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Participatory breeding: tool for conservation of neglected and underutilized crops

Mejoramiento participativo: herramienta para la conservación de cultivos subutilizados y olvidados

Creucí Maria Caetano[1*], Richard Danilo Peña C.[1], José Luis Maigual J.[1,2], Linda Nataly Vásquez D.[1], Diego Caetano Nunes[1], Bruna Rafaela C.N. Pazdiora[1,2]

[1]GIRFIN – Research Group on Neotropical Plant Genetic Resources, Universidad Nacional de Colombia - Palmira, Valle del Cauca, Colombia. [2]Universidade Federal de Rondônia, campus Presidente Médici, Brasil.
*Corresponding author: cmcaetano@unal.edu.co

Abstract

Although a significant number of plant species are recognized as food, only a small fraction meets the protein demand of the world population. Breeding crops, with a very narrow genetic base, most likely will not counteract the adverse effects of climate change. On the contrary, the crops named as underutilized, neglected, orphaned, obsolete or minor, may contain the answers in their genomes to ensure safety, nutrition and food sovereignty of populations. Duly adapted to extreme growing conditions, these local varieties, such as indigenous and landraces of Colombian maize, are part of the cultural heritage of many ethnic groups or native people, that select, use and conserve these varieties. Besides these, another concept refers to the promising resources, also little used, although for different reasons. Therefore, Participatory Plant Breeding is a tool to promote traditional local varieties or underutilized crops, to meet the needs of communities. In the PPB, members of the production chain (farmers, breeders, technicians and others) work together in the process of development of varieties, in a decentralized and participatory process. A PB program with Colombian maize germplasm resulted in the promotion of some local varieties. Alongside, new maize landraces to Colombia were described.

Key words: Orphaned crops, underutilized species, original peoples, race, ancestral knowledge, local variety.

Resumen

A pesar de un número significativo de especies vegetales ser reconocidas como alimenticias, solo una pequeña fracción cumple con la demanda proteica de la población mundial. Los cultivos mejorados, con una base genética muy limitada, muy posiblemente no podrán contrarrestar los efectos adversos del cambio climático. Por lo contrario, los cultivos considerados subutilizados, infrautilizados, olvidados, huérfanos, obsoletos o menores, pueden contener en sus genomas las respuestas para garantizar la seguridad y la soberanía alimentaria y nutricional de las poblaciones. Esas variedades locales, debidamente adaptadas a condiciones agroclimáticas extremas, como las de maíz criollo e indígena colombiano, hacen parte del patrimonio cultural de muchos grupos étnicos o pueblos originarios, que las seleccionan, las utilizan y las conservan. Además de estos, otro concepto se refiere a los recursos promisorios, igualmente poco utilizados, aunque por razones diferentes. Así, el Mejoramiento Participativo es una herramienta para promocionar variedades locales o cultivos tradicionales subutilizados, por atender las necesidades de las comunidades. En el Fitomejoramiento Participativo, los miembros de la cadena de valores o productiva (agricultores, fitomejoradores, técnicos y otros) trabajan juntos en el proceso de desarrollo de las variedades, en un proceso descentralizado y participativo. Un programa de MP con germoplasma de maíz colombiano resultó en la promoción de algunas variedades locales. Paralelamente se describieron nuevas razas de maíz para Colombia.

Palabras clave: Cultivos huérfanos, especies subutilizadas, pueblos originarios, raza, saber ancestral, variedad local.

Introduction

Genetic resources (GR) and their surroundings at global level, are found, according to the IUCN - International Union for Conservation of Nature (Buyck *et al.,* 2015) – and the FAO - Food and Agriculture Organization of the United Nations (2015), under imminent risky situations of several origins, from natural causes till the depredatory human intervention on the environment (WCMC, 1992).

The most recent situation, climate change, anticipates an uncertainty state about how to feed the world population and ensure the availability of the domesticated species by the different human groups since the onset of agriculture. It is foreseen that for 2050 the human population will be 9000 millions of people (FAO, 2015), distributed mainly in marginal zones, that present high levels of food and nutrition insecurity. In this sense, the survival of the human race is in his own hands.

According to FAO (2015), there are more than 500 million of family units habiting the agricultural areas of the planet which produce most of their food. However, although diverse, thee cities are placed on the extremely poor strings with low productivity levels. In order to promote a sustainable growth of productivity, strategies for improving harvesting yields, genetic resources conservation and adoption of innovative management practices for crops should be applied, generating aggregate value and increasing the rural income.

In many of these marginal areas, in addition to conventional crops, domesticated or semi-domesticated germplasm, product of targeted selection and maintained by indigenous peoples and other traditional communities, with broad genetic base, adapted to abiotic stresses such as adverse weather and ecologic conditions, or biotic, as tolerance or resistance to pests and pathogens.

Founded in 2004, the Research Group on Neotropical Plant Genetic Resources (GIRFIN) of the Universidad Nacional de Colombia – Palmira, supports the postgraduate programs in the Faculty of Agricultural Sciences, in special the Master in Biological Sciences with focus on research on Neotropical Plant Genetic Resources. In its academic, extension and research actions, it has built special human capabilities to work on topics that contribute to characterize, preserve, value, document, manage and use sustainably plant genetic resources.

According with this perspective, the GIRFIN, develops basic and applied studies with different GR, mostly on Andean crops and from the Andean valleys and wild relatives of cultured species. Used tools are Participatory Action Research –PAR, in special the Participative Plant Breeding (PPB). Colombian local races and varieties of maize are considered as those crops that, although with broad genetic base, have been minimally or poorly used.

PPB is understood as a decentralized and participatory form of improvement where the community members, plant breeders and technicians actively participate to obtain certain germplasm that meets the needs and preferences of farmers and indigenous peoples, especially in marginal areas (Ashby, 2009). The communities are those who, in principle, decide what they want and what they want to improve, thereby contributing to its food and nutrition security and sovereignty.

The two basic and more recognized strategies for PPB, used for the first time in the nineties in Syria, Morocco and Tunes, according to Cecarelli (2012), are PVS (Participatory Evaluation and Selection of fixed lines or varieties; Participatory Varietal Selection) and PPB itself (participatory creation and selection in segregant populations, Participatory Plant Breeding PPB).

In the PVS, the objective is to value the available germplasm. Easy to implement and with own cost, at short term it generates results, it means, the varieties are rapidly adopted by the participant farmers of the process. For decision making the appreciation from the farmers and the agronomical results are complemented.

In turn, the PPB is applied when the objective is to rescue and/or value the quality of the local varieties, or for marginal environments and/or specific crop conditions or quality requests, or to increase the genetic base, or when the PVS did not reach satisfactory results.

Therefore, it involves aspects associated to the following set goals:

1 To recognize the PB as a tool that supplies food and nutritional security and sovereignty to the local communities of Colombia, contributing to the preservation and promotion of the forgotten, underutilized, orphan,

outdated and minor PGR, together with having the potential to counteract the adverse effects of climate change;

2 To promote PB techniques in farmer, indigenous and academic communities, as an alternative to promote and use germplasm, and as consequence, to preserve it.

Plant genetic resources

According to the UPOV (1991), CBD (1992), FAO (1996) and the World Conservation Monitoring Centre (WCMC, 1992) a plant genetic resource is "the material of reproduction or vegetative propagation of the following types of plants:

1 Crop varieties (cultivars) currently in use and newly obtained varieties;

2 Disused cultivars (obsolete);

3 Primitive cultivars (local varieties);

4 Wild and weed species (currently considered as weeds or companying plants), close relatives to crop varieties;

5 Special genetic lines.

Associated to these crop species are found the wild relatives, important sources of genes with immediate use in plant breeding programs. However, those wild relatives and the ancestral crops have been neglected without recognizing their value for use and/or disuse.

Traditional crops are identified in several categories according to their frequency of use, exploitation and position in the market: forgotten, underutilized, orphan, outdated and minor plant genetic resources. These PGR are somehow accepted by the ITPGRFA and GPA (FAO, 1996, 2011). Besides them, another category of underutilized PGR belongs to the promising crops which have food and/or agricultural potential that has not been properly recognized.

Plant genetic resources for food and agriculture (PGRFA) and the global plan of action (GPA)

Through the International Treaty on Plant Genetic Resources for Food and Agriculture – ITPGRFA, FAO (1996) have determined some regulations with the common objective of preserving and make a sustainable use of the PGR, associated to a set of activities that assume the startup of those strategies displayed by the Global Plan of Action (GPA), in its 1996 and 2011 versions.

Defined by a group of priority actions, the GPA should offer answers to the use and preservation of plant genetic resources for food and agriculture, among their different categories, that ensure to the communities the safety and sovereignty in their food and nutrition, coupled to sustainable agriculture and sustainable management of ecosystemic resources (FAO, 2011c). This means that it is priority, not only the production, but the availability and access to food resources on a fair and even manner, for the current or future use, according to the international regulations and agreements intended to this matters.

As basic principle and in summary, the ITPGRFA and the GPA have as common goal the preservation of PGRFA and the promotion of local varieties, that have genetic value (option) and quasi option (information), with possible potential to confront climate change. In general, after its revision in 2011, the GPA objectives are

1 To promote effectiveness and efficiency in the global actions for preservation and sustainable use of PGRFA;

2 To link the preservation with the use in order to better use the plant germplasm;

3 To strengthen the systems for seeds and crop breeding as an impulse for economic development;

4 To create capabilities, strengthen the national programs and widen the collaborations for PGRFA management;

5 To consolidate the implementation of the International Treaty for Plant Genetic Resources for Food and Agriculture.

A first step in knowing and recognizing the PGR of a country or region for their value and sustainable use, is the generation of species inventories. These can be done using basic tools as collection and taxonomic identification activities, till the use of more sophisticated technologies like bioprospection, that uses geographic information systems (GIS) and other tools to diagnose and monitor the biological diversity of each country for preservation and valuation.

Concepts of biodiversity and agrobiodiversity

Biological diversity or biodiversity (BD) is the variety of life in the planet Earth including the resources comprising the genetic heritage, represented by the different plant, animal and microorganism species, all the genetic variability among species and all the diversity in the ecosystems composed of different combinations of species (CDB, 1992). Biodiversity also refers to the complex relationships among live beings and between them and their environment (BRASIL, 2008).

Additionally the BD comprises the environmental goods and services –food, drugs, clean water and air and, other natural resources that sustain several human activities-. To keep the biodiversity in front of the growing human impact is one of the biggest challenges nowadays (Toledo Machado, Santilli, and Magalhães, 2008).

The GIRFIN considers the biodiversity from a wide and holistic meaning. Thus, the biodiversity is the product of the summation of all the resources of flora, fauna and microorganisms which are affected by anthropic action, where the ancestral crops are highlighted by their management and use, associated to the traditional and ancestral knowledge. Therefore, there are three supplementary views of biodiversity: biologic, ethnic and cultural, that continuously interact.

In the fifth meeting, in 2000, in Nairobi, Kenya, the COP-5 adopted decisions on a working program on arid and sub-humid lands; ecosystemic approaches; access to genetic resources; exotic species; sustainable use; biodiversity and tourism; incentive measures; Global Strategy for Plant Preservation; Global Taxonomy Initiative (GTI); CHM, financial resources and mechanisms; identification, monitoring, evaluation and indicators; evaluation of impacts, responsibility and compensation; and finally, the definition of the term Agrobiodiversity, which established a link between this and the preservation role of the ancestral communities. COP-5 also included a high level segment on the Cartagena Protocol on Biosafety with a Ministries Roundtable and a Special Signature Ceremony (Toledo Machado, Santilli and Magalhães, 2008).

Preservation of crops or forgotten and underutilized species (EOS/NUS)

Although the PGR are considered to be 300.000 identified species and 30.000 are catalogued as edible plant species, only three crops – maize, wheat and rice- represent around 40 to 50% of the global calorie and protein consumption required in the food diet and, only 30 supply 95% of the food global needs (Thies, 2000; EMBRAPA, 2015).

Several crops that have been used historically for food and other uses at a larger scale, or, that can be used because their potential, have been neglected to the underutilized, orphan, obsolete and/or minor state. As a whole, these marginal crops are known as NUS (Padulosi *et al.*, 2011). To these traditional undervalued crops Silva-Ramos (2002) name them, in general, as marginal crops, even though they are extremely important in food and nutritional security and sovereignty in the Andean region and have an almost unlimited genetic breeding potential.

Hernandez-Bermejo & León (2013) consider as marginal species those crops that in the past and in the current conditions were representative for the agricultural activity or the traditional agriculture and, also, in the feeding of indigenous ethnic groups and other local communities. They are not promising crops since they were cultured in a more recent past. However, currently they do not represent areas in production or substantial consumption. Their distribution relies on regulations and dissemination strategies and, their rescue do not require their intensive production nor their use as product for exportation only.

Such crops are characterized by:

1 Being local and traditional, and their distribution, biology, cropping and use are badly documented;

2 Being linked to the cultural heritage of their location of origin;

3 Being adapted to specific agroecological niches and marginal lands;

4 Participating on an informal or formal systems (in some cases) for seed supply (small scale);

5 Being present in traditional agroecosystems for production, with low or none external input;

6 Having traditional uses in localized areas;

7 Receiving low attention by research, extension services, decision makers, donors, technology providers and consumers, despite their potential for diet diversification and supply of micronutrients like vitamins and minerals;

8 Being very nutritive and/or with medicinal properties and other multiple uses, like environmental services because of their adaptation to marginal soils or weather conditions;

9 Playing an important role in the subsistence or survival and in the economy of marginal regions in the planet, especially in the tropics, where the agrobiodiversity is rich (Pastor *et al.,* 2007).

According to Hernández-Bermejo & León (2013), the reasons why a crop or species becomes marginal are social, agronomic and biologic, predominating the first ones. Among the reasons are the substitution of local germplasm by a more productive one; disappearance of ethnic groups that knew the techniques and uses of the species, additional to the crop management; demand variation; restrictions at the economic, cultural, politic or religious levels, leading to the deliberate eradication of self-sufficient life forms, that are replaced depending on outside interests.

Categories for NUS

Underutilized and forgotten species (NUS) are important resources for agricultural and rural development, because they positively contribute to life wellness through better incomes and nutrition, additionally they include cultural dimensions associated with history, religion and mores of the communities (GFU, 2007).

Different concepts have been stated to define what are and which the categories are for NUS. Thus, according to some authors, is included:

1 FAO/WHO (1992): "a marginal crop is one that in the past, under different conditions, was more important in conventional agriculture, but now it focuses on feeding of local communities and allowing food sustainability of the populations with subsistence economy";

2 IPGRI (1998) currently Biodiversity International: "…crops (which) may become widely distributed, but tends to occupy restricted niches in the economy and local production; they are maintained by socio-cultural preferences and practices of local use";

3 Thies (2000): "species of these crops are inadequately characterized and marginalized by research and conservation programs";

4 Padulosi & Hoeschle-Zeledon (2004): "the main characteristics of underutilized species are its great importance in local production systems and self-consumption; great adaptability to different agro-ecological niches and marginal areas; being excluded from research and development agendas and national policies; cultivation and use are developed based on local and traditional knowledge; the need, in most cases, of a significant degree of genetic breeding and management; the fragility and even lack of seed supply systems and low representation in national gene banks."

5 GFU (2004): "an underutilized species is one whose potential is not fully utilized or exploited to contribute to food security and poverty reduction";

Other concepts and terms that identify these crops are:

1 Underutilized or forgotten crop: SUB-O – is "that crop grown in restricted areas, with small production, local presence (not in large national or international markets) and very sporadic. It may have been used for centuries or millennia for human food, fiber, forage, oil or medicinal properties, but have declined in importance over time";

2 Orphan crop: HUÉR – refers to "that crop specially found in marginal regions, without any research, therefore, there is insufficient information" (value of quasi option);

3 Obsolete crop: OBSO – is "that crop/commercial variety previously sowed but, currently with less use and outside the market."

Other terms that are strictly associated are:

4 Promising crop: PROM –"that crop with great potential for use, but that has not been exploited enough and still has low production and sowing area; often it is not defined its management". According to this

feature, it can also refer to an orphan crop.

5 Native or indigenous crop: NATI –"species in its center of origin or domestication (where its wild relatives are found)";

6 Introduced crop: INTR –"introduced species (exotic), with good adaptability, sometimes renaturing";

7 Domesticated crop: DOME –"species that depends on for survival (reproduction) on anthropic actions";

8 Semi-domesticated crop: SEM-D –"species in process of domestication";

9 Wild relative: PSPC/PSEC –"wild relative of plants/cultured species";

10 Race: – "a group of individuals with enough number of common characters to be recognized as a group" (Anderson & Cutler 1942);

11 Creole race: RC –"genetic material introduced several years ago, that has been selected and adapted according to some environmental conditions";

12 Indigenous race: RI –"genetic material selected and preserved by native peoples under some specific environmental conditions";

13 Local variety: VL –"genotype with some characteristics that secure its use, although with low production and, which diffusion is done through informal seed markets, seed fairs, exchanges and other interchange forms".

The concept of variety

The International Union for the Protection of New Varieties of Plants (UPOV, 1991) defines "variety" as a group of plants within a single botanical taxon of the lowest known rank that, with interdependence of itself, do or do not fully respond to the conditions for the grant of a breeder's right, which can:

1 Be defined by the expression of the resulting characters of a genotype or a combination of genotypes;

2 Be recognized from any group of plants by the expression of at least one of such characters;

3 Be considered as a unit, because its aptitude to propagate without alteration.

Toledo Machado, Santilli, and Magalhães, 2008 consider local and/or traditional varieties as the basis of family and native people's agriculture as result of the management and genetic selection for adaptation to different environments, translating into an essential cultural heritage of humanity, which will ensure food and nutrition security and sovereignty.

Frankel and Brown (1984), Thurston *et al.* (1999) and Toledo Machado, Santilli, and Magalhães, 2008 define as traditional variety a race or a variable population of cultured plants, adapted by the farmer using the natural conditions or artificial selection. They are adapted to the management system from the adopted crop and/or developed by local communities, collectively, according to their relationship with the environment and also, are being cultivated in the same agroecosystem for at least three successive generations.

According to Toledo Machado, Santilli, and Magalhães, 2008 by old traditional variety is understood a meaning that is the same as the previous one, but that was developed in the primary and secondary centers of origin, selected by more than ten family generations. In contrast, a local variety is a population under continuous management in at least five cycles of crop by farmers in specific agro-ecological and socio-economic environments. In turn, Thurston *et al.* (1999) define a modern variety as that selected by improved or 'scientific' methods, for agronomic characteristics, among others, such as production, plant height, response to inputs. Finally, the term native variety is used for both a traditional variety to a local variety introduced in a community for less than 20 years (Toledo Machado, Santilli, and Magalhães, 2008).

Marginal crops in some countries of South America and Spain

Some crops in the different categories for marginality are described as follows for different countries or regions.

Andean region

Silva-Ramos (2002) showed a list of native Andean species but, many of them are subjected or vulnerable to genetic erosion processes, they need attention by the responsible entities for preservation, among them:

1 Andean roots and tubers: oca (*Oxalis* spp.),

potato (*Solanum* spp.), camote (*Ipomoea* spp.), mashwa (*Tropaeolum* spp.), arracacha (*Arracacia* spp.), ajipa (*Pachyrrhizus* spp.);

2 Grains: quinoa (*Chenopodium* spp.); quiwicha (*Amaranthus* spp.), tarwi or chocho (*Lupinus* spp.);

3 Fruits and vegetables: cocoa (*Theobroma* spp.), sinini (*Annona* spp.), tuna (*Opuntia* spp.), paico (*Chenopodium* spp.); chilto (*Physalis* spp.), motacú (*Attalea pharelata*), pacay (*Inga* spp.), guayaba (*Psidium* spp.), achachairú (*Rheedia* spp.) and peanut (*Arachis* spp.);

4 Stimulants and spices: different kinds of pepper (*Capsicum* spp.).

And more: *Phaseolus* spp., *Manihot* spp., *Lycopersicon* spp., *Mirabilis* spp., *Cucurbita* spp., *Carica* spp. (posibly *Vasconcellea* spp.) and *Passiflora* spp.

Ecuador

Espinosa *et al.* (1996) surprisingly state as marginal crops in the Ecuadorian territory the ARTCs (Andean roots and tubers), mainly the *Arracacia xanthorhiza* (white carrot), *Ullucus tuberosum* (ollucos), *Oxalis tuberosa* (oca), *Tropaeolum tuberosum* (mashua) and *Canna edulis* (achira). Their cropping has reduced drastically in 10 to 20 years.

However, in this case the interest for their use has not been reduced, but some factors are shown as limiting for the sowing of ARTCs, among them, the unavailability of seeds, adverse weather conditions (frost, wind), the soil fertility reduction, irrigation inaccessibility, high cost of agricultural inputs and pests that affect these crops.

Bolivia

According to Silva-Ramos (2002), the highest value for the genetic resources in Bolivia, primary center of origin of several plant species, consists on the high inter and intraspecific genetic variability and also in its cultivars. These comprise the genetic material of high importance to be used at the short, middle and long term in breeding programs, either conventional, assisted or by Participative Breeding (PBP). A PBP program can be developed in quinoa, beans, sweet potatoes, corn, peanuts, cassava, potato, squash and peppers, among others.

Taking into account the active centers for germplasm conservation, the *ex situ* method for those species of orthodox seeds in Bolivia. For recalcitrant seeds the recommended preservation is *in situ* till *in vitro* conservation is implemented at the centers. Agroforestry species, pastures and others must specifically involve conservation *in situ*, under the system of protected areas and/or agro-ecological systems (Silva-Ramos, 2002).

Peru

Pastor *et al.* (2007), point out as main underutilized crops in Peru to “those native crops that meet at least, two of three proposed criteria, (1) low production, (2) irregular presence or absence in the exports market and (3) absence in the capital city´s markets. Among the underutilized crops in Peru are some ARTCs like potatoes, ollucos, oca, mashua, tomatoes, sweet potato, Andean cereals and grains ((quinoa, amaranto, some maize varieties) and fruits.

Brazil

Bohrer-Monteiro Siqueira and Veasey (2009), name the role of traditional agriculture that, besides directly generate diversity, keeps ‘ethno varieties’ of cassava, yams and sweet potato, all with high genetic variability. If human action does not exert direct influence, these local varieties resist in nature for a short time or become extinct due to competition with wild plants. This aspect differentiates domesticated plants -crop- from wild plants and demonstrates the interaction of dependence to crop plants –human being-.

According to the same authors, a diagnosis of the causes of abandonment or loss of these local depreciated or in marginal state varieties, initiated through a reading of rural areas, and especially the socio-economic and environmental situation in which family farming is inserted, leading to strategies for rescue and wider use of ethno varieties of cassava, yams and sweet potatoes.

Spain

Hernández-Bermejo and León (1992), draw attention to forgotten crops and uses in Spain. The marginalization of many crops is the "result of the impact of the flora of the Old World in America and American flora in Spain. Among these causes:

a. Loss of competitiveness of some species in front of more productive ones;

b. Slow and progressive changes in the mores, feeding habits and life styles;

c. Stablished competence by the economic and politic interests outside the reference region and cultures;

d. Religious or cultural persecutions generally associated to the previous cause;

e. Disappearance of ethnic groups and local communities that know the uses of the plants and crop forms and uses”.

However, Hernández-Bermejo (2013), highlights that “the Iberian agrodiversity also suffered in parallel a significant loss with marginalization or neglect of many crops altogether”. Some were hidden, others came and settled in the "New Continent, being conserved until today, incorporated into its ethnobotanical, agricultural and food heritage.”

“Hence the Maya gardens are (…) a (…) niche for *in situ* conservation of NUS, especially of some subtropical fruits like citrus and, (…) in the feeding of some countries like Argentina it is preserved the consumption of bitter herbs like arugula and radicchio”, being possible “to recuperate the germplasm (…) including their associated food traditions”. Hernández-Bermejo (2013) concludes that crop diversification by using NUS, will always be a successful strategy and overall a need for agriculture.

Colombia

Caetano and coworkers have proposed, from direct and indirect inventories, the construction of a NUS list for Colombia, with emphasis on those that contribute to the food and nutrient sovereignty and security from direct and indirect inventories (Table 1).

Table 1. Identification of orphan, obsolete, promisory and underutilized (forgotten) crops of Colombia.

Id	Common name	Scientific name	Family	Category				Origin		Classification		Wild parent	Preservation State (IUCN)*
				Orphan	Obsolete	Promising	Underutilized	Native	Introduced	Domesticated	Semi-domesticated	PSPC	
1	Acelora, cereza colorada	*Malphigia glabra* L.	Malphigiaceae			x			x		x		Not evaluated yet
2	Achote	*Bixa orellana* L.	Bixaceae			x		x		x			Not evaluated yet
3	Agraz	*Vaccinium meridionales* Swartz.	Ericaceae			x		x			x		
4	Aguacate, cura, palta.	*Persea americana* Mill.	Lauraceae			x	x		x		x		Not evaluated yet
5	Arazá	*Eugenia stipitata* McVaugh.	Myrtaceae			x			x		x		Not evaluated yet
6	Borojó, boronjó	*Borojoa patinoi* Cuatr.	Rubiaceae			x		x			x		Not evaluated yet
7	Camu-camu, camo camo	*Myrciaria dubia* (Kunth) McVaugh	Myrtaceae			x		x			x		Not evaluated yet
8	Carambolo	*Averrhoa carambola* L.	Oxalidaceae			x			x	x			Not evaluated yet
9	Castaño	*Compsoneura cuatrecasasii* Smith	Myristicaceae			x		x			x		Not evaluated yet
10	Cerezo	*Prunus serotina* Ehrh	Rosaceae	x					x		x		Not evaluated yet
11	Chiguas	*Zamia chigua* Seem	Zamiaceae			x		x			x		Almost threatened
12	Chirimoya	*Annona cherimola* Mill.	Annonaceae				x		x		x		Not evaluated yet
13	Chontaduro o cachipay	*Bactris gasipaes* Kunth	Palmae				x	x				x	
14	Ciruelo, jobo, hobo	*Spondias purpurea* L.	Anacardiaceae			x			x		x		Not evaluated yet
16	Cubio, papa amarga	*Tropaeolum tuberosum* Ruiz & Pavón.	Bretschneideraceae	x					x		x		Not evaluated yet
17	Copoazú	*Theobroma grandiflorum* (Willd ex Spreng) K. Schum	Sterculiaceae				x	x			x	x	
18	Cúrcuma	*Curcuma longa* L.	Zingiberaceae			x			x	x			Not evaluated yet
19	Curuba	*Passiflora mollissima* Bailey	Passifloraceae			x		x			x		Not evaluated yet
20	Curuba roja	*Passiflora cumbalensis* (H.Karst.) Harms	Passifloraceae				x	x			x		
21	Fríjol ayocote	*Phaseolus coccineus* Lectin	Fabaceae		x			x		x			
22	Granada	*Punica granatum* L.	Punicaceae	x					x		x		Minor worries
23	Guayaba	*Psidium guajava* L.	Myrtaceae			x				x			

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	Common name	Scientific name	Family	Category				Origin		Classification		Wild parent	Preservation State (IUCN)*
				Orphan	Obsolete	Promi-sing	Under-utilized	Native	Intro-duced	Dome-sticated	Semi-dome-sticated	PSPC	
24	Guayabilla	*Eugenia victoriana* Cuatrec.	Myrtaceae	x				x			x		Not evaluated yet
25	Inchi, cacay, cacao maní	*Caryodendron orinocense* Karst	Euphorbiaceae			x		x			x		Not evaluated yet
26	Inga o Guaba	*Inga edulis* Mart.	Leguminosae				x	x			x		Not evaluated yet
27	Lulo amazó-nico	*Solanum sessiliflorum* Dunal	Solanaceae			x		x			x		Not evaluated yet
28	Madroño	*Garcinia madruno* (Kunth) Hannel	Clusiaceae			x		x			x		Not evaluated yet
29	Maíz	*Zea mays* L.	Poaceae				x		x	x			
30	Mamey	*Mammea americana* L.	Guttiferae			x			x		x		Not evaluated yet
31	Mamoncillo	*Melicoccus bijugatus* Jacq.	Sapindaceae			x		x			x		Not evaluated yet
32	Mangostino	*Garcinia mangostana* L.	Guttiferae			x			x	x			Not evaluated yet
33	Mirajó, almirajó	*Patinoa almirajo* Cuatr.	Malvaceae			x		x			x		Not evaluated yet
34	Níspero	*Eriobotrya japonica* L.	Rosaceae	x					x		x		Not evaluated yet
35	Ñame	*Dioscorea* spp; *Dioscorea alata* L. (blanco-amarillo-negro). *Dioscorea rotundata* Poir (ñame portugués)	Dioscoreaceae	x					x		x		Not evaluated yet
36	Oca	*Oxalis tuberosa* Molina	Oxalidaceae				x	x		x			
37	Pacó, mem-brillo	*Gustavia superba* O.Berg	Lecythidaceae			x		x			x		Not evaluated yet
38	Papayuela	*Vasconcellea cundinamarcensis* V.M. Badillo	Caricaceae				x	x			x	x	
39	Piscande	*Pachira patinoi* (Dugand & A. Robyns)	Bombacaceae	x				x			x		Not evaluated yet
40	Pitahaya	*Selenicereus megalanthus* (K.Schum.ex Vaupel) Moran	Cactaceae			x		x			x		
41	Pitahaya roja	*Hylocereus undatus* (Haw.) Britton &Rose	Cactaceae	x				x			x	x	
42	Quinua	*Chenopodium quinoa* Willd	Amaranthaceae				x		x	x			Not evaluated yet
43	Seje	*Oenocarpus bataua* Mart	Arecaceae			x		x			x		Not evaluated yet
44	Taparín	*Attalea allenii* Moore	Arecaceae			x		x			x		Minor worry
45	Táparo, corozo	*Attalea cuatrecasana* (Dugand) A.J.Hend.,Galeano & R. Bernal	Arecaceae					x					Almost threatened
46	Tomate de árbol	*Solanum betacea* Cav.	Solanaceae			x		x			x		
47	Tomate de ár-bol de monte	*Solanum putumayensis*	Solanaceae	x				x				x	
48	Tomate silvestre	*Solanum circinatum* Bohs	Solanaceae	x				x			x		Not evaluated yet
49	Uva caimaro-na, uvilla	*Pourouma cecropiifolia* Mart.	Cecropiaceae			x		x			x		Not evaluated yet
50	Zapote	*Matisia cordata* Humb. & Bonpl.	Bombacaceae				x	x			x		Not evaluated yet

NUS according to the CFF

'Crops for the Future' (CFF 2015), the new operative denomination for the 'International Centre for Underutilized Crops' (ICUC) and the 'Global Facilitation Unit for Underutilized Species' (GFU) point out that NUS contribute to the improvement of the survival means of human populations since they:

1 Increase the farms income, valuing the life style adopted by the family farming (AF);

2 Assure the food and nutrient sovereignty and security;

3 Encourage the creation of new markets, mainly for eco-friendly produces;

4 Secure the production with low external inputs and the stabilization of the ecosystems;

5 Collaborate with increasing biodiversity, because by supporting stress conditions, they occupy important ecological niches,

giving then support for functional redundancy.

Participative breeding

The first projects involving the methodology of participatory action research and more specifically the tool for participatory selection of plants tool (PSP), participatory breeding (PB) or participatory plant breeding (PPB) in the late 1990s, were developed in Morocco, Syria and Tunisia by ICARDA (International Center for Agricultural Research in Dry Areas) (Cecarelli *et al.*, 2001).

In these marginal areas, yield of staple crops was low, while malnutrition and risk of famine were high. Conventional breeding methods were ineffective, centralized and in their selection criteria did not include those features of importance for farmers (Walker, 2007).

Experience in Syria showed that decentralized selection, associated with the participation of farmers from the beginning of the breeding process resulted in the most appropriate methodology to fit crops to specific biophysical, social and economic contexts, and thus respond to the needs and knowledge of farmers (Vernooy 2003, Vernoy and Song, 2004).

By Participatory Crop Improvement (PCI), Participatory Plant Breeding (PPB), is understood a plant breeding strategy in which the members of the productive chain (plant breeders, technicians, farmers and others) work together in the variety development process. Opposite to the conventional plant breeding, the PPB is decentralized and participative (Cecarelli *et al.*, 2001).

Therefore, linking communities is vital in implementing a proposal of this nature, since they are the ones who best know the origin, behavior and adaptation of their seeds, in addition to direct contribution to food and nutritional sovereignty, through the promotion of use of local resources for food and agriculture (Eyzaguirre *et al.*, 1998).

The PB process is mainly characterized by the systematized inclusion of the abilities, experiences, practices, knowledge and expertise (Toledo Machado, Santilli and Magalhães, 2008), of the local communities in their reread and perception of their environment. In this way, the PB is a rescue and valuation tool for the ancestral expertise and traditional knowledge associated to it.

The Participative Breeding reaches wider objectives than the genetic 'conventional' or 'formal' breeding. According to Toledo Machado, Santilli and Magalhães (2008); Morris and Bellon (2004), earnings in productivity are observed together with, conservation and promotion of biodiversity and genetic variability; gain and use of adapted germplasm to local conditions; intrapopulational selection; evaluation or participative selection of varieties; launch and dissemination of new germplasm; diversification of cropping systems and the production and promotion of seeds. Being a decentralized and participatory process contributes to the empowerment and decision making of key managers and stakeholders: local populations.

For Almekinders and Elings (2001), the PB is an alternative and complementary tool to the conventional or formal plant breeding, which is closely related to the conservation *in situ*. The main limitation of the formal breeding is based on productivity or crop yield in favorable environments with high use of chemical inputs and irrigation; also does not consider cultural preferences and local conditions in marginal regions.

Among the methodologies, techniques and tools used, work with traditional communities developed today by the GIRFIN is oriented toward methodologies of PR-Participatory Research or PAR- Participatory Action Research. This has been applied in the study of the races of maize described for Colombia, under the approach of Participatory Breeding (PB), Participatory Plant Breeding (PPB) or Participatory Plant Selection (SPP).

Considered a strategy of conservation of agricultural biodiversity, with the proposed participatory plant breeding many of the characteristics of rusticity and adaptation of local seeds remain. These seeds are the product of selection pressure by traditional communities over time, driving the selection process according to their needs and preferences (Cecarelli *et al.*, 2009). Therefore, the decision-making in a PB program is complemented by the appreciation of farmers and agronomic results.

Among the preferences of communities, for maize, are the color of grains (yellow, white, purple, red, black, etc.), type of grain (crystalline, semi-crystalline and floury or soft), size and grain shape; number of ears per plant, cob size, number of rows on the cob; precocity; tolerance or resistance to pests or pathogens;

culinary use as cob and dry states, among others.

According to Cecarelli (2012), from the two basic strategies for PB, in the PVS the goal is to value the available germplasm. At the same time, the PPB is applied with the goal of rescuing and/or valuing the local varieties qualities or, for marginal environments and/or crop conditions or strict quality specifications.

The PVS is easy to implement: its cost is low and generates results at short term, it means that the varieties are quickly adopted by the farmers that participate in the process. On the other hand, the PPB is useful to increase the genetic basis or, even when the implementation of PVS did not reach the successful results.

Under the perspective of Participatory Breeding, in all the five stages of development of a new variety it is fundamental the participation of farmers, or community members. The first three stages comprised the PPB. The first four comprise the PVS:

1 Goals of selection (what characteristic is aimed for selection);
2 Creation of variability (crosses);
3 Selection;
4 Evaluation;
5 Dissemination.

According to Machado *et al.* (2006), it is essential that varieties, after rescued, be subjected to experimentation in different locations and for several years to determine its value as a local variety, allow their diffusion through the exchange of materials by farmers, or assess their potential for genetic breeding, validating its use in different agro-ecosystems. The evaluation of different local maize varieties in different agro-ecosystems provides important genetic sources for various types of biotic stress (pests, diseases, weeds or companion planting) or abiotic (Maize Program 1999).Additionally, through the PB the collection and assessment of varieties adapted to local agro-ecological conditions is given, which are associated with a given functional agroecosystem. It should, therefore, prioritize the development of varieties and their seeds, according to the requirements of communities that can respond positively to agro-ecological production systems.

Participative breeding of corn in farm and indigenous communities in Colombia

In several Latin American countries, small farmers from the family farming have been included in the rescue of the genetics of native varieties and the preservation of the agrobiodiversity in their farms, opposite to the current model and the imposed global politics (Santilli 2005, Santilli and Emperaire 2006). For corn, experiences have been recorded in countries such as Brazil (Soares *et al.,* 1998, Machado *et al*., 2006), Honduras (Smith *et al*., 2001), Mexico (Smith *et al.,* 2001; Zambrano, 2013) Argentina (Brocolli and Pardías, 2009), Guatemala (FAO 2011a, 2011b), among others.

In Colombia, the first proposal for PB in native corn “Recuperation and conservation of native and indigenous corn from highlands in Colombia under the methodology of participative breeding”, was developed by the GIRFIN between 2010-2011 (Vásquez and Caetano, 2011), in the surrounding of Tenerife-El Moral, located on the western edge of the Central Cordillera, municipality of El Cerrito, Department of del Valle del Cauca. The local population is

In Colombia, the first proposal for PB in native corn “Recuperation and conservation of native and indigenous corn from highlands in Colombia under the methodology of participative breeding”, was developed by the GIRFIN between 2010-2011 (Vásquez and Caetano, 2011), in the surrounding of Tenerife-El Moral, located on the western edge of the Central Cordillera, municipality of El Cerrito, Department of del Valle del Cauca. The local population is mainly originated in the Departments of Antioquia (antioqueña, Colombian northwest) and Nariño (nariñense, Colombian southwest). In this zone abundant crops are long onion, cilantro, cabbage, strawberry, blackberry, among others. No large or medium corn crops are found.

GIRFIN (Research Group on Neotropical Plant Genetic Resources, Universidad Nacional de Colombia - Palmira), that keeps a germplasm collection of local races/varieties of Colombian corn, supported by ICA, have selected initially the place for multiplication of highlands corn seeds (those developed in thermal floors above 1800 masl), in the Experimental Station of the governorship of the Department of Valle del Cauca in Tenerife, located at 2664 masl, 3°43'47.8'' N and 76°4'35.6'' W and, El Moral at 2125 masl, 03°41'09.6'' N and 076°04'25.6'' W, with average temperature between 10 °C and 17 °C and annual rainfall of 2.000 mm. The sowing happened in December 2009.

The diversity of corns awoke in the local community interest in exchanging seeds, learn methods of controlled pollination and new varieties for planting in their areas, although characterized as small areas (less than 1 ha), consisting of solar, gardens or plots. Few families have the right to possess the land. No corn crops in medium or large scale and few local varieties are planted, according to inventory by us.

The first socialization of the project at the local school (Figure 1), was reported by local radio, through brochures and personally. In this, the corn characteristics required by farmers were defined. Some farms select corn for its production, that is, the number of ears per plant, the size of cob, size and weight of grains, or precocity, or grain colors or texture, or resistance to cold and other abiotic and biotic conditions.

It was agreed between the participants (Tenerife and El Moral farmers, researchers and technicians) that the experimental plot (multiplication by GIRFIN) will be used for

Figure 1. First socialization of the project in the village Tenerife, municipality of El Cerrito, Valle del Cauca, Colombia. Jorge Isaacs School, 2010; a- b) Socialization of the project: "Recovery of highlands corns" with members of the community; c) Multiplication plot of highland corn in Sibundoy Valley, Putumayo, Colombia; d) controlled pollination to obtain pure seeds. (Source: GIRFIN, 2010-2012; photograph records with previous authorization).

workshops on the species biology and for controlled pollination (Figure 1), but in each specific space each participant will give the management that he used to give to the crop.

Later, the experimental plot served as a comparison with the farmers plots, where, the traditional management benefits were easy to document (crop associations, plantings according to the lunar calendar, among others), in comparison to the conventional agricultural management (chemical input use, monocrop planting, breed germplasm).

Then, a socio-economical diagnose from farm to farm was developed and the sowing area was established. In the second general socialization the seeds of several races and varieties (Capio, Pollo, Pira Naranja, 'Timbrado', 'Porva' –from savanna with floury grains– and 'Arroz' –from savanna with crystalline grains –) were delivered, that are supposedly adapted to similar environmental conditions. Among the local corns that were inventoried, corn seeds exchanged were 'Amarillo', 'Morocho', 'Negro' de Perú and Capio ('Pintado').

A practical workshop for recovery of traditional uses of corn in feeding was done. In special, the main forms for corn consumption were shared (cob, wrapped, bread, corn bread, soup, chicha, among others) in the event "First Meeting Sharing the Harvest Nurturing Life – Creole Corns" in the local school, September 24, 2011, with the aim of assessing the use of native seeds in food and promote the exchange of traditional knowledge and seeds.

The community in Tenerife and El Moral do not have a properly constituted association for defense of the conservation of local or introduced and renatured genetic resources. However, among participants they highlighted some arrangement for keepers of seeds, as they keep on their farms an interesting biodiversity. These people can be identified as custodians or guardians of seeds in Tenerife-El Moral, ie. with conservationist calling (Figure 1).

The project achieved awareness of the importance of conservation of native seeds, diversity and traditional knowledge associated with the management of the maize crop. Germplasm was identified with the greatest potential for adaptation to agro-climatic conditions in the region. In addition, other species of cold weather such as quinoa (*Chenopodium quinua*), oca (*Oxalis tuberosa*) and yellow potato (*Solanum* spp.) were recovered (Figure 2).

Figure 2. Corn varieties adapted and multiplied by farmers of the village Tenerife, Cerrito, Valle del Cauca in 2011; a) Corn Pollo; b) Negro Peruano, Timbrado and Amarillo (izq.-der.) Promotion of other species of feeding importance in moderate cold weather; c) Fava bean (*Vicia faba*); d) *V. faba* associated with oca (*Oxalis tuberosa*); e) Quinoa (*Chenopodium quinoa*); f) potato seeds (*Solanum phureja*). (Sources: Nunes Pazdiora B.R.C., GIRFIN, 2010-2013; Vásquez D.L., 2011).

Conceived to meet the needs of small farmers and their families in social conditions and economically marginal in different countries (Cecarelli *et al.,* 2001), the PB was shown as an efficient tool for contributing to food sovereignty, conservation and use of plant genetic resources in Tenerife, as it integrates the biological component (knowledge and plant breeding) to the psychological and social dimensions of human relationships (behaviors and cultures). Germplasm conservation on farms (*in situ* conservation '*on farm*') and Participatory Breeding resulted in innovative practices developed under the PAR methodology (Participatory Action Research).

Finally, the extension of the proposal was requested by indigenous communities Kokonuko (Cauca) and Camentsá Biya (Putumayo), in July 2011, which led to develop the project in the framework of the First National Call for Solidarity Extension – Direction for National Extension of the Universidad Nacional de Colombia.

Towards the creation of a PB program

The area of influence of the Universidad Nacional de Colombia - Palmira reaches all the southwest of the country (Putumayo, Nariño, Cauca and Valle del Cauca), which receives indigenous and rural students of the highlands and lowlands, whose benefit from research and extension with regional agricultural vocations, complementing their practical-empirical– traditional knowledge.

The goal of a new phase of the project PB was to contribute to the conservation and recovery of Colombian races of maize, also strengthening the food sovereignty of indigenous communities of Kokonuko in Puracé (Cauca) and Camentsá in the Sibundoy Valley (Putumayo) and farmers of Santa Teresa-La Quisquina (Palmira) and Tenerife-El Moral (El Cerrito, Valle del Cauca), through the reappraisal of traditional knowledge associated with the use and crop management.

The socialization of the proposal with communities was followed by a diagnosis of participating families by semi-structured interviews, participant observation and indirect observation (literature review) on the study areas. Later, training workshops were conducted in techniques for controlled pollination and data acquisition for characterization according to the interests of communities.

In areas of indigenous reserves the recognition and documentation in the field of local varieties and traditional management was also performed, being two populations culturally entrenched to corn and preservers of an extensive knowledge of the species. For Santa Teresa-La Quisquina was conducted in parallel an inventory of plant diversity on farms.

From the upland germplasm multiplied under controlled pollination samples were stored in the working collection of GIRFIN and also, seeds for donation were arranged for the participating communities and new exchanges. 'Highlands', 'high' or 'cold lands' corns are those races (or varieties) that develop from 1800 masl therefore are adapted to cold weather and, usually present annual development.

Roberts *et al.* (1957), have recognized for Colombia 23 corn races, 12 are from highlands and 11 from lowlands (between 0 and 1800 masl). Highlands races are: Pira, Pollo, Imbricado, Pira Naranja, Maíz Dulce, Cabuya, Montaña, Amagaceño, Capio, Sabanero, Clavo and Harinoso Dentado. Additionally to the described races, GIRFIN preserves in its collection locally identified germplasm, from different regions of the country which is called native corn or native variety (Figure 4). It is the case of 'Rojo', 'Negro', 'Amarillo' (Putumayo), 'Granizo', 'Granizado' (Putumayo, Nariño), 'Diente de Caballo', 'Propio' (Cauca), among others.

The communities linked to the PB process (Figure 3) have the following general characteristics:

1 Rural community village of Santa Teresa, municipality of La Quisquina, Palmira, Valle del Cauca. Located in the foothills of the Central Cordillera between 1600 and 1900 masl, with a climate of tropical dry forest. The study area is located between 1,745 masl 3°35'50,50'' N and 76°10'12,94'' W and 1673 masl 3°35'46.6'' N and 76°10'7,50'' W. Average temperature of 20 °C. Annual average rainfall of 1010 mm. Composed of eight families from different regions of the country who migrated to this area for nearly five years ago, after being displaced from their own territories.

2 Rural community of the village of Tenerife, El Cerrito, Valle del Cauca. Located in the western mountain range with fog forest ecosystem is part of the buffer zone of the National Natural Park Páramo de las Hermosas, with temperature between 10 °C and 17 °C. Annual rainfall of 2000 mm. The area in which this proposal was developed is at an altitude between 2664 masl 3°43'47.8'' N and 76°4'35.6'' W and 2125 masl 3°41'09.6'' N and 76° 04'25.6'' W. Group composed of five families in the area.

Figure 3. Communities linked with the stage II: Participatory breeding in traditional communities of Colombia: a) Rural community village Santa Teresa, La Quisquina, Palmira, Valle del Cauca; b) Rural community of the village Tenerife, El Cerrito, Valle del Cauca; c) Indigenous community Kokonuko, reserve Puracé, Cauca; d) Indigenous community Camëntsa Biyá in Sibundoy, village San Felix, Sibundoy, Putumayo. (Sources: GIRFIN, 2011-2012; Vásquez D.L., 2012; photograph records with previous authorization).

3 Indigenous community Kokonuko, reservation of Purace, Cauca, at 2818 masl 2°22'39,27'' N and 76°27'10,09'' W. Temperature between 10° and 17 °C. Annual average rainfall 1811 mm. Group of seed keepers of the Cabildo Purace, villages Chapio, Ambiro, el Tablon and Carpinteria. Group composed of ten keepers (10 families). This indigenous group is located in the central-eastern department of Cauca, in the municipality of Purace, on the western slope of the Central Cordillera area. Its territory is located on the right bank of the upper basin of the Cauca River; in a range of altitude between 2400 and 4000 masl.

4 Indigenous community Camëntsa Biyá in Sibundoy, village San Felix, Sibundoy, Putumayo. Located in southwestern Colombia in the foothills of the Colombian Macizo in the Andes-Amazon region, northwest of the department of Putumayo at an altitude of 2200 masl, 1°10'50,75'' N, 76°53'05,47'' W. With an average temperature of 16 °C. Annual average rainfall of 2300 mm. Group composed of 10 elders of the community group.

Throughout the entire process of PB the use of native corn for feeding was promoted through practical workshops for recovery of traditional food uses of corn. On each day or encounter different traditional recipes from each region were prepared with corns from the same communities, involving the whole family.

Considering the lack of a generational change in rural areas of Colombia, participation is encouraged in children of families in integration activities and assessment of daily tasks that preserve landraces. Seed and knowledge exchanges among participating families and GIRFIN and dissemination techniques for *ex situ* conservation of seeds were other key activities in the process of awareness of the importance of traditional knowledge.

The adoption of the strategy PPB is due to that in the worked areas, which are introduced in the Andean region or Andean foothills, much of the production of basic grains, roots and tubers, it is carried out in marginal conditions by small and medium producers. These farmers make almost no use of improved varieties, believing that these do not respond well in marginal conditions and/or low input systems.

They also consider that improved varieties are not always adapted to the different uses given to a local variety, and that access to improved seeds is limited, it has a high cost (technology package). Therefore, in these traditional agro-ecosystems predominate informal seed systems, with swaps and exchanges.

Through the PPB local genetic diversity at risk and underutilized is promoted, valued and the ancestral knowledge, preferences of farmers, agro-ecological conditions and cultural practices are considered and finally, there is better control of genotype x environment interactions (Soares *et al.* 1998). It is also possible to do a gender analysis, which determines who participate in the various decisions and therefore the impact of such participation in research. This tool is understood as a particular type for stakeholder analysis, where the most important variable to discriminate the definition of the interest group is the genus (CGIAR 1999, Lilja *et al.* 2001).

As stated by Desclaux (2005) and Toledo Machado, Santilli and Magalhães (2008), the right of the farmers and/or holders of agricultural biodiversity as cultural heritage collectively built as local varieties, practices, accumulated ancestral knowledge and innovation, which together constitute the traditional knowledge must be guaranteed by legal instruments. Although indigenous and rural communities play an important conservationist role, they are excluded from political processes and decision making. Inadequate policies and laws related to the PGR can be major causes of genetic erosion, because they recommend sowing high-yielding varieties, a process that leads to the replacement of varieties, traditional practices and uses.

Germplasm selection

In the study described here for some communities PVS was adapted and for others PPB was used. Thus, for Tenerife the available Capio corn germplasm was valued. For Purace and Sibundoy communities the local varieties were valued such as Yucatan and Capio for the first one and 'Granizo', 'Timbrado', 'Rojo' and 'Negro' for the second one. In corn the genetic variability is high, reducing the stage for creation of it. As methodologic tools surveys were used with a semi-structured questionnaire, participant observation, theory-practical workshops, seed fairs and interchange of knowledge (thought meetings).

Stages developed

1 Local germplasm rescue: it was done with the aim of increasing the genetic variability of the corn varieties in the village San Felix, in the municipality Sibundoy, to select varieties better adapted to this agro-ecosystem. Besides local varieties, varieties or races from other locations in Colombia were tested to know their behavior under the weather conditions of the Sibundoy Valley.

2 Evaluation assays: in order to know the genetic variability of the rescued varieties, evaluating their adaptation to the local environment and the system of agro-ecological production, exchange experiences of farmers in different communities, workshops in the field for learning assisted pollination and genetic diversity of corn, two trials were conducted, the first in the San Felix, in Sibundoy, Putumayo and the second in La Quisquina, Palmira, Valle del Cauca.

The trial established in Sibundoy aimed to increase and characterize the morpho-agronomy of highland materials from the GIRFIN collection (70 entries). In this collection are included 14 entries from the municipalities Sibundoy, Santiago and San Francisco. In the case of the materials tested in La Quisquina, the aim was to increase and observe the behavior of some materials in these weather conditions, at 1800 masl, since some varieties considered lowland and upland were planted there.

From the morphoagronomic characteristics evaluated for selection were considered: (1) days to male flowering; (2) days to silking; (3) plant height (m); (4) ear height (m); (5) length of the cob; (7-9) average, basal and apical diameter of the ear; (10) number of rows from the cob; (11-13) color, type and texture of the grain; (14-15) length and number of branches of the spike, among others, similarly to Machado (1998), in a program of PPB with local maize varieties in Brazil.

3 Stratified massal selection in corn crops: methodology of plant breeding to select individuals by the phenotype, to improve agronomical characteristics of interest for the user. Involves five steps at different growth stages of the plant (Witcombe and Virk 2009). These are:

 3.1 Pre-sowing (seed selection) and sowing (plot location, sowing, isolation);

 3.2 Vegetative (identification of the plot, division of the plot, plant labelling, and labelling and selection of plants);

 3.3 Reproductive (removal of male flowers in undesirable plants, selection and labelling of plants);

 3.4 Physiological maturity (selection by coverage, harvesting) and

 3.5 Pre and post-harvesting (drying, storing).

In the present study the selection of the features of interest to farmers initially was the agroclimatological adaptation; all harvested material was planted in the next cycle to increase the adaptation and amount of seeds.

It is recognized by several participants that expectations towards the material selected initially for planting do not necessarily resulted in a good harvest, for example floury materials have a high rate of rotting in fresh cob, which prevented obtaining seed. Despite this, the Capio corn from Sibundoy, with floury texture, showed their adaptation to a stable production with grain quality considered by the farmer as "excellent”.

Promoting use of local breeds and varieties with their food and nutraceutical qualities or generates in every local community and the tendency to increase, improve and maintain the culture thereof. Participation in the practice of food processing by individual family members, using own resources, is a way of revaluing cultural traditions, recreating them according to the needs of new generations (De la Calle, 2010).

For this reason, intrinsic to plant research, is fundamental the integration to wider programs that allow continuity for the search of local varieties that are more stable, the improve the life quality of farmers in their regions and strengthen their culture and identity, which is very important to preserve the knowledge of the native communities.

Production of community seeds

The seed production work was always linked to Participatory Breeding works. Within the care measurements adopted by communities are the choice of area and isolation of the field to avoid contamination. Storage was done in plastic bottles or traditional systems being the most widely used the conservation of whole cobs to constant smoke from wood stove.

The genetic variability of corn is a strength for the Department of Putumayo and southwestern Colombia, as it represents a significant reservoir of different kinds of this grain that strengthen the sovereignty and food and nutrition security. Corn is tied to social, cultural and historical processes of traditional communities, being considered a cultural and natural heritage (Zambrano 2013, Caetano and Díaz 2014).

In addition to contributing with the conservation and sustainable management of the present genetic variability of corn, rescue and valuing traditional knowledge, empowerment of stakeholders with knowledge about how to acquire their own breeding varieties according to their own selection objectives was emphasized. According to Machado *et al.* (2006), empowerment (or self-independence efforts in community development) of rural communities can be made from the sustainable management of agricultural biodiversity in agro-ecological systems.

The loss of farming systems, races and local varieties cause that the values (ie. cultural and social) are also lost, as a result of erosion processes impoverishment of communities of subsistence farmers is verified, which puts at risk the security and food and nutrition sovereignty (Stella *et al.* 2006).

How much of the diversity of races have been really lost? How much of these have been transformed into modern varieties? How much diversity was collected by previous explorers? and how much it is preserved in genebanks? Are the races conserved enough for agriculture today and tomorrow? These are the questions to be resolved, according Hammer *et al.* (1996).

The development of this proposal for PB in southwestern Colombia allowed, for some communities, restitution of the diversity of native and indigenous corn and contributed to the use, management and conservation of local varieties of high value of direct and indirect use, or value of nonuse - option, heritage and existence. PB program has to be innovative regarding food security policies without proposing transitional and short-term measures but structural transformations, for social inclusion and income generation to needy families. In addition to food security, it should prioritize strengthening family agriculture (production for own consumption), since it can be produced in sufficient quantities, nutritional quality and facilitate access to feed the local population in a situation of social vulnerability and food insecurity (Gazzolla and Schneider, 2004).

However, as a turning point, Desclaux (2005) notes that the PPB should not be reduced as 'assisted selection by the farmer'. Agronomists are support for farmers in a better characterization of the environment. As cropping systems are associated to social criteria, their identification leads to recognize the real needs of farmers, and therefore generate more suitable varieties. The PPB should not be limited to studies for a limited time to document indigenous knowledge and preferences period farmers.

For efficiency, the participation should be a permanent characteristic of the plant breeding programs associated to crops in difficult agriculture and surroundings with the environment (Desclaux, 2005). According to Morris and Bellon (2004), “more participation is not necessarily better. Participation should be seen as a mean towards an aim”.

The main goals of the PB are to get a locally adapted germplasm, promote the genetic diversity and viable the empowering in the farmers. It is not a program lead by farmers, neither by a formal professional organization. The interaction is collegial and decentralized, with farmer participation during the first three steps of the breeding scheme. Participating farmers have the right to be considered partners of the breeding program and not just consumers or end users varieties (Desclaux, 2005).

New corn races for Colombia: PGR for value and use

During the 50’s a process for collection of native and indigenous corn was done in most of the Colombian territory, recording 1899 entries for the national germplasm bank. One of the products was the description and classification of all the germplasm in 23 races, grouped into three racial groups (Roberts *et al.*, 1957). The first group, Primitive races, is composed for only two races. The second group, with nine races, is known as Probably Introduced. Finally, the third group, de Colombian Hybrids comprises 12 races (Table 2).

Between the years 2007-2014 the GIRFIN, supported by the Colombian Agricultural Institute (ICA), made a sampling in those places described by Roberts *et al.* (1957) comparing the ecogeographical distribution in these two times (50’s and now). Thus, we increase to 34 the number of races of Colombian corn and described an important number of local varieties (Figures 4 and 5, Caetano *et al.*, 2014).

All this germplasm of corn is considered with the NUS criteria. Additionally, we postulate a fourth racial group and the existence of a genic complex formed by the variants of the race Chococeño. Therefore, the racial groups according to Caetano *et al.* are: Primitive, Introduced Colombian Hybrids and Strictu Sensu Colombian Hybrids Races (Table 2).

The morphological analysis (Maigual and Caetano, in preparation) and the molecular analysis done (RAM, SSR and cpDNA, genomic region AtpB-1-RbcL-1; Revelo *et al.*, 2015) identified three racial groups defined by Roberts *et al.* (1957), although with variation among the races that composed them and, a fourth group. The cpDNA study located the race Imbricado in the ‘Primitive’ racial group together with Pollo and Pira, all pop-up corn of small cobs and crystalline grains (Table 2).

With cpDNA, for the ‘(Probably) Introduced’ group were determined seven of the nine races described by Roberts *et al.* (1957). Both categories have in common the races Güirua, Clavo, Andaquí and Cariaco. To the seven races are associated Yucatán, Costeño and Cabuya. Additionally, with the recently introduced races are 13 races: Güirua, Clavo, Andaquí, Cariaco, Yucatán, Costeño, Cabuya, Morocho, Morochillo, Capia, Negro Peruano, Canguil and

Table 2. Distribution of racial groups of Colombian corns according to Roberts *et al.* (1957) and Caetano *et al.*

Colombian corn races		
Racial group	**Roberts *et al.* (1957)**	**Caetano *et al.***
Primitives	Pollo	Pollo
	Pira	Pira
		Imbricado
Probably introduced	Andaquí	Andaquí
		Cabuya
		Canguil
		Capia
	Cariaco	Cariaco
		Chulpi
	Clavo	Clavo
		Costeño
	Güirua	Güirua
	Harinoso Dentado	
	Imbricado	
	Maíz Dulce	
		Morochillo
		Morocho
		Negro Peruano
	Pira Naranja	
	Sabanero	
		Yucatán
Colombian Hybrids	Amagaceño	Amagaceño
		Azul Vallecaucano
		Caucano
	Cabuya	
	Cacao	
	Capio	
	Chococeño	Chococeño
	Común	Común
	Costeño	
		Harinoso Dentado
	Montaña	Montaña
	Negrito	Negrito
		Negro de Tabanok
		Pira Naranja
	Puya	Puya
	Puya Grande	Puya Grande
		Rojo Sureño
		Sabanero
		Timbrado
	Yucatán	
Strictu sensu Colombian Hybrids		**Cacao**
		Capio
		Maíz Dulce

Chulpi or 'Ecuadorian Sweetcorn' (Caetano *et al.*, 2014).

The third racial group 'Colombian Hybrids' is composed of 13 races according to the cpDNA analysis (Revelo *et al.* 2015), with similar races counting for nine in relation to Roberts *et al.* (1957). These two categories do not share the races Pira Naranja, Sabanero, Harinoso Dentado and Maíz Dulce, since Roberts *et al.* (1957) considered them as 'Probably Introduced'. The other races, common to both studies are Montaña, Negrito, Puya, Chococeño, Amagaceño, Común, Puya Grande, Capio and Cacao.

Figure 4. Colombian races and varieties of corn. (Source: Vásquez D.L., 2011).

Figure 5. A show of corn variability in Colombia. a) Amarillo Corn; b) Timbrado Corn; c) Negro Corn; d) Rojo Corn. (Source: Caetano Nuñes D., GIRFIN, 2013).

Based on the studies developed by us, the 'Colombian Hybrid' races are: Montaña, Negrito, Puya, Puya Grande, Amagaceño, Común, Pira Naranja, Sabanero, Harinoso Dentado, Chococeño complex (with its variants), plus the new races Caucano, Timbrado, Azul Vallecaucano, Negro de Tabanok and Rojo Sureño, for a total of 15 races (Caetano *et al.* 2014).

Based on the cpDNA, the Colombian Sweetcorn comprises, together wih Capio and Cacao, a group derived from the Colombian Hybrids. This two latest races are categorized both, by Roberts *et al.* (1957) and by the cpDNA, as Colombian Hybrids. Possibly the Colombian Sweetcorn and Capio are influenced by Ecuadorian germplasm of 'Sweet corn or Chulpi' and from 'Capia' respectively. Cacao is related by its floury endosperm and aleuronic color, also present in Capio. This group is named 'Strictu sensu Colombian Hybrids' (Caetano *et al.* 2014), because of their germplasm origin (Table 2).

Perspectives

The native and indigenous seeds are a heritage and invaluable genetic reservoir and are the basis for improving local seed systems and corn production. Therefore, the Community reserves of seeds should be considered a local technology alternative to support climate change mitigation in vulnerable communities and revive production, therefore there is a need to assess the feasibility of an additional study to address this issue from the social point of view.

The PB is a research validated tool that guides and defines the process of obtaining plant varieties, in accordance with the preferences and needs of farmers and their environment. Graphic documentation may be a greater impact, since besides the self-recognition of the participants in these outreach materials serve as input for the awareness of children for conservation. Moreover, recognition of local authorities is necessary and that regional and/or national government directives consider the establishment of permanent PB programs with communities.

In the present study, it is observed that farming aimed at family food production in traditional communities are now almost exclusively in the hands of the elderly. The need to involve young people in order to maintain traditional knowledge associated, conserve native seeds and bring them to their environment is evident. The above is a strategy to be used by the directives to generate empowerment of the possibilities offered in the environment, so that they are directly involved in its territory and reduce the migration to urban centers.

The methodology PPB provided along germplasm adapted and improved to local needs of communities, empowering participants' knowledge, strengthening communities in their cultural identity and the integration of isolated communities with different entities of the civil society (academic institutions, scientific, local authorities). Therefore, it should be inserted in the academic context of the relevant areas, in addition to continuing education programs.

According to Machado *et al.* (2008), institutions and government entities should encourage the development of participatory research, including MP, to strengthen family farming and public policies directed at the conservation and sustainable use of agricultural biodiversity, in order to adopt a sustainable model of production to respond effectively to security and food and nutrition sovereignty of local populations. We complement that universities, through their mission of solidary extension, should encourage the dissemination of this tool, training professionals from a more holistic view.

It is highly feasible an integrated conservation and utilization of PGRFA approach. Such approach should be anchored on increasing productivity through continued access and exchange of genetic resources; sustainability resulting from the combination use-preservation; the partition of the benefits resulting from the use of PGR and equity through the full participation of those responsible for the conservation of these resources.

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References

Anderson, E., and Cutler, H. C. (1942). Races of *Zea mays*: I. Their recognition and classification . *Annals of the Missouri Botanical Garden, 29*, 69-88. Retrieved from http://www.biodiversitylibrary.org/item/54271#page/77/mode/1up

Bohrer Monteiro, M. V., and Veasey, E. A. (2009). Raíces y tubérculos tropicales olvidados o subutilizados en Brasil. *Revista Colombiana de Ciencias Hortícolas, 3*(1), 110 - 125. Retrieved from http://revistas.uptc.edu.co/revistas/index.php/ciencias_horticolas/article/view/1203/1202

Broccoli , A., & Pardías , S. (2009). El rescate de semillas como aporte a la soberanía alimentaria. Descripción de una experiencia de conservación de maíz con agricultores familiares santafecinos., (pág. 19). Buenos Aires, Argentina.

Caetano, C. M., and Díaz, J. A. (2014). *Evaluación del grado de variación genética en las razas de* *maíz criollo e indígena de Colombia.* UNAL-GIRFIN; UNAL-ICA.

Caetano, C. M., and Vásquez D, L. N. (2011). Recuperación y conservación de maíces criollos e indígenas de altura de Colombia bajo la metodología de mejoramiento participativo. *VIII Simposio Internacional de Recursos Genéticos de América Latina y El Caribe.* Quito, Ecuador: SIRGEALC. Retrieved from http://es.scribd.com/doc/203782436/SIRGEALC-2011-Resumenes#scribd

Cecarelli , S., Grando, S., and Capettini , F. (2001). La participación de los agricultores en el mejoramiento de la cebada en el ICARDA. En L. Daniel, *Memorias de la Conferencia Internacional sobre futuras estrategias para implementar mejoramiento participativo en los cultivos de las zonas altas de la región Andina* (págs. 23 - 27). Quito, Ecuador.

Ceccarelli, S. (2012). *Plant breeding with farmers - a technical manual.* Aleppo, Syria: ICARDA. Retrieved from https://www.researchgate.net/publication/236962212_Plant_Breeding_with_Farmers__a_Technical_Manual_ICARDA_Aleppo_Syria

Ceccarelli, S., Grando, S., Singh, M., MIchael, A., Shikho, M., Al Issa, A., . . . Al Hasan, A. L. (2003). A methodological study of participatory barley breeding. II. Response to selection. *Euphytica,* 185 - 200. doi:10.1023/A:1025535609828

Ceccarelli, S., Guimarães, E. P., & Weltzien, E. (2009). *Plant breeding and farmer participation.* Rome, Italy: ICRISAT, ICARDA, FAO. Retrieved from ftp://ftp.fao.org/docrep/fao/012/i1070e/i1070e.pdf

Consultive Group on International Agricultural Research (CGIAR). (1999). *Crossing perspectives: farmers and scientists in participatory plant breeding.* Cali, Colombia. 49 p. Retrieved from http://ciat-library.ciat.cgiar.org/articulos_ciat/crossing.pdf

De la Calle, R. (2010). *Gastrobotánica: 100 temas al natural para cada estación de año.* Madrid, España: Temas de Hoy. 216 p.

Dudley, N., Buyck, C., Furuta, N., Pedrot, C., Renaud, F., and Sudmeier-Rieux, K. (2015). *Protected Areas as Tools for Disaster Risk Reduction. A handbook for practitioners.* Tokyo and Gland, Switzerland: MOEJ and IUCN. doi:10.2305/IUCN.CH.2015.02.en

Espinosa, P., Vaca, R., Abad, J., and Crissman , C. C. (1996). *Raíces y tubérculos andinos. Cultivos marginados en Ecuador. Situación actual y limitaciones para la producción.* Quito, Ecuador: Departamento de Ciencias Sociales del Centro Internacional de la Papa, Estación Quito. Ediciones Abya-Yala. 178 p.

Eyzaguirre, P. B., Padulosi, S., and Hodgkin , T. (1999). IPGRI's strategy for neglected and underutilized species and the human dimension of agrobiodiversity. In S. Padulosi, *Priority-setting for underutilized and neglected plant species of the mediterranean region* (págs. 1-19). Rome, Italy: International Plant Genetic Resources Institute (IPGRI).

FAO. (2011). *Agricultores mejoradores de su propia semilla. Fortalecimiento de la producción de maíz a través del mejoramiento participativo en comunidades de Sololá.* Sololá, Guatemala. 56 p. Retrieved from http://www.fao.org/3/a-ar653s.pdf

FAO. (2012). *Manual técnico de fitomejoramiento participativo de maíz en áreas de altiplano y de sequía en Guatemala.* Ciudad de Guatemala, Guatemala. 44 p. Retrieved from https://coin.fao.org/coin- static/cms/media/11/13305372975590/manual_fitomejoramiento_participativo_nov_ 2012_atinar_ii.pdf

FAO. (2014). *State of Food and Agriculture. Innovation in family farming. Economic and Social Development Department.* Rome, Italy. 175 p. Retrieved from http://www.fao.org/3/a-i4040e.pdf

Hammer, k., Knüpffer , H., Xhuveli , L., and Perrino, P. (1996). Estimating genetic erosion in landraces - two case studies. *Genetic resources and crop evolution, 43*(4), 329- 336. Retrieved from http://link.springer.com/article/10.1007/BF00132952

Hernández Bermejo, J. E., and León, J. (1992). *Cultivos marginados : otra perspectiva de 1492.* Roma, Italia: FAO. Produccion y proteccion vegetal, 339 p.

Hernández-Bermejo, J. E. (2013). Cultivos infrautilizados en España: pasado, presente y futuro. *Ambienta,* 38 - 55. Retrieved from http://www.revistaambienta.es/WebAmbienta/marm/Dinamicas/pdfs/versionpdf/Esteban13.pdf

La vía campesina. Movimiento campesino internacional. (2003). *¿Qué significa soberanía alimentaria?* Retrieved from http://www.redes.org.uy/wp-content/uploads/2008/09/que-significa-soberania-alimentaria.pdf

Machado, A. T. (1998). Resgate e caracterização de variedades locais de milho. In: Soares AC, Machado AT, Silva BM, von der Weid J.M. eds. Milho Crioulo: conservação e uso da biodiversidade. Rio de Janeiro: AS-PTA.

Manrique, K. (2000). *Nociones de manejo postcosecha. Documentos Centro Internacional de la Papa.* Lima, Perú: Ministerio de Agricultura del Perú.

Morris, M., and Bellon, M. (2004). Participatory plant breeding research: Opportunities and challenges for the international crop improvement system. *Euphytica, 136*(1), 21 - 35. doi:10.1023/B:EUPH.0000019509.37769.b1

Naciones Unidas. (1992). *Convenio sobre la diversidad biológica.* Río de Janeiro, Brazil.18p. Retrieved from https://www.cbd.int/doc/legal/cbd-es.pdf

Padulosi, S., and Hoeschle-Zeledon, I. (2004). ¿A qué denominamos especies subutilizadas? *Leisa. Revista de Agroecología, 20*(1), 6- 8. Retrieved from http://www.leisa-al.org/web/images/stories/revistapdf/vol20n1.pdf

Pardo de Santayana, M., Morales, R., Aceituno, L., Molina, M., and Tardío, J. (2012). Etnobiología y biodiversidad: el inventario español de los conocimientos tradicionales. *Ambienta, 99*, 6 -25. Retrieved from http://www.revistaambienta.es/WebAmbienta/marm/Dinamicas/pdfs/versionpdf/Tradicional.pdf

Pastor, S., Fuentealba, B., and Ruiz, M. (2007). *Cultivos subutilizados en el Perú. Análisis de las Políticas Públicas Relativas a su Conservación y Uso Sostenible.* Fiumicino, Italia: The Global Facilitation Unit for Underutilised Species (GFU); Asociación Civil Pro Uso DIVERSITAS - PROUD; Sociedad Peruana de Derecho Ambiental – SPDA . Retrieved from http://www.spda.org.pe/?wpfb_dl=62

Programa de Maíz. (1999). *Desarrollo, mantenimiento y multiplicación de semilla de variedades de polinización libre.* Mexico D.F.: CIMMYT. 16 p. Retrieved from http://repository.cimmyt.org/xmlui/bitstream/handle/10883/762/68195.pdf

Revelo Portilla, E. A., Cardozo Conde, C. I., and Caetano, C. M. (2015). Estudio molecular preliminar de accesiones de maíz (*Zea mays* L.) criollo e indígena colombiano utilizando una región de ADN cloroplástico. *Acta Agronómica, 64*(1), 72 - 82. doi:10.15446/acag.v64n1.40724

Roberts, L., Grant, U. J., Ramírez, R. E., Hatheway, W. H., Smith, D. L., and Mangelsdorf , P. C. (1957). *Razas de maíz en Colombia. D.I.A. Boletín Técnico No.2.* Bogotá, Colombia: Ministerio de Agricultura. Editorial Máxima. 159 p.

Silva Ramos, M. Á. (2002). *El rol de los cultivos marginales en la seguridad alimentaria.* La Paz, Bolivia: Instituto Interamericano de Cooperación para la Agricultura.Oficina IICA Bolivia.

Smith, M. E., Castillo, F. G., and Gómez, F. (2001). Participatory plant breeding with maize in Mexico and Honduras. *Euphytica, 122*(3), 551 - 563. Retrieved from http://link.springer.com/article/10.1023/A%3A1017510529440

Soares, A. C., Machado, A. T., Silva, B. M., & Von Der Weid, J. M. (1998). *Milho Crioulo: Conservação e uso da biodiversidade.* Rio de Janeiro, Brazil: AS-PTA.185 p.

Thies, E. (2000). *Promising and underutilized species crops and breed.* Eschborn, Germany: GTZ. 23 p. Obtenido de https://cgspace.cgiar.org/bitstream/handle/10568/3682/thies.pdf?sequence=1

Toledo- Machado, A., Arcanjo- Nunez, J., Torres, d. C., Lourenço-Nass, L., and Rocha Bettero, F. C.-d. (2006). Mejoramiento participativo en maíz: su contribución en el empoderamiento comunitario en el municipio de Muqui,Brasil. *Agronomía mesoaméricana, 17*(3), 393 - 405. Retrieved from http://www.mag.go.cr/rev_meso/v17n03_393.pdf

Toledo Machado, A., Santilli, J., and Magalhães, R. (2008). *A agrobiodiversidade com enfoque agroecológico : implicações conceituais.* Brasília, DF: Embrapa Informação Tecnológica. (Texto para Discussão / Embrapa. Secretaria de Gestão. Retrieved from https://www.embrapa.br/documents/1035106/1047819/texto34.pdf/5448d115-890d-4314-b7ff-ba46b9687671

Toledo Machado, A., Torres de Toledo, C., and Lourenço Nass, L. (2011). Manejo da diversidade genética e melhoramento participativo de milho em sistemas agroecológicos. *Revista Brasileira de Agroecologia, 6*(1), 127 - 136. Retrieved from http://www.abaagroecologia.org.br/revistas/index.php/rbagroecologia/issue/view/52

UPOV. (1991). *Convenio Internacional para la Protección de las Obtenciones Vegetales.* Ginebra, Switzerland. Retrieved from http://www.upov.int/portal/index.html.es

Vernooy, R. (2003). *Semillas generosas. Mejoramiento participativo de plantas.* Ottawa, canadá: IDRC-CRDI . Retrieved from https://idl-bnc.idrc.ca/dspace/bitstream/10625/52959/1/IDL-52959.pdf

Vernooy, R., and Song, Y. (2004). New approaches to supporting the agricultural biodiversity important for sustainable rural livelihoods. *International Journal of Agricultural Sustainability, 2*(1), 55 - 66. Retrieved from http://betuco.be/voorlichting/New%20Approaches%20to%20Supporting%20the%20Agricultural%20Biodiversity.pdf

Walker, T. S. (2007). *Participatory Varietal Selection, Participatory Plant Breeding, and Varietal Change.* Washington, DC. USA: Background paper for the World Development Report. Retrieved from http://hdl.handle.net/10986/9182

Witcombe, J. R., and Virk, D. S. (2009). Methodologies for generating variability. Part 2: Selection of parents and crossing strategies. In S. Ceccarelli, E. P. Guimaraes, & E. Weltzien. Rome, Italy: Plant Breeding and Farmer Participation. FAO.

WCMC. World Conservation Monitoring Centre. (1992). *Global Biodiversity: Status of the Earth's Living Resources.* London, UK: Brian Groombridge.

Zambrano Zambrano, E. E. (2013). *Valoración del mejoramiento genético participativo in situ en poblaciones de maíz (Zea mays L.) criollo en el sureste del Estado de México.* Montecillo, Texcoco, Mexico: Master thesis on Science, Genetics. Postgraduate School. Retrieved from http://hdl.handle.net/10521/1863.