seed exchange helps to establish and to maintain social ties within communities and beyond. In some instances the mere holding of diversity (or sometimes of a particular species or variety) confers a household or individual a favorable social status within the community. And conversely, a particular role in society—for example a shaman or ritual healer—may give a person an exclusive right in a community to grow or otherwise obtain a particular species.

Different species and varieties may also be important to different members of households depending on their roles and responsibilities. This is sometimes the case for women (see *Gender Relations in Local Plant Genetic Resource Management and Conservation*). Women are often in charge of producing and maintaining so-called minor crops—crops that although important to human nutrition and health do not singularly have a major significance for food security across regions and have not been targeted by breeding programs of agricultural research institutions. Women have generally been credited with the domestication of many of the world's landraces (of yam, beans, culinary maizes, millet, bambara groundnuts, and so on) and of harvesting wild species and relatives of major crops. A notable example of these wild species is the little publicized *quelites,* a wide array of wild greens (several species) that complement the predominantly maize-and-bean diets of Mexican farmers. With regard to species and varieties that men also cultivate, Farnworth and Jiggins observe that women often value some characteristics different from those favored by men. This reflects their particular concerns with family nutrition, cooking quality and postharvest processing, storage, a range of ancillary uses of plant parts, and their own time allocation.

Economically, a diversity of crops and species gives some farmers the opportunity to exchange with different members of their communities and of offering different goods and services in return. Where markets are available and functioning they can supply specialized crops to meet the distinct demands of consumers. These demands are often different from preferences for home consumption which give farmers an added incentive to grow varieties and crops that they would not otherwise cultivate. In the case of extreme poverty and/or landlessness, a farming household's choice of what to plant may not be their own but rather determined by what sells in the market or what the landowner allows.

In summary, plant genetic resources are important to farmers because they provide them with the opportunity to protect themselves against hunger, or in less extreme circumstances to engage in an exchange for other necessary resources. Diversity is important because it minimizes the risks inherent in practicing agriculture in areas that by definition are ill-suited for cultivation. Different resources will be important to different groups of farmers—delineated by socioeconomic, ethnic, or gender lines—for different reasons. Ironically, both cultural diversity and poverty are correlated with crop genetic diversity.

3. How Farmers Manage and Use Plant Genetic Resources

Farmers' need for diversity both within and among species has led them to develop over centuries practices that have resulted in the existence of a vast genetic store at the local level (see *Conventional Plant Breeding for Higher Yield and Pest Resistance*). Each growing season farmers decide what to plant, how to plant it, and where to obtain seed. These are conscious decisions that are influenced by a number of socioeconomic and cultural factors and have important implications for crop genetic diversity on farms. Farmers' activities related to plant genetic resources have been grouped and labeled into three broad and somewhat overlapping areas: farmer breeding, *in situ* conservation, and informal seed systems.

Knowledge and appreciation of farmers' activities related to the improvement and conservation of plant genetic resources has led to the creation of the terms *farmer breeding* and *farmer-breeders.* While it is acknowledged that most farmers are engaged in some degree of PGR management (see *Conventional Plant Breeding for Higher Yield and Pest Resistance; Plant Breeding and Molecular Farming*), the term *farmer-breeding* as defined in 1999 by McGuire and his colleagues refers to the deliberate activities of expert farmers, or farmers who have a more intricate and detailed knowledge of their PGR, embedded in social processes and leading to desired characteristics in their crop populations. The term *farmer-breeding* encompasses all the genetic processes that farmers are engaged in independently of formal breeders (including storage, exchange, conservation, recombination, and selection) (see *Plant Cell Culture; Genetic Engineering of Plants*).

In situ conservation has been defined by Bellón as the "continuous cultivation and management of a diverse set of populations by farmers in the agroecosystem where a crop has evolved." This definition is further refined by Brush who distinguishes two types of *in situ* conservation: a) the ongoing "historical phenomenon" of farmers maintaining a diversity of landraces against a backdrop of modernization of agriculture, and b) the specific projects and programs that are emerging to support and promote the maintenance of diversity on-farm.

The term *informal seed systems* refers to the diverse processes, sources, and relationships surrounding farmers' attainment of seed from other farmers. These systems are based on local communication channels and are often limited in scale. The seed that moves in these systems is mainly from local varieties. As with farmer breeding and *in situ* conservation, the term covers a range of activities and has been targeted as an entry point for support from the formal system.
This section will explain farmers' use and management of PGR as a number of closely interrelated activities or processes each of which falls into one or more of these three groupings. The next section will address each of the three groupings, explaining how the formal agricultural research system (and in some instances NGOs and other types of organizations) has aimed at managing PGR together with farmers.

3.1. Varietal Choice

Varietal choice refers to how many varieties farmers plant, which varieties, in what proportions, and on what percentage of crop area. While some of these decisions are purely a matter of choice, farmers are often constrained in their decisions by factors out of their control such as agroecology (extreme edafoclimatic conditions), market integration (access to markets/seed and input values), and the need for agricultural intensification (higher yields/opportunity cost of growing lower-yielding varieties). Wealth, productivity, dependence on off-farm income, labor availability, ethnicity, land tenure, and gender also will play an important role in these decisions.

Generally, resource-poor farmers cultivate a large percentage of their cropping areas with landraces. These are often morphologically heterogeneous populations of plants recognized for their particular characteristics—earliness or drought resistance, for example. The distinguishing characteristics of most landraces are that they are genetically diverse, they are well adapted to the locality, and they are bred, cultivated, and maintained by farmers from one generation to another. Considerable controversy exists around the precise identities, definitions, (and now ownership) of landraces, as some are thought to be exotic materials that were introduced to regions many years ago and have changed under farmers' management. It has also been observed that farmers sometimes give a new name to a material when it is introduced to a new locality, leading to the phenomenon of many names for one variety. In Rwanda, a bean variety, known to researchers as G2333, had at least 33 local names only 5 years after its introduction. The converse, several varieties with the same name, is also common. A further element of confusion is brought at the genetic level when one asks how static or constant the genetic structure of an open-pollinated landrace can be given the high levels of gene flow between different varieties? Louette and other scientists have tried to define exactly what a landrace is. While these interrogations still exist around the definition of landraces, it is important to differentiate between these varieties and the processes that have formed them, and modern varieties and their development.

In many instances it has been observed that farmers manage mixtures of plant genetic resources and not one or another single variety. These mixtures can be made up of local varieties, improved varieties, or both. In Rwanda, women farmers will keep anywhere from 3 to 30 different bean varieties per production niche, adjusting the mixture to different growing conditions such as soils and intercrop patterns. Individual farmers may manage up to three different mixtures per growing season, with these mixtures continuously changing as varieties are added or removed according to the circumstances and objectives of the farmer. Prain, Schneider, and Widiyastuti's work offers another example from the highlands of Irian Jaya. Here, farmers manage sweet potato mixtures, maintaining several beds in gardens at different stages of development and mixes of varieties in each bed. People compare the mixing of the sweet potato cultivars in one garden bed with the need to mix up the clans for marriage—to ensure procreation of the tribe. Hecht notes that women farmers are generally known to cultivate a greater diversity of crops and other domesticated and wild materials than their male counterparts.

3.2. Varietal Management, Recombinations, and Introductions

Farmers' varietal management affects the genetic composition of their crop populations. This is clearly dependent on the crop's breeding system. With out-crossing species such as maize and pearl millet, farmers are cautious and deliberate in their management, separating varieties (spatially and/or temporally) to maintain their morphological distinctiveness. A few interesting cases have been noted, however, where farmers did the exact opposite. They purposefully planted two different varieties side by side to allow intervarietal pollination, thus creating hybrid varieties with characteristics of both varieties. As well documented by Monyo and his team in 1997, Maria Kaherero, a Namibian pearl millet farmer, developed a composite variety in this way which is now used as the base for the national breeding program. Some farmers also allow the introgression of genes from wild and weedy crop relatives into domesticated crops in this way.

Accounts of farmers planting mixed plots of self-pollinated crops are more common. The case of women bean farmers in Rwanda mentioned above is one. Rice farmers in West Africa are also known to have a similar practice. The limited amount of outcrossing that does occur among self-pollinated crops allows farmers the opportunity to generate some new crosses (natural crosses) with a reduced risk of full-scale genetic contamination.

Introductions of new materials are common. This can be local materials from other farmers and/or improved varieties from the formal research system. A word of caution is warranted with regard to introductions and the conservation of biological diversity. While some argue that the introduction of improved materials threatens diversity, this claim cannot be confirmed nor questioned without looking deeper into two important issues. One is the diversity of the materials being introduced: While modern varieties are often far less genetically diverse than their local counterparts, increasingly the improved varieties that are introduced as part of participatory breeding projects, for instance, are often hybrids of local and exotic materials with varying levels of genetic diversity. The other issue is that of farmers' definitions and objectives with regard to diversity. Do farmers want varietal diversity or genetic diversity or both? Which do they value more?

Farmers' agroecological management also affects their plant genetic resources. A microenvironment where a farmer decides to grow a particular variety, or a particular planting or land preparation method, may favor or disfavor certain characteristics (or varieties per se) that are highly susceptible to these factors, leading the farmers to keep or reject the variety. And farmers in marginal areas often multicrop, which is another source of competition or bias in any variety's performance. In their *in situ* training guide, Jarvis and her colleagues particularly note that the size of the crop population that the farmer chooses to plant per plot also makes a difference to the eventual genetic structure of that population.

3.3. Seed Selection within Populations

By far the most common plant genetic activity in which farmers are involved is selection. Most resource-poor farmers save some of their own seed from the previous harvest and often complement it with seed from other farmers in the same community, from local markets, and/or from other localities (as many as 11 different seed channels have been used by farmers just for a single crop). Farmers constantly evaluate their varieties for performance regarding a number of criteria and continuously select seed based on them. Farmers' selection strategies vary greatly according to their priorities, constraints, cultures, gender, knowledge, and interests in breeding or in improving/modifying their crop populations. This was shown on work about beans in Colombia, and work in Rajasthan, India. In many areas seed selection is performed through (or as) rituals. On farm diversity in turn is highly influenced by farmers' selection strategies.

Seed selection is an important complement to varietal management as farmers often select plants that they perceive to be different from the variety in question. They do this either to discard or separate them in an effort to maintain the characteristics of the particular population, and/or to single out off-types for further experimentation and scrutiny.

Farmers in Sierra Leone practice a type of mass selection according to genotype by environment interactions and duration. Longley and Richards documented how farmers harvest panicles of early maturing types as they ripen and leave the rest in the field for general harvest later in the season. This selection strategy over the years has led to the creation of three distinct "duration classes," making it possible to have three harvests throughout the year. Interestingly, different members of society are associated with each duration class. For example, women and younger (dependent) members of the household cultivate the longer duration flood-tolerant types. This is because as casual farmers they often have to tend to the main family farm before their own, and have to glean materials left over after harvest on upland farms for planting materials. Moreover, water control is beyond their time and resource allocations, so their fields often flood, and only the flood-tolerant types survive this natural selection.

On a germplasm collection expedition in southern Sudan, Berg accidentally discovered that women are the main protagonists in a strong culture of farmer selection. Women select sorghum panicles in the field immediately before harvest, but the true process of selection is actually based on observation of the plants starting at germination and continuing throughout the growing season. It is also based on discussions with other farmers, particularly within the family and including children. In his 1914 account of the Pueblo Indian culture of Mexico, Collins writes of the lead role played by the *corn matron* in seed selection. Numerous studies have elucidated the central role that women play in seed selection in various crops and regions (see *Gender Relations in Local Plant Genetic Resource Management and Conservation*).

3.4. Storage

Farmers use different sources and techniques to access and store seed. Storage is of major significance to small farmers, as there is often a time lag between harvest and planting. If storage facilities are not adequate, if climatic conditions change unpredictably (e.g., too much rain or humidity), or there is a pest outbreak, farmers may lose part or all of their seed. This in itself may be considered a selection force as only seed that is resistant to these stresses will survive and germinate when planted. In some cases a household's socioeconomic status will not allow it to store seed either because it cannot afford the facilities and accessories or because it cannot assimilate the opportunity cost of consuming or selling surplus grain in the market in the short term.

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Louise Sperling has a Ph.D. in Anthropology from McGill University, Montreal, Canada. She has more than twenty years of field experience across Africa and Asia working with smallholder farming communities, international and national agricultural research systems, and civil society groups, on an array of farming system and plant genetic resource issues. She facilitates a working group on participatory plant breeding under the umbrella of the CGIAR Systemwide Program on Participatory research and Gender Analysis (PRGA). The group helps plant breeders and farming communities make their joint work more responsive to end-user needs (especially in marginal areas and for women and the poor) and also aims to strengthen farmers' own local systems of plant breeding and seed supply maintenance. Having conducted field research in an array of war-torn societies (including Rwanda, DRC, and Ethiopia), Sperling's work also increasingly focuses on the multiple strategies for restructuring society (including agricultural systems) after natural and manmade disasters.

Jacqueline Ashby is a sociologist and research director at the International Center for Tropical Agriculture (CIAT) whose research focuses on the application of participatory approaches and organizational models to the problems of agriculture and natural resource management in developing countries. In the process she has worked extensively with farmer and community-based organizations, including the formation of a farmer-managed NGO, to improve farmers' capacity to work effectively with scientists and to increase the accountability of science bureaucracies to rural people.