Seeds that give *revisited*

Participatory plant breeding and rural revitalization

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PREFACE

Small seeds and a big story: Enlightenment from participatory plant breeding

The book *Seeds that gives* revisited*: Participatory plant breeding and rural revitalization* is the sequel to *Seeds that give: Participatory plant breeding* book published by the International Development Research Centre of Canada (IDRC) in 2003. IDRC has long been committed to funding relevant institutions to carry out participatory plant breeding (PPB) and crop improvement practices around the world. *Seeds that give: Participatory plant breeding* was the first book that systematically summarized the achievements, problems, policy bottlenecks and suggestions to resolve them regarding local participatory plant breeding and crop improvement. Time is flying and almost 20 years have passed since 2003. What new developments are there in participatory plant breeding? Has the practice expanded? Have there been innovation in the field? To find an answer to these questions, Dr. Ronnie Vernooy and Dr. Yiching Song contacted the original *Seeds that give* authors of different country cases and asked them to update their cases with what they have done in the past 20 years. At the same time, some colleagues who have participated in Chinese PPB activities in the past 20 years were invited to join the compilation of the new book. This new book aims to systematically review the work done since 2003 and look to the future of PPB in China and the world. Thus, the book *Seeds that give* revisited:

Participatory plant breeding and rural revitalization can be regarded as "new wine in an old bottle"!

This book consists of an introduction, 11 case studies, and a conclusion. The introduction and conclusion were written by Dr. Ronnie Vernooy and Dr. Yiching Song, who have been collaborators for more than two decades. They introduce the origin of this book and the major changes, new trends and features of participatory plant breeding in the past 20 years. Chapters 1 to 7 are global case studies, from Africa, South America, and South and Southeast Asian countries. Cases collected from China are presented in Chapters 8 to 11, reflecting and building on Dr. Yiching Song and her team's exploration on community seed bank establishment in Southwest China and farmer participatory seed selection and plant breeding. The book is not thick, but very rich in substance. I believe it will be very helpful to all those who are engaged in agricultural biodiversity conservation, participatory crop breeding and community development in China and beyond.

Seeds are the foundation of agriculture. The quality of seeds is a big deal. Chinese people of my age may remember that there is a key message in the "Eight-character Constitution of Agriculture", which is that the agricultural production process must pay special attention to the eight key elements—soil, fertilizer, water, seed, density, protection, management, and skill. The "seed" is referring to crop seeds and other propagation materials, such as suckers, tubers, and seedlings. In the media, there have been some reports about farmers being cheated when purchasing seeds. Farmers purchased fake and inferior seeds, which caused crop yields to be reduced or failed altogether. As the Chinese saying goes, "A good baby is from a healthy mother, and quality seeds means more food". Good quality seed is the most important input for farmers; and ensuring the supply of high-quality seeds has become the most important matter for governments around the world too. The Seed Law of the People's Republic of China, which came into effect on March 1, 2022, is the key statute of enforcement and supervision, protecting the interests of farmers, and punishing illegal acts that violate the interests of farmers.

Nowadays, even in remote villages and towns in China, there are seed sales outlets. They sell seeds of all kinds of crops, fruits and vegetables that come from all over the world, with the main characters of high yield and strong resistance. However, there are still farmers complaining that they cannot obtain appropriate seeds. As everyone knows, the farmers' criteria for choosing seeds are far more complicated than "high yield and strong resistance". They often choose seeds based on a comprehensive judgment of many factors, such as farming time, land, geography, labor force, inputs, irrigation conditions, food quality, etc. I remember that in the late 1990s, I went to a Yi community in Yunnan to do fieldwork. I found that there were seven landraces of potato and four landraces of buckwheat in the local area. One potato variety had low yield and very ordinary taste. Farmers kept this variety because it has the shortest growth period and is known as "famine-saving potatoes". There is also a buckwheat variety that has the lowest yield, yet the fruit has relatively long sharp hails and is the least stolen by birds. Farmers called it "buckwheat that birds can't eat". Farmers' selection criteria are not just limited to agronomic traits, such as high-yield, high-quality, or high-resistance. In the past few decades, as more and more rural laborers have moved to cities to work, it is an indisputable fact that nowdays women and the elderly are the major labour forces engaged in farming. In many remote mountainous areas, agricultural facilities are outdated, capital investment is limited, and various extreme weather events occur more frequently. Under the above-mentioned conditions, it is not a simple matter for farmers to select suitable crop seeds, but a major challenge. Therefore, farmer participation in crop selection and breeding is a way to solve urgent problems and meet their specific needs and interests. The cases of farmers selecting maize varieties in Shanggula Village in Guangxi and Stone Village in Yunnan have proved that participatory plant breeding is not only feasible but also popular among smallholder farmers.

However, currently it is difficult to guarantee farmers' benefits from their efforts on seed conservation and participatory plant breeding. According to Article 37 of the Seed Law of the People's Republic of China, if individual farmers have a surplus of conventional seeds for self-propagation and self-use, they can be sold or exchanged in the local bazaar. There is no need to apply for a license for seed production and marketing. The judicial interpretation of this clause is: "individual farmers" should be understood to be limited to their own contracted lands, but the clause does not refer to the large households, family farms and seed producers who transfer arable land. The so-called "surplus" means that the amount of surplus should not exceed the seeds for self-use. The requirement of " sold or exchanged in the local bazaar" should not exceed the scope of the village or township. In short, farmers selling surplus seeds must not damage or infringe the legitimate rights and interests of the seed market (companies), otherwise they will be dealt with according to law. It can be seen from the cases of Guangxi and Yunnan that the resulting seeds of selection and breeding of new crop varieties through farmer cooperatives and other forms can only be used by farmers and exchanged within farmer networks. There are many policy barriers to free market circulation. It is even more difficult for farmers to make a profit by selling farmer improved new varieties.

Through the case studies from China and abroad, it is found that the story of seeds (that give) goes far beyond the seeds themselves. For example, Dr. Yiching Song and her team have established more than 25 community seed banks in 10 provinces in the past 20 years to assist farmers in the collection, evaluation, registration, and conservation of native crop germplasm resources. This is a very remarkable achievement! The community seed bank is undoubtedly an important supplement to the national and regional official gene banks, and even the national seed bank has become the backup bank of the community seed banks.

I remember someone said that in the long history of human civilization, the earliest crop breeders are farmers rather than well-trained breeding scientists. The early domestication of many crops and the selection and breeding of excellent varieties were done by native farmers. Cases from China and abroad have proved that the cooperation between farmers with rich traditional knowledge and modern breeders proficient in genetics and phenotyping is very important and successful. They learn from each other and complement each other in their breeding knowledges and materials. For example, a woman farmer leader, Lu Rongyan led 10 women farmers in Shanggula, Guangxi, and formed a participatory maize breeding team in 2006. They have successively selected 10 maize varieties adapted to the mountainous environment with the help of the breeders from the Maize Research Institute of the Guangxi Academy of Agricultural Sciences and the Chinese Academy of Agricultural Sciences. In 2013, these women farmers in Shanggula shared their Guinuo 2006, a PPB variety, and its parent lines with the farmers in Stone Village in Yunnan. Guinuo 2006 has adapted and produced seed in Stone Village and has been distributed in neighboring villages in the region since then. Many cases also show that participatory selection and breeding not only bring high-quality crop varieties to local communities, increases their income, but also have other social impact and policy influences. The PPB practices in southwestern China have promoted the establishment of community—based multifunctional cooperatives, and women have been empowered, becoming agricultural experts, breeders, and seed business operators in their communities and cooperatives. A national platform organization – Farmers Seed Network, was established aiming to support community-based seed conservation and improvement through PPB and other mechanisms. The PPB activity in Shanggula gave birth to the display and exchange of local community and farmer seeds, the establishment of farmer cultural theater, the operation of community development funds, ecological planting and breeding cooperatives, and the improvement of women's abilities and self-confidence. Therefore, we are convinced that the main role and pioneering spirit of these farmers from the grassroot communities will play an increasingly important role in the great practice of rural revitalization in the future! Small seeds will bring profitable and sustainable synergies!

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Introduction

A "new" approach revisited: Participatory crop improvement and resilient seed systems

Ronnie Vernooy, Yiching Song

1 Farmer seed practices under stress

Do you know how smallholder farmers in developing countries obtain their seed? Perhaps, you think that they are mostly buying certified seeds from what is known as the "formal seed system", the system regulated by government rules and regulations. This is not the case though. Estimates suggest that 60%-90% of the seeds on which smallholder farmers in developing countries depend, is saved on-farm or obtained through local distribution channels, such as exchanges between farmers, community sharing systems, and local markets. Women farmers play key roles in farmer seed systems (including seed saving practices), although they are often overlooked by researchers and development personnel, policies, and programmes.

Unfortunately, almost everywhere, local seed practices are under stress. Urbanization, agricultural intensification and commoditization and privatization of natural resources are contributing to a decline in farmer-based, individual, and collective local seed management. Farmers are substituting local varieties with hybrids that can be easily purchased from agro-dealer shops or at local markets (although prices could be high).

Traditional seed exchange relationships have become weaker in many areas. In some countries, local seed saving, and distribution practices are becoming criminalized due to new revised seed policies or laws. Recent studies reveal that the legal operating space for farmers and communities to save, produce, exchange, and sell seed is being reduced and related farmer practices of sharing and distributing seed, criminalized (Herper, et al., 2017; Vernooy, 2017). Only in a few countries, such as Bolivia, Ethiopia, Nepal, and Uganda, are farmer-centered seed production and exchange practices obtaining increased recognition and support.

One major challenge farmers face in producing and obtaining seed is poor quality. Quality control of farmer-saved seed is largely based on trust embedded in social relationships, while quality control of seed produced by the other social actors is often subject to external written rules and regulations. How much actual quality control takes place is, however, a moot point. In many rural communities, poor storage practices and facilities affect seed quality negatively. Farmers face another problem: almost everywhere, sale of “fake” seeds is taking place by local traders, for instance, grain sold as seed or non-certified, low-quality seed sold as “improved” seed. Fake seeds have direct negative impacts on crop productivity and farmer income.

2 The challenge of accessing new crop diversity

Another major challenge is that in many countries it is very difficult to obtain new varieties of interest to farmers due to poorly developed or badly supported variety delivery systems. Farmers often do not know about which other crops or crop varieties they could grow on their farm and have no or poor access to new and improved crop diversity. Many farmers and their communities, in particular those in remote and/or marginalized areas, cultivating under rain-fed conditions, hardly benefit from the efforts made by plant breeders. Although conventional crop research has contributed to substantial yield increases, mainly in high-input areas, smallholders with limited access to inputs or credit, often relying on rain-fed farming at marginal sites and under variable climatic conditions, have enjoyed little benefit. In Africa and Latin America in particular, even farmers who have had access to improved varieties have often stopped growing them after a few years because the seeds failed to meet their needs in their production systems.

Farmers often have different priorities from scientists or breeders. To identify varieties that are of maximum use to farmers – for household consumption, sales, cultural use, animal feed, or a combination of these – locally specific characteristics need to be taken into account, beyond purely agronomic attributes like productivity. These characteristics might include cooking quality, marketability, or the quality of stubble for animal feed – features that are of high local and cultural specificity. In addition, experience has shown that not all farmers have the same needs, interests, and preferences. Women farmers often have different ideas than men about what traits or characteristics are important. Women farmers are often interested in different portfolios of crops and crop varieties, for example, requiring less regular labour inputs, easier to transport, with a longer shelflife and with a high nutrient density. Younger farmers may have different views from older ones, as a result, for example, of their higher education levels or more exposure to influences from outside the community.

The obstacles described above seriously hinders farmers' efforts to adapt to climate change. Climate change has begun to put additional pressure on farmers' seed and food production systems and on the multiple functions that they fulfil. Future impacts of climate change are expected to become more pronounced in many parts of the world, forcing farmers to change their practices and causing them to search for information about crops and varieties better adapted to new weather dynamics. Access to quality seeds will become even more important.

3 Towards resilient seed systems

It is important that farmers continue to maintain crop diversity individually and collectively. Under supportive policy and socioeconomic conditions, a diversity of seed production and distribution practices makes up a resilient seed system. A resilient seed system contributes to greater food availability throughout the year, the production of more nutritious and healthy crops, income generation and a sustainable resource base. These outcomes together will contribute to healthier food systems. Resilient seed systems should be gender-responsive and support women's agency, and their ability to make decisions about how to successfully manage their farms and gain access to the resources they need including seeds.

Resilient seed systems (Subedi, Vernooy, 2019):

- Rely on the ability of seed system actors to absorb disturbances, re-group or re-organize, and adapt to stresses and changes caused by a perturbation;
- Result from multiple seed and knowledge interactions and continuous learning among seed system actors and related institutions;
- Are demand driven and responsive to differentiated needs and interests supporting all users and farming systems;
- Recognize, respect and support the key roles played by women farmers as seed custodians, managers, networkers and entrepreneurs.

They reduce vulnerability by:

- Ensuring access to seeds in terms of preference, affordable price and avalailbility when needed;
- Ensuring availability in terms of production and distribution;
- Guaranteeing seed quality in terms of adaptability, safety and longevity;
- Guaranteeing seed choice and diversity;
- Producing crops which underpin a healthy diet;
- Recognizing and respecting seed as social and spiritual capital.

Core elements of a comprehensive resilience strategy are (Subedi, Vernooy, 2019):

- Smarter ways of addressing climate change;
- Identifying best-bet portfolios;
- Novel and efficient distribution;
- Innovative business models and value chains;
- Empowerment of farmers;
- Local implementation of international and national policy.

Ultimately, farmers should benefit from a secure and diversified supply of quality seeds suitable for local conditions and which contribute to healthier diets, more sustainable livelihoods, and stronger capacity to adapt to climate change. Useful and timely information should accompany seeds, for example, regarding the nutritional value of the variety, capacity to withstand drought and recommended management practices.

4 Participatory variety selection

In successful participatory variety selection (PVS), organized farmer groups (usually made up of a mix of women and men farmers, but sometimes women only or young farmers only) grow a set of promising varieties or fixed lines in experimental quantities on one or more plots that have been volunteered by one or more farmers in the group. In other words, experimentation takes place in target environments that represent real-life agro-ecological conditions. Together with a facilitator, the farmers evaluate the varieties according to the attributes that matter most to them and maintain the best materials for replication in the next season. Farmer groups may intuitively select a variety that complies with local needs and preferences and discard varieties recommended by breeding stations or governments.

PVS includes five steps:

- Needs assessment: identification of a portfolio of farmer-preferred traits;
- Searching for resources that have the desired traits;
- Small-scale field experimentation: Comparison of newly introduced varieties or fixed lines with a local one;
- Wider dissemination of successful varieties or fixed lines;
- Monitoring of further spread and possibly adaptation.

PVS has been in use since the 1990s and has become a mainstream practice in many plant breeding and rural development programs and projects. The extent of farmer participation in selection activities may range from merely visually selecting among a few pre-released varieties at a field day to selecting and ranking during the growing cycle; participating in selection from a larger, initial pool of materials; cultivating a large number of varieties and selecting on-farm; or engaging in seed production and marketing of promising materials.

At the lesser end of participation, preselected, improved varieties at physiological maturity are presented to farmers by researchers at a breeding station. Usually during a field day, the invited farmers select a variety they would prefer to grow and are then offered small amounts of seeds to test on-farm. In more participatory-oriented approaches, farmers make key decisions throughout the whole process, although usually in close consultation with researchers. This allows the farmers to consider qualities that do not show up at the field day: resistance to wind, drought, or flooding; weed incidence; labour requirements, etc.

Varieties that are released after PVS often have a higher adoption rate and higher field sustainability, because they respond to the specific requirements of marginal environments, whereas conventional released varieties often do not. PVS is, therefore, especially suitable for typical staple crops of smallholders or vulnerable dryland farmers, such as legumes, maize, wheat, barley, rice, sorghum, or tef.

5 Innovating PVS: Seeds for needs

"Seeds for Needs" is an innovative participatory crop improvement approach, developed by a team of Bioversity International (now the Alliance of Bioversity International and CIAT) researchers, which introduces and tests demand-led crop diversity making use of crowdsourcing. Crowdsourcing is an approach used by scientists and companies worldwide to collect data from large numbers of volunteers instead of just a few researchers. Well-established crowdsourcing projects include ones in which thousands of hobby birdwatchers contribute to regular national surveys on bird migration or citizens classify the quality of their nearby water bodies. "Crowds" can fulfill many tasks that highly specialized researchers cannot, because of their geographic spread, the accumulated time they can dedicate to a task, and the sheer number of contributors.

Crowdsourcing field trials of new crop varieties implies that many farmers carry out small trials instead of a research station conducting one large trial. Farmers test varieties using the so-called “tricot” (triadic comparisons of technologies) method (Box 1). Farmers receive packages of seeds with three different varieties and rank them as best, middle and worst for different traits. Each package contains a different combination of varieties. Researchers merge and analyze data from all trials. This offers the possibility of testing promising material in different climatic regions, on different soil types, under different management regimes, and, most important, under the real-production conditions of many participating farmers (Bessette, 2018). However, crowdsourcing requires special preparation to motivate enough contributors and ensure data quality. The tricot approach has demonstrated how different varieties are differentially adapted to different growing conditions across large areas (Van Etten, et al., 2018). Farmers are now adopting these better adapted varieties. The approach has been adopted by several large-scale initiatives in South Asia, East Africa (e.g., the Integrated Seed Sector Development programme in Ethiopia supported by the Dutch government) and Central America.

BOX 1 **Triadic comparisons of technologies: Tricot**

By Jacob van Etten

It is now possible to obtain farmers’ feedback on crop breeding products and their on-farm performance using a crowdsourced citizen science approach: triadic comparisons of technologies or tricot. This approach combines a simple farmer-participatory evaluation format with digital media (Internet and mobile phone) (van Etten, et al., 2016). The tricot approach can mobilize farmers to actively engage in crop experimentation using their own time and resources (Beza, et al., 2017). The approach has several benefits: i) it reduces the cost per data point of the variety testing process; ii) it exposes large numbers of farmers to new materials, creating demand; and iii) it avoids the potential biases, lack of external validity, or accountability issues of on-farm evaluation closely managed by researchers (rather than farmers).

The tricot approach is motivating for farmers (Beza, et al., 2017). The accuracy of the data they produce has been shown to support statistically robust analyses (Steinke, et al., 2017). Tricot trials cover the variability of farming systems in the target environment, and feed into sophisticated analyses of genotype-by-environment interactions as they realistically occur in farmers' fields (van Etten, et al., 2019). In addition, they serve to generate variety recommendations that increase performance and allow risk management through varietal portfolios (Fadda, van Etten, 2018; van Etten, 2019). As the approach is individual rather than group-based, it allows for close investigation of individual differences of trait preferences driven by gender and other social factors.

The approach is also being used with processors and consumers. Ongoing collaborative work is readying the protocols to apply the tricot approach to clonally propagated crops. Also, it is being explored how tricot can be integrated into genomic selection. In 2019, Bioversity International launched a stable version of ClimMob, the digital platform that provides researchers support for the entire trial process, from experimental design, through data collection to (automatic) reporting. The approach is now ready for wide deployment by national research organizations enabling them to organize on-farm trials in a more effective and efficient way, and extracting more insights from it for breeding, variety release and dissemination.

Further innovations include:

- Combination with sensor networks and improved environmental data (e.g., Davids, et al., 2019);
- Integration of tricot into modern plant breeding, including through genomic selection;
- Streamlined data management (data standardization, ontology);
- More refined gender and socio-economic analysis;
- Collaboration with companies that sell seed packages – innovation around designing arrangements and supporting local business development;
- Experimentation with different ways of agenda setting – with farmers and farmer organizations, local seed businesses, etc.

6 Participatory plant breeding

Participatory crop improvement emerged as a response to the shortcomings of conventional plant breeding approaches. It is based on the principle that farmers participate as equal partners alongside agricultural scientists, fairly sharing their knowledge, expertise, and seeds. The results of such collaboration include, not only more effective crop improvement practices, but also strengthening of farmers' capacity to experiment, learn, and adapt. Participatory crop improvement, including PVS and PPB, emerged in the early 1990s piloted by several researchers in countries as diverse as China, Cuba, Colombia, Honduras, India, Nepal, Nicaragua, Mali, Niger, the Philippines, and Syria. It was called a novel approach to agricultural research and development needed to conserve agricultural diversity, improve crops, and produce food of quality for all (Vernooy, 2003).

Like PVS, PPB was born out of the insight that small farmers in unfavourable conditions benefit very little from formal crop research. In PPB, farmers and plant breeders jointly select cultivars by segregating materials in target environments. It is more difficult than PVS because some degree of knowledge of heritability and genetic gain is required.

Officially or formally released varieties are often designed for high-input farming practices used in large agro-ecological areas. In contrast, smallholder farmers practice agriculture in micro-regions where particular environmental conditions predominate. In other words, conventional breeding fails to take smallholders' constraints, needs, and preferences into account. To produce varieties that match the specific requirements of small-scale farmers, PPB involves producers at earlier stages of the plant breeding process than PVS. In PPB, farmers set breeding goals and select parental material; they are trained in the identification and choice of parent lines, making crosses, and managing trials of many varieties. Professional researchers and breeders act as facilitators in this process, guided by the paradigm that the more decision-making power the farmers have in the breeding program, the better adapted and more useful the outcome will be.

PPB relies on lasting relations between researchers and farmers and seeks out “custodian farmers” or local farmer experts who can be further trained in breeding techniques, conserve varietal diversity on their farms, and act as links between the scientific world and their fellow farmers. Experience in various parts of the world has shown that farmers are able to distinguish between very large numbers of crop lines and make choices that are at least as effective as those made by researchers. Moreover, the learning process and access to new varieties can stimulate and encourage farmers to perform further on-farm experimentation and keep adapting varieties to the environmental conditions via selection. A local or regional PPB program can include many farmers at all stages, provided that some technical and financial support is available over several years of experimentation.

There is no general roadmap for PPB. PPB is feasible in very different environments and conditions and can contribute to shorter- and longer-term outcomes including societal and ecological resilience (Lammerts van Bueren, et al., 2018). Creating a system adapted to local conditions and capacities requires motivation and creativity, but can lead to rewarding outcomes. Successful experiences in various countries have taken very different paths (Ceccarelli, et al., 2000; Halewood, et al., 2007; Vernooy, 2003; Witcombe, et al., 1996), but they all share the acknowledgment that:

- The top-down approach to plant breeding has brought limited benefit to small-scale farmers;
- Farmers are able to participate and take responsibilities at all stages of a plant breeding programme;
- Participatory, decentralized approaches are likely to lead to more effective outcomes: varieties that are adapted to the local environmental and economic conditions, are higher yielding, and are socially acceptable.

7 Seeds that give revisited

One of the organizations supporting the development of participatory crop improvement was the International Development Research Centre of Canada (IDRC). In 2003, after 10 years of support for projects to promote agricultural biodiversity and participatory plant breeding, IDRC published *Seeds that give: Participatory plant breeding* (Vernooy, 2003; first published in English, French and Spanish; and later translated to Arabic, Chinese, Nepali, Vietnamese). Based on a comprehensive review of the achievements and challenges of 10 years of participatory crop improvement around the world(1990–2000), it examined several key issues in detail: from research questions, design of on-farm research to farmers' and plant breeders' rights. It argued for the development of new, supportive policies and legislation and made several recommendations for governments and organizations involved in agricultural research and development. Six project stories illustrated how farmers and plant breeders were working together in remote regions from the Andes to the Himalayas and beyond. Finally, the author took a speculative look 10 years into the future of participatory plant breeding (see Box 2 for a summary of these speculations).

BOX 2 **A look into the future**

By Vernooy, 2003

Increased relevance: Agricultural policymakers and policy institutions are actively involved in efforts to conserve biodiversity. As a result, the critical importance of conserving agricultural biodiversity is widely accepted, and PPB has been embraced as a new and rational way of improving crops and increasing plant genetic diversity. Equally important, PPB has also been accepted as a new way of doing research.

New partnerships: In this new environment where PPB is accepted as the norm, it is only natural that local community-based agrobiodiversity conservation and improvement activities are connected to changes at the international and national policy levels. Thus, there is opportunity for community input to global arrangements such as the Convention on Biological Diversity (CBD), the FAO's Resources for Food and Agriculture (ITPGRFA), and the World Trade Organization's agreement on the trade-related aspects of Intellectual Property Rights (IPRs).

Quality interaction and cooperation: Researchers, extension agents, and farmers – as well as other stakeholders, such as processors and traders – work together side by side. They all are making better use of researchers' access to knowledge, from breeding principles and methodologies to seeds and technologies to social science insights. As a result of changing attitudes, ethical issues and intellectual property rights are a standard and important part of the research and policy agenda and discussed from the very beginning of new initiatives. Many issues that were previously ignored are now raised and dealt with. These include prior informed consent, explicit ex ante defined access – and benefit-sharing agreements, recognition of farmers' contributions to the creative process, and recognition of the farmer's rights to distribute, exchange, or sell seeds.

Good practice mainstreamed: Because of the increased acceptance of and interest in PPB, documentation and analyses of longer-term diversity trends are more readily available. Sound social analysis is now common practice in many countries. Researchers and policymakers pay systematic attention to resource tenure and its links with diversity and the livelihoods of rural people, especially the rural poor. PPB has an impact on policy making emphasizing the need for government policies to remain flexible and informed by on-the-ground realities. Key is for adaptive, participatory research and natural resource management approaches to allow the custodians of biodiversity to deal more effectively with heterogeneous and changing agroecosystems.

Quality participation: CIALs (Local Agricultural Research Committees) are now more than a movement, in many countries they are part of, and supported by, the Ministry of Agriculture. CIAL representatives are respected and influential members of provincial and national policy advisory bodies. In the field, monitoring and evaluation are no longer the sole prerogative of the researchers. The CIAL is generally a much more inclusive organization and welcomes those who for a long time were not meaningful participants – particularly women and members of poorer households. The CIAL model has “traveled” to other part of the world. In Asia and Africa, and even in some countries of the North, communities are forming their own versions of the “local agricultural research committee” to gain a greater measure of control over their biodiversity and their livelihoods.

An active new generation of practitioners: The widespread acceptance of PPB as a new research methodology has made available the resources needed to develop new teaching and training methodology and materials that meet the demand for more and better training. PPB has caught the imagination of a new generation of young professionals who want to get involved in the worldwide effort to conserve biodiversity.

Almost 20 years have passed since *Seeds that give: Participatory plant breeding* first appeared. What has become of this “new” approach to agricultural research and development needed to conserve agricultural diversity, improve crops, and produce food of quality for all? How has it evolved in the last 20 years? What have been the innovations? Have decision makers in government, agriculture, and development organizations taken the approach on board? What has become of the speculative look into the future? In which ways has it contributed to resilient seed systems and healthier food systems? In this publication, following the same format that was used in the original *Seeds that give*, we try to answer these questions. We are pleased that several of the contributors to the original publication have written new chapters about their work in the last 20 years. They are joined by colleagues who more recently started practicing participatory research. All contributors share the passion for working with farmers, conserving, and sustainably using agrobiodiversity and innovating research for development. We hope that “Seeds that give”-revisited will inspire a new generation of researchers.

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Part 1

International cases

Return to diversity: Evolutionary plant breeding

Salvatore Ceccarelli

1 Introduction

The global issues most frequently debated today are climate change, poverty, malnutrition (which includes undernutrition and obesity), water scarcity, loss of biodiversity in general, and of agrobiodiversity in particular. In several international reports these problems are often discussed separately even though they are closely interconnected: through seed. Seed is related to climate change because we need crops that are better adapted to changing conditions. Seed is associated with food as most of our food is coming directly or indirectly from plants, and with poverty through food and child nutrition. Seed is related to water, because about 70% of global water use is for irrigating crops. Varieties able to produce an economic yield with less water will make more water available for other human uses. Seed is associated with malnutrition: the three crops from which we derive about 60% of our calorie intake, namely maize, wheat and rice, are far less nutritious than crops such as barley (Grando, Macpherson, 2005), millet and sorghum (Dwivedi, et al., 2011; Boncompagni, et al., 2018). Moreover, millet and sorghum need less water than maize, wheat, and rice, which together use nearly 50% of all water used for crop irrigation.

Last but not least, concerning (agro)biodiversity, there is a contradiction between the argument emphasizing the importance of agrobiodiversity for food security (Cardinale, et al., 2012; Hooper, et al., 2012; Zimmerer, de Haan, 2017) and reducing the risk of yield losses (Renard, Tilman, 2019) and the practice of modern plant breeding towards uniformity (Frison, et al., 2011). Most modern varieties are pure lines, hybrids or clones depending on the crop and market. This has contributed to a decline in diversity, which in turn has increased crop vulnerability (Esquinas-Alcázar, 2005; Hajjar, Hodgkin, 2007; Keneni, et al., 2012). Their genetic uniformity makes them unable to respond to climate changes, in particular short-term ones (Ray, et al., 2015). In addition to the increased uniformity of the varieties that we grow, plant breeding has also contributed to the decrease of the number of crops. Today, only about 30 plant species supply 95% of the global demand for food (FAO, 2010), with only nine (sugar cane, maize, rice, wheat, potatoes, soybeans, oil-palm fruit, sugar beet and cassava) accounting for over 66% of all crop production by weight (FAO, 2017).

Crop diversity, by contrast has demonstrated to be highly beneficial, particularly in restricting the development of diseases (Wolfe, et al., 1992; Zhu, et al., 2000; Döring, et al., 2011).

2 The biodiversity inside us

Science has recently begun associating the decline of biodiversity with several types of diseases, including many types of cancer (von Hertzen, et al., 2011). The increase in the frequency of inflammatory diseases has been associated with a decreased efficiency of our immune defenses (von Hertzen, et al., 2011). The association between the microbiota – the complex of bacteria, fungi, protozoa, viruses, yeasts that is in our intestine (sometimes called microbiome, which refers to the genes of the microbiota) and our immune system has been confirmed and thus with the susceptibility to contract inflammatory diseases (Khamsi, 2015). Diet strongly influences the microbiota. A change in diet changes the microbiota composition in only 24 hours. However, upon returning to the original diet, it takes 48 hours for the microbiota to return to normal (Singh, et al., 2017). The microbiota also appears to be involved in several neuropsychiatric disorders, such as anxiety, autism, depression, schizophrenia, and stress response (Hoban, et al., 2016). Given the importance of the relationship between diet and microbiota, there are many studies on the effect of various diets (omnivorous, Mediterranean, vegetarian, vegan Western, etc.) on the composition and the diversity of the microbiota itself (Singh, et al., 2017). The opinions of the nutritionists studying the effects of various diets do not always coincide, but they all seem to agree that diet diversity is of paramount importance for having a healthy microbiota (Heiman, Greenway, 2016).

3 Diversity and uniformity

How can we have a diversified (healthy) diet if 60% of our calories come from just three crops (maize, rice and wheat) (Thrupp, 2000) ? How do we diversify our food if almost all the food we eat is produced from varieties that to be legally marketed, must be registered in a catalogue called variety register? And that to be registered, they should be uniform, stable, and distinct? If our health depends on the diversity and composition of the microbiota, which in turn depends on the diversity of the diet, how can we have a diversified diet if the agriculture that produces our food is based on uniformity? The need to diversify our diet and the uniformity imposed by law on seed and thus on crops leads to a contradiction. In addition, there is a contradiction between uniformity and stability and the need to adapt crops to climate change.

Who are the food masters? It is not us, ordinary citizens, although when entering a supermarket, we seem to have many choices. Whatever we buy, when carefully reading the labels, it turns out that the products mostly come from a large company: Johnson & Johnson, Kraft, Nestlé, Mars, PepsiCo, Kellogg's, P&G, Unilever, and a couple of others. There is not only a food oligopoly, but also a seed one. The world seed market, worth billions of dollars, is for about 55% in the hands of five large multinational corporations (Bonny, 2017, based on 2016 data), up from only 10% in 1985. Some of the same corporations also control another multi-billion dollar market: pesticides (i.e., herbicides, insecticides, and fungicides). This is very worrying because it has been established beyond reasonable doubt that there is a close relationship between exposure to pesticides and the rise of chronic diseases (Mostafalou, Abdollahi, 2013) and autism (von Ehrenstein, et al., 2019).

4 What can evolutionary plant breeding do?

To build healthy food systems, plant breeding needs to change from cultivating uniformity to cultivating diversity. The objective of cultivating diversity can be achieved with PPB defined as the participation of clients (more often, but not only, farmers) in all the most important decisions during all stages of a plant breeding program (Ceccarelli, Grando, 2019). However, PPB has seldom been accepted by institutions as a plant breeding approach. This is likely due to the difficulty to accept the paradigm shift that participation implies. The objective of cultivating diversity can be achieved quickly and inexpensively with evolutionary plant breeding (Suneson, 1956; Ceccarelli, 2009), which consists in cultivating mixtures or populations (Figure 1).

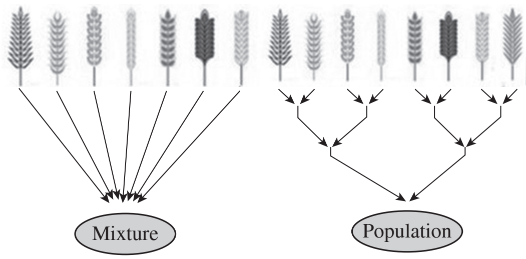

Figure 1　The difference between mixtures and populations

In the case of mixtures, we distinguish static from dynamic mixtures. Static mixtures are made up by mixing in each season the seed of each of the components in various proportions. Although such physical seed mixtures are genetically more complex than monocultures and can therefore be modified by natural selection, they do not capture the effects of natural selection occurring in the field. When grain from such mixtures is used as seed for the following crop cycle, thus capturing the effects of selection for the next year, they become dynamic mixtures. If such dynamic mixtures are maintained over time, it is likely that, over a few generations, low or high levels of out-crossing will occur (dependent on the crop). This together with natural selection will lead to segregation of new gene combinations. Where this occurs, the genetic structure of the crop would then move from dynamic mixture to population (Wolfe, Ceccarelli, 2019).

Evolutionary populations (EP) are made by crossing *n* varieties in all possible combinations. In the case of both mixtures and populations, the choice of the varieties (how many and which) depends on the objectives. For example, if disease resistance is one of the problems affecting the productivity in the target environments, one or more parents of the EP or one or more varieties of the mixture should be selected for carrying the desirable genes of resistance. The availability of suitable genetic markers for the desirable genes will make the handling of EPs more effective. Similarly for quality: natural selection is not effective in the case of quality traits and therefore those traits should be present in the parents of the EP or the mixture (Brumlop, et al., 2017).

Once a population is planted, it is let to evolve as a crop, using part of the harvest as seed for the next growth period or selecting the best plants or both. Because of the joint effect of natural selection and natural crossing, the seed which is harvested is genetically different from the one that was planted. In other words, the populations (including those derived from an original mixture) evolve continuously: hence, the term evolutionary populations. Farmers, alone or with the collaboration of breeders, can adapt the crops to their soil, climate, and the particular way in which each of them practices agriculture, including organic farming, in an evolutionary plant breeding (EPB) program.

The science of EPB is based on research conducted earlier than the publications of Suneson's paper (1956), which used for the first time the term evolutionary plant breeding. In 1929, Harlan and Martini proposed the composite cross (CC) method of plant breeding. They synthesized a barley CC (CCⅡ) by pooling an equal number of F_2 seeds obtained by 378 crosses among 28 superior barley cultivars representing all the major barley growing areas of the world (Harlan, Martini, 1929). Other historical CCs were the CCXII (synthesized from 6,200 barley accessions from the USDA collection) and the CCV (similar to the CCII except that 30 intercrossed parents were used). These and other CCs, as well as mixtures, were the object of numerous studies, which show how evolutionary populations and mixtures are able to adapt their phenology to the growing environment (Allard, Hansche, 1964); increase yield (Patel, et al., 1987; Suneson, 1956; Rasmusson, et al., 1967; Soliman, Allard, 1991); increase yield stability (Allard, 1961); increase disease resistance (Simmonds, 1962; Smithson, Lenné, 1996; Ibrahim, Barret, 1991; Mundt, 2002; Mulumba, et al., 2012); and increase plant height (Suneson, Wiebe, 1942). More recently, there have been several papers confirming that evolutionary populations do adapt to different geographical areas by changing their phenology (Goldringer, et al., 2006). They tend to perform better than uniform varieties in years affected by drought (Danquah, Barrett, 2002) and combine higher yield and higher yield stability (Raggi, et al., 2016a, 2016b, 2017). In an IFAD-funded project, which introduced EPs in Iran, farmers found that the bread obtained through traditional baking from a bread wheat EP was beneficial to health.

The use of EPs, both in cereals and in some horticultural species, is spreading in Italy. Evolutionary-participatory breeding is conducted in Sardinia by Domus Amigas (CSA). In Emilia-Romagna, regional projects that experiment on mixtures are carried out at the University of Bologna and at the company Open Fields (BIO Project). Studies on mixtures and EPs are currently underway at the Universities of Perugia, Bologna and Florence. Thanks to the work of Rete Semi Rurali (http://www.semirurali.net), there are populations in Sicily, Basilicata, Molise, Puglia, Abruzzo, Marche, Tuscany, Emilia-Romagna, Veneto, Lombardy, Friuli-Venezia, Giulia, and Piedmont. The Italian Association for Organic Agriculture also supports this approach. These organizations argue that EPB leads to seed sovereignty in its biological rather than ideological meaning. For each farmer there cannot be better seed than the one produced in his/her own fields.

The cultivation in Italy of an EP of over 2,000 different types of bread wheat coming from all over the world, has produced a bread that apart from having an extraordinary smell and taste, is tolerated by people suffering from gluten intolerance. We propose to call this population, the Mixture of Aleppo, in recognition that it was first constituted in Syria. Recently, pasta was produced in Molise and Marche, Italy, with an EP of durum wheat. In Iran, shepherds who have used the barley EP as food to feed sheep, have noted an improvement in milk quality.

These results indicate that, in addition to all the benefits already mentioned, the cultivation of EP represent an ideal way to combine food security with food safety while at the same time contributing to income generation.

The use of populations in Europe has been made legal in the case of maize, oat, rice, and wheat by the Commission Implementing Decision of 18th March 2014 pursuant to Council Directive 66/402/EEC. The Council Directive makes it possible to market experimentally heterogeneous materials of the four different cereals up to 31st December 2021. As a result, 34 populations have been registered, and in several cases, their seed has been commercialized.

5 Conclusion

Mixtures and evolutionary populations represent an alternative type of genetic material that has all the characteristics of an integrated genetic solution. The multiple benefits include:

• Gradual evolution adapting not only to different locations, but also to every single micro-environment within the same farm in a type of "precision agriculture";

• Guaranteeing a stable production to the farmer despite the climatic variations from one year to the next;

• Allowing control of weeds, insects and diseases without the use of chemicals;

• Gradual adaptation to long term climate changes;

• Ensuring income both as seed and grain;

• Guaranteeing a healthy product to the consumer;

• Making the farmer the owner of his/her own seed.

Evolutionary plant breeding and participatory plant breeding can merge, and farmers' selections within the evolutionary populations can flow into a participatory breeding program. Evolutionary seeds can therefore be considered, from all points of view, the seeds of the future.

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Participatory plant breeding in North Africa and the Near East: Nearly 25 years of experience

Salvatore Ceccarelli, Alessandra Galiè, Stefania Grando

1 Introduction

Participatory research was first proposed in two classic papers at the beginning and in the mid-eighties (Rhoades, Booth, 1982; Rhoades, et al., 1986). Applied to plant breeding, participatory research has been implemented as participatory plant breeding (PPB). We define PPB as the participation of clients (more often, but not only, farmers) in all of the most important decisions during all the stages of a plant breeding program as shown in Figure 1.

Depending on when the participation starts, a distinction is made between PPB and participatory variety selection (PVS). The latter is when farmers' participation begins during the testing of experimental varieties. On one side, PVS is technically easier to organize than PPB, because farmers are only involved in expressing their opinion about the limited number of lines that usually reach that stage. On the other side, PVS usually allows farmers to make a very limited number of choices. With PVS there is a risk for breeding material potentially desirable to farmers to be discarded before it is even seen by them. However, because it is simple to organize, PVS, when fully decentralized, can be a useful entry point to start experimenting

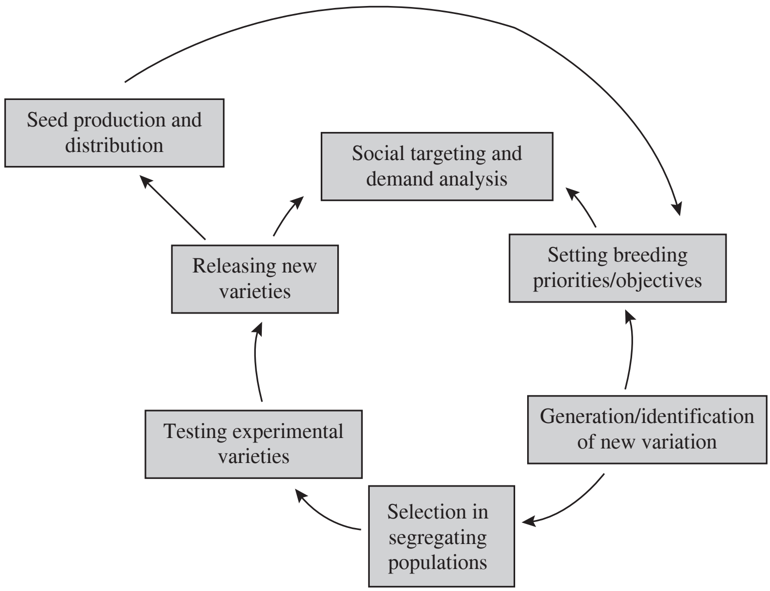

Figure 1 Main stages of a breeding programme

with the participation of farmers. In this chapter we will describe how PPB was used initially in the barley breeding program at the International Center for Agricultural Research in Dry Areas (ICARDA) in Aleppo (Syria) and then implemented in several countries in North Africa, the Horn of Africa and the Middle East.

2 Methodology

It was in September 1995 when we had a meeting with a group of farmers in Jurn El Aswad, a village in the Raqqa province in North-East Syria. We wanted to explore the feasibility of transferring most of the selection work from ICARDA's Research Stations to farmers' fields and of having farmers participating in selection and other major decisions. This change was the ultimate consequence of our analysis of the effects of Genotype × Environment Interaction (GEI) in our barley breeding program at the International Center for Agricultural Research in Dry Areas (ICARDA) in Aleppo (Syria) (Ceccarelli, 1994; Ceccarelli, et al., 1994).

The farmers of Jurn El Aswad expressed strong interest in our proposal. We decided to visit an additional eight villages representing different agro-climatic environments, but also different ethnic groups. The first experiment, with one set of 200 extremely variable modern varieties and landraces, was designed with the specific objective of exposing these communities to as much barley biodiversity as possible. The set was planted in the fall of 1995. The German Organization for Technical Cooperation (GTZ) – now GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit) – provided the financial support for this initial work. In 1998, with the financial support of the International Development Research Center (IDRC), the Barley Breeding Program expanded the PPB work first to Tunisia and Morocco, then to Jordan, and later to other countries with the support of other donors.

The PPB evolved methodologically in the course of time, while maintaining the fundamental aspects of a breeding program.

In the classic flow chart of a breeding program (Figure 2-1), the ICARDA barley breeders were responsible for the generation and identification of new variation by making targeted crosses. These were different types of crosses for each of the countries where PPB was implemented, based on social targeting and demand analysis that determined the breeding priorities and objectives. For example, there was one crossing program targeted for the dry areas of Syria using predominantly germplasm with black seed as well as the barley wild relative *Hordeum vulgare* spp *spontaneum*. There was a second different crossing program targeted for the wetter areas of Syria using predominantly germplasm with white seed. Similarly, the strategy of targeting crosses was applied to all other countries served by the program.

In all cases there was always a large use of landraces often at a specific farmer's request. The segregating F_3 bulks (the number of F_3 bulks was almost equal to the number of crosses) – not the F_2 because the seed amount was not sufficient – were used to set trials in farmers' fields without any previous selection on station.

These trials have been shaped and, with time, modified, in collaboration with farmers, who indicated the preferred size of the plots, the preferred type of germplasm and the amount of land they could make available for the trial, hence the size of the plots. The trials also evolved because of the progress in experimental designs and statistical analysis made by conventional breeding programs. Therefore, over the years, we replaced the augmented design with the partially replicated design. We replaced the randomized block design with the row and column design allowing for spatial analysis. Eventually, we replaced ordinary randomization with optimized randomization. While the program evolved methodologically, we made sure that it maintained a robust scientific basis. In other words, all the data generated by the program, namely agronomic data, and farmer preferences, were amenable to the most advanced statistical analyses. This allowed to give farmers access to unbiased predictors of the materials under selection. This, in turn, would maximize the efficiency of their selection.

The selection between the segregating populations, starting with the F_3 bulk, was solely conducted in farmers' fields, and was typically organized in a 4-year cycle. The reason for this was to select for stability of grain yield, in addition to other traits. Stability of yield in the case of a crop such as barley grown as animal feed predominantly in marginal environments was one of the farmers' top priorities. In Syria and Jordan, scoring of lines was in some cases conducted in private homes (with the help of visual material from the field and actual samples of lines). Such scoring facilitated the participation of women in selecting their preferred lines. Gender norms generally discouraged women and young women in particular from participating in public events (such as PPB scoring days) with unrelated men.

Within a single village, the structure of the program included Stage 1 trial in year 4 after the crosses were made on station (Figure 2); in year 5, the selections (obtained as described later) from the Stage 1 trial were planted in a variable number of Stage 2 trials. However, as a breeding program is a cyclic process and new crosses are made every year, a new Stage 1 trial was planted in year 5 as well as in the following years.

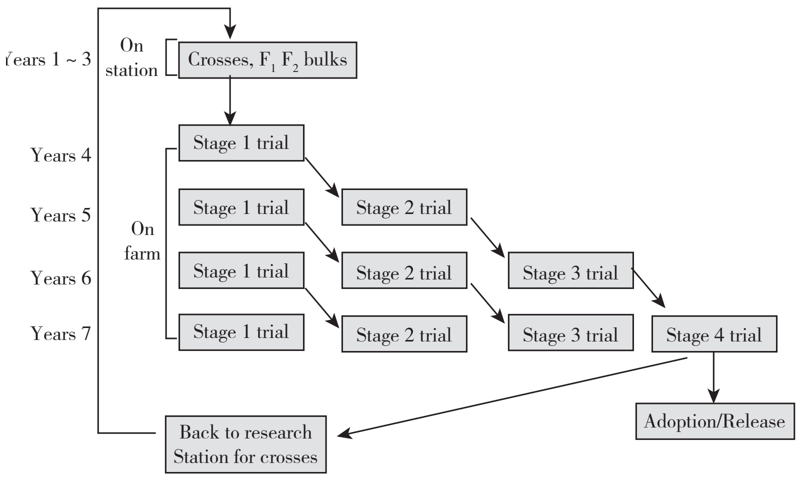

Figure 2　The structure of the Participatory Barley Breeding Program at ICARDA in a single village

The selections from Stage 2 were tested in year 6 in a number of Stage 3 trials, which in each village was the same as the number of Stage 2 trials. After a fourth-year testing in Stage 4 trials, the seed of the final selections was sufficient for large scale (usually > 1 hm^2) planting by the farmers participating in the process. In theory, it could also be submitted for official release – in theory, because in practice this only happened in some countries. The final selections from Stage 4 were also used for the crossing program targeted to the area where the selections were coming from.

Therefore, when in a given village the process was fully implemented, the village itself looked like a research station, with the different stages grown by different farmers within the village. In Syria alone, where the program was eventually implemented in 24 villages, each year there were more than 200 field trials with over 400 breeding lines belonging to the different stages. Moreover, as shown in Figure 2, after the process was fully implemented, the farmers selected the parents for the following cycle.

A number of steps in the process need further clarification:

2.1 Choice of the country

This was either a donor's preference, or a self-promotion (as in the case of Jordan and later of Algeria, Egypt, Iran and Yemen), or the choice because of poverty (the case of Eritrea).

2.2 Choice of locations within a country

This was based on the priorities of the specific project supporting the program in a given country, or on previous contacts between local scientists with farmers' communities, but also on self-promotion by farmers themselves as in a number of cases in Syria.

2.3 Structure of the trials

The size of the Stage 1 trial, which was the one with which the program started in any given location, was negotiated with the farmers and ranged from 200 plots covering nearly 0.3 hm^2 in Syria, to 100 plots in Jordan and Eritrea, to 60 in Egypt, to 45 in Yemen. This, combined with a plot size which varied from 12 m^2 in Syria and Jordan, to 1 m^2 in Yemen and Eritrea, allowed to fit the program to situations where farmers' holdings was very different, ranging from > 5 hm^2 in Syria to <1 hm^2 in Eritrea and Yemen. The leading principle was to make sure that in Stage 1 there was enough diversity to allow meaningful selection by farmers.

2.4 Farmers' field selection

In all countries farmers decided when to make the selection and how often. In most cases they decided that visual selection as close as possible to harvest was the best option. After trying different methods, in most countries farmers found that an overall score from 1 (the worse plot) to 4 (the best plot) was the easiest and the fastest. In Iran, farmers decided to use an individual score from 1 (less desirable) to 10 (most desirable) to each of five traits, namely plant height, tillering, spike length, lodging and kernel size.

The women involved in the project in Iran also expressed an interest in the taste and cooking qualities of rice (which they tested at home before scoring the experimental lines). In Syria and Jordan, women valued the elasticity of the flour -which they used to make local bread, and the elasticity and length of the stem–which they used to make local baskets for home use and sale. In all countries however, quantitative characteristics remained the priority for selection by the group. Ranking was never used being considered problematic because ranks give no idea of "distance" between preferences (Abeyasekera, 2005).

2.5 Data recording

At the time of farmers' field selection, and in most countries, researchers recorded several quantitative traits (typically plant height and spike length) indicated by farmers as important in deciding the merit of a line. Grain, and often straw yield were recorded at harvest by threshing samples of $1m^2$ harvested manually by the farmers themselves and stored until a combine harvester was available. On the harvested sample, researchers measured kernel weight, also a highly valued trait by farmers. In Iran, most of this work was done directly by farmers under the supervision of the staff of an NGO.

2.6 Data analysis

The statistical analysis of the data was done, on a village basis, at the research station as quickly as possible after harvesting. The spatial analysis (Rollins,et al., 2013) generated the BLUPs (Best Linear Unbiased Predictors), which were tabulated and translated in the local language. The tables were then made available to farmers for the final selection. In this way, farmers had access to the same quality and quantity of information usually available to breeders for the final selection. Breeders participated in the final selection only with the objective of recording farmers' choices.

2.7 Final selection

This was done independently in each village, usually at the residence of one of the farmers of the village, usually but not always, on a rotational basis and at a mutually agreed date but sufficiently early to allow enough time to organize the trials for the following cropping season. At this time, and during the same meeting, the allocation of trials to different farmers in the village was also discussed and finalized.

2.8 Naming of varieties

This was entirely left to farmers to decide. Farmers used different criteria. The name could be that of the son of a prominent farmer, that of the village, or the name of a newly born baby girl, or a symbolic name. Breeders only interfered in those extremely rare cases when, at the end of a four year cycle, the same material was selected in more than one village and given different names. This would have caused problems when using that material for crossing. Therefore, the breeders mediated to reach a consensus on the same name.

3 Partnership

The PPB program described in this chapter has been conducted in partnership with various institutions ranging from those responsible for plant breeding (our first choice in view of the possible institutionalization), such as the Ministry of Agriculture in Syria, Jordan, Eritrea, Yemen, Morocco, Tunisia and Algeria, NGOs in Iran, or Government Institutions not necessarily involved in plant breeding, such as the Desert Institute in Egypt.

4 Results

Some of the key results were:

• In their own fields, farmers were slightly more efficient than the breeder in identifying the highest yielding entries;

• The breeder was more efficient than the farmers in selecting in the research station located in a high rainfall area, but less efficient than the farmers in a second research station located in a low rainfall area. The research paper about this finding was awarded the price for the best CGIAR scientific paper for the year 2000, but, most importantly, it indicated that "it is possible to transfer the responsibility of selection to farmers in their fields, that farmers can handle selection choices among a large number of lines, and that farmers' selections are objectively high yielding and yet different from one location to another";

• 32 varieties in 5 countries were adopted by farmers by 2007 (Table 1). In Syria adoption took place the first time in low rainfall areas (< 250 mm annual rainfall);

• In Syria, in villages with a mean total annual rainfall ranging from 189 to 277mm, yield advantages of 5%-25% over the local landraces were obtained with lines/populations selected from PPB (Desclaux, et al., 2012);

• In Eritrea, where the program was conducted using five crops (wheat, lentil, faba bean, chickpea and barley), new varieties were adopted for all crops except faba bean and farmers' seed production started within four years from the start of the project;

• In some villages, women and men farmers were found to have different trait priorities both in cases when they performed complementary activities (i.e., women were interested in a soft stem for hand harvesting and for basket making while men preferred higher yield because involved in seed marketing) and when they performed the same activities. In the latter case gender norms and dynamics may affect the way each group can perform these same activities (i.e., when selling seed, women may sell to other women mostly and in local market only; men may sell mostly to other men and in urban markets. Therefore, men may prefer traits desired by urban and rural male customers and women may prefer traits desired by rural, women customers);

- A 4-year study conducted on the potential of PPB in empowering women farmers showed positive results when a gender-responsive approach is intentionally adopted to mediate local gender norms that may discourage women from participating in PPB activities and from benefiting from the improved varieties. The research paper discussing these findings was awarded the Elsevier ATLAS Award for potentially most impactful papers (Galiè, et al., 2017).

Table 1 Number of varieties selected and adopted by farmers in the PPB programs in 5 countries

Country	Crop	Varieties
Syria	Barley	19
Jordan	Barley	1 (submitted)
Egypt	Barley	5
Eritrea	Barley	3
Yemen	Barley	2
	Lentil	2

5 Other action research results

Given the importance of agricultural biodiversity and the perception that modern (conventional) plant breeding reduces agrobiodiversity, PPB has an obvious advantage in increasing biodiversity being decentralized and giving priority to specific adaptation (Figure 3).

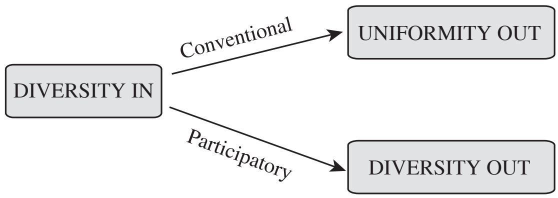

Figure 3 Participatory plant breeding and agrobiodiversity

Therefore, PPB can significantly contribute to a diversification of farming systems which in turn supply multiple ecosystem services to agriculture, thereby reducing the need for off-farm input (Kremen, Miles, 2012).

6 Gender analysis and women empowerment

The PPB program in Syria, as well as in several other countries, initially adopted a gender-neutral approach, and it was open, in principle, to both men and women. However, while in countries like Jordan, Ethiopia and Eritrea, the women participation was, at least numerically, equal to that of men, in Syria after ten years only men farmers were involved.

In 2006, a diagnostic study was conducted to understand the reasons for the absence of women farmers from the PPB program. We found that women expressed a strong interest in participating in the program and starting in 2007 an assessment was undertaken to start evaluating the impact of the PPB program on their empowerment. Within this context, a number of women from three villages were invited to attend and to speak at a Farmer Conference held in Aleppo in 2009 (Galiè, et al., 2009). Two examples of the result of a progressive involvement in the PPB program in Syria were: first, that women became involved in the sale of seed of varieties developed through the program; second, one widow farmer found in PPB seed a reliable source of otherwise expensive cow feed resulting in increased milk production and hence farm income. These two examples show the transformative potential that PPB can have in supporting new opportunities for women (Galiè, et al., 2017).

7 Capacity development

The full assimilation of the methodology used in implementing PPB as well as of its advantages, as seen with farmers' eyes, was already evident in the early stages. For example, since the first few years, farmers fully understood the advantages of replication in space, given the large spatial variability in the soil physical and chemical properties in farmers' fields.

The way our work started in Jordan is worth mentioning. During a visit to ICARDA of a group of professors at the University of Jordan in Amman, they were taken to one of the villages where the Participatory Plant Breeding Program was implemented and met with the farmers. They were most impressed by the way the farmers where talking about the program and, in particular by the possibility the program gave them to express their knowledge of the crop. While traveling back to Aleppo, one of them asked to start a similar program in Jordan, which eventually happened in 2000, initially in partnership with the University of Jordan, and later with the National Center for Agricultural Research and Extension (NCARE) – now NCAR (National Center for Agricultural Research): the program is continuing without interruption till today.

Using social science terminology, the barley participatory program at ICARDA was initially scientist-driven, as the scientists introduced it to the farmers and decided the type of germplasm to use. However, as it should happen in a truly participatory program, the roles soon changed. The farmers gradually started influencing the methodology (how to organize field selection), suggesting suitable scoring methods, and choosing the type of germplasm (for example, suggesting the ratio between improved and landraces), and organizing the harvesting.

Several formal training courses were held not only in countries where PPB programs were in place, such as Syria through lectures at various universities, Jordan (2 courses), Ethiopia (3 courses) and China (1 course), but also in countries which expressed an interest in PPB such as Italy (3 courses), Australia, South Africa (3 courses), Cambodia, Philippines, India (4 courses) and Bhutan. One book (Ceccarelli, et al., 2009) and one training manual were published (http://www.fao.org/family-farming/detail/en/c/326138).

8 Policy influence

One notable failure of the Barley Participatory Program at ICARDA was that the Centre never adopted it. In fact it was not adopted by any other CGIAR centre despite the positive reaction of the farmers and its solid scientific basis (Ceccarelli, 2015). However, a partial success was that, despite the lack of CGIAR support, some countries such as Jordan, Algeria, Yemen and Eritrea actually adopted PPB as their mode of doing plant breeding or as a component of their national breeding program. In some of these countries (Jordan and Algeria) PPB is continuing while in others, external factors such as social unrest or war, did not allow its continuation.

The major problem with PPB in influencing policy decisions is that it represents a reversal of the tendency of plant breeding towards uniformity. This tendency started since the early days of plant breeding for technical, commercial, historical, psychological and aesthetic reasons (Frankel, 1950). One should notice here the absence of the term "biological" in the previous sentence. Frankel added that the concept of purity "has not only been carried to unnecessary length, but that it may be inimical to the attainment of highest production". In addition, PPB brings seed production, varietal innovation and conservation of genetic resources back in farmers' hands by empowering them in a process that Kloppenburg (2010) defines as "repossession". In so doing, the adoption of PPB implies changes in issues such as power, authority and control (Fitzgerald, 1993). This, in several countries sounds very radical and perhaps even subversive (Crane, 2014). Galiè (2013) also analyzed the interactions between governance regimes regulating the rights to access and control of genetic resources at international and national levels, and women farmers' ability to access and control the seed varieties co-developed with the PPB programme. The paper argues for international legislation that explicitly protects the rights of women farmers to access and share the benefits of genetic material to avoid that local gender norms restrict women's ability to benefit from the new varieties.

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Farmer – plant breeder collaboration: The case of sorghum breeding in West Africa

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1 Introduction

Sorghum (*sorghum bicolor*) is widely cultivated across West Africa, in a broad range of agro-ecological conditions and contrasting production objectives of individual farmers, women and men. These farmers use and manage varietal diversity of sorghum to optimize their household's productivity and minimize risks (Haussmann, et al., 2012). The intimate knowledge of West African farmers of these varieties calls for collaboration among farmers and researchers for variety development. Our plant breeding activities included collaborative setting of priorities, generation of new diversity, identification and testing of experimental varieties, and developing seed system activities with farmer organizations, like the "Cooperative des Producteurs Semenciers du Mandé" (Seed producers coop of Coprosem, Mali), the "Union Locale de Producteurs de Cereales" (Union of cereal producers, ULPC) in Mali and others in Burkina Faso (vom Brocke, et al., 2010).

The participating sorghum breeders came from the national agricultural research organizations in Mali (Institut d' Économie Rurale, IER; Institute of Rural Economy) and Burkina Faso (Institut de l'Environnement et Recherches Agricole, INERA; Institute of the Environment and Agricultural Research), the French Agricultural Research Centre for International Development (CIRAD), and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT).

The collaborative activities are described here for each step in the breeding process, followed by a brief section on policy impact, and conclusions.

2 Setting priorities for the breeding program

The priority setting included efforts to predict farmers' production system constraints and understand trait preferences, taking gender roles into account. The priorities for sorghum breeding in Mali were to develop new open-pollinated varieties with higher grain yield and better adaptation to the predominant growing conditions (Siart, 2008; Clerget, et al., 2008; Leiser, et al., 2012; Rattunde, et al., 2018). Grain quality should be appropriate for storage, processing, and food uses (Isaacs, et al., 2018; Weltzien, et al., 2018). In addition, the concentration of iron (Fe) in the whole grain should be maintained at or above the threshold of the local control variety named Tieblé (initially registered as CSM 335), derived from a Malian landrace.

3 Generating new diversity as a basis for breeding

The sorghum team emphasized use of local germplasm of the guinea-race of sorghum to provide a strong foundation for the diverse adaptation and grain quality traits demanded by farmers (Weltzien, et al., 2018). Exotic germplasm (mostly the caudatum race of sorghum) was introgressed at approx. 12% to increase variability for productivity. We used introgression with a single backcross generation and recurrent selection for population improvement in collaboration with farmers for this purpose.

We created backcrosses using a farmer-preferred guinea-race variety as recurrent parent. Several exotic donor parents were used, based on experiences in Australia (Jordan, et al., 2011). Farmers were very interested to select in these BC1-sub-populations, because of the acceptable levels of key farmer-preferred panicle, grain and glume traits, combined with useful diversity.

Recurrent selection for the improvement of populations, created by crossing multiple parents, is a cyclical process that results in novel gene combinations from the repeated recombination of the diverse parents, using a genic male-sterility system. In each cycle, the more promising progenies are selected and then inter-crossed to form the next population bulk. This is expected to increase the frequency of progenies with superior performance for the targeted traits while retaining genetic variation for further selection.

Farmer' collaboration with breeders to improve populations evolved over time (Table 1). Farmers engaged in deriving new progenies from the population bulk by growing plots of the population bulk selecting single plants, which then entered the breeders' program for either variety development, or the next cycle of recurrent selection. The farmers frequently detected differences not seen by the breeders. They thus helped to increase the population size of the breeding programs, and to focus the limited resources on plant types that were more acceptable. The farmers kept half of the seed of each selected panicle and gave the other half to the plant breeders.

Farmers also evaluated progenies in on-station and on-farm trials. Farmers with special expertise in observing panicles scored hundreds of progeny plots prior to harvest for critical traits, such as traits related to threshing. Women farmers judged grain quality of progenies by visually scoring grain desirability and grain hardness after harvest. These farmers were paid for contributing their special expertise. Farmers also volunteered to evaluate population progeny trials by attaching labels to more desirable progenies and afterwards discussed the strengths and weaknesses of the new materials they observed.

Table 1 Recurrent selection schemes used for sorghum in Mali (Weltzien, et al., 2019)

Year	Material sown and main step	Farmer Activity	Breeder Activity
1	Random-mated S0 population bulk (3-10,000 plants/field) to derive new progenies	Sow bulk in isolated fields, thin to single plants, label male-fertile plants at flowering, select desirable male-fertile panicles to derive S_1 lines	
2	S_1 progenies (500-750) for evaluation	On-station scoring of grain desirability, panicle appreciation, and threshability in S_1 trial; contribute to selection of panicles to derive S_2 lines. Experienced women farmers score grain quality	Manage S_1 progeny trials, evaluate for maturity, disease resistances, grain yield and overall appreciation, chose progenies for further testing based on index of farmer and breeder observations; conduct S_1 nursery to derive S_2 lines

continued

Year	Material sown and main step	Farmer Activity	Breeder Activity
3	S_2 progenies (approx. 125) for S_2 testing and selection	Score grain and panicle desirability, threshability, label desired progenies in S_2 trial; contribute to selection of panicles to derive S_3 lines for on-farm testing	Manage S_2 progeny trials, evaluate for maturity, disease resistances, grain yield and overall appreciation, create selection index to choose best progenies to recombine; conduct S_2 nursery to derive S_3 lines for line/variety development Plant remnant S_1-seed of the selected progenies in isolation for an initial random mating and increasing the frequency of the male sterility gene. Only seed from sterile plants will be harvested
4	S_1 progenies derived in S_0 (approx. 30) for random mating	Contribute to selection of desirable panicles based on form, grain and glume characteristics	Sow remnant S_1-seed of selected progenies in isolation, in alternating rows with seed harvested from sterile plants from the first random mating, label male-sterile and male-fertile plants, select panicles of desirable sterile-plants and bulk to create next cycle

4 Selecting in segregating materials

Selection over several generations in this phase operates like a funnel in reducing the total genetic diversity, attempting to focus on a more limited number of progenies/sub-populations of greatest interest for achieving the breeding objectives. The breeding programs strived to apply their evolving understanding of farmers' needs and preferences to define the breeding strategy for the following stages of selection.

Farmers' evaluation of progenies, as described for the population improvement activities, became an integral part of the breeding program and contributed to final selection of progenies to use for developing experimental varieties. Farmers sowed nurseries of between 30 to 50 early generation progenies to select within these segregating materials using their own criteria and growing conditions.

Selection for grain yield in early generations

Selection for grain yield only based on on-station testing was of questionable utility for achieving yield gains in farmers' fields under low-input, conditions (Bänzinger, Cooper, 2001). The sorghum team with 34 farmers tested the feasibility of early-generation yield testing on-farm, using a set of 150 progenies (S_2/S_3) and a trial design with sub-sets of 50 progenies and two common repeated check varieties tested per farmer. The farmers grew single-row plots to make sowing of the trials easy for farmers. Progenies were selected using either combined on-farm or on-station results and their on-farm yield performance was tested in subsequent years in a series of replicated on-farm trials. Despite the farmers' management practices and field conditions differing greatly among the various on-farm selection trials, early generation on-farm yield testing was found to be effective (Rattunde, et al., 2016).

5 Testing experimental varieties

5.1 Evaluation of grain yield performance and adaptation traits

The farmer-researcher collaboration in the testing stage addressed two main objectives: i) arriving at a joint assessment of varieties and their advantages and disadvantages; and ii) evaluating grain yield and its stability across a wide range of growing conditions within the priority target zone for the new varieties (Rattunde, et al., 2013; Weltzien, et al., 2006a, 2008).

The team developed a system for farmers (sometimes assisted by a village facilitator) to score a standard set of priority traits identified by farmers (crop duration, adaptation to the local conditions, panicle appreciation, overall appreciation) (Weltzien, et al., 2006a). Researchers assisted the farmers with grain yield and yield component measurements. The field book with all observations was kept by the farmers who conducted the trial, with researchers keeping a photocopy, for use for data analysis.

In each trial village, farmer visits were organized to evaluate the trials before harvest (Weltzien, et al., 2006a). The farmers chose the three most important criteria for which they scored varietal differences in small groups (vom Brocke, et al., 2010). The technicians recording the scores also noted reasons mentioned for scoring certain varieties especially high or low. Two separate trials were conducted, each with 16 entries (tall and short varieties separately) with two replications each. We used an alpha-lattice design with sub-blocks of four plots. A common landrace check variety (Tieblé) was used in all trials. Both trials were conducted in each of 10 to 12 villages by two farmers each, and in 2 to 3 research stations. Each set of experimental varieties were tested for two years, based on the farmers' and researchers' desire to see varietal performance over years. All experimental varieties were given short vernacular names that could easily be remembered, but without any suggestive meaning to facilitate farmers' discussions and feedback. The breeders conducted the analysis of individual and combined farmers' trials. The results were presented to the farmers for discussion and selection of entries for post-harvest grain quality tests, including village level sensory evaluations, and second stage, fully farmer-managed, on-farm testing. Robust data on grain yield performance and farmer appreciation of the experimental varieties over many diverse environments could thus be collected (Kante, et al., 2017; Rattunde, et al., 2013).

5.2 Post-harvest quality evaluations

Grain processing traits and culinary evaluations of experimental varieties were conducted in each of the participating villages after harvest, because grain quality, grain storage and food-processing attributes are critical for variety adoption. The farmers choose four of the experimental varieties for this evaluation based on the results from the field trials. For these post-harvest evaluations, teams of women provided quantitative and qualitative measurements of varietal differences for the ease and time taken for various processes, decortication losses, flour-to-grit ratios, and the swelling potential (i.e., the capacity to absorb water) of the stiff porridge (known as tô), one of the main local dishes (Isaacs, et al., 2018). A village-based panel of men and women taste testers evaluated the color, taste and consistency of the prepared food.

These grain quality evaluations provided the entry-point for evaluating nutritional qualities as a possible selection criterion, specifically iron concentration (Fe). The team initially tested approaches for assessing Fe concentrations in the food products consumed by farm-families, as obtained and measured during the culinary trial evaluations. As farm families consume only decorticated sorghum grain, we focused on iron analysis of decorticated grains, initially. We identified significant genetic variation for iron concentrations in decorticated grains (grain from which the pericarp had been removed, using a mortar and pestle). These variations could not completely be explained by decortication yields (the amount of dry matter removed from the grain during the decortication process). In addition, we observed that approx. 50% of the total iron contained in the whole grain was removed during the decortication process.

The nutritionists on the team then tested procedures for producing acceptable flour and food products from flour prepared from whole sorghum grains, in collaboration with the women groups conducting the culinary tests and variety trials. A process that combined soaking the grains overnight and milling them by machine resulted in a highly acceptable product. Based on these results, the team limited their breeding effort for high iron concentrations to a monitoring activity to ensure that new varieties were not causing reduced iron concentration. The team also focused on the identification of those varieties that provided significantly higher levels of iron than a local control. More effort was invested in developing a training program for women, and to work with women groups to learn about the nutritional advantages of whole grain flour, as well as other options for providing their children with adequate nutrition, using local ingredients (Bauchspies, et al., 2017).

5.3 Testing varieties under fully farmer-managed conditions

The second stage trials were conducted to provide a larger number of farmers the opportunity to evaluate varieties under their own field and management conditions (Weltzien, et al., 2006a). The testing procedure evolved to include an option to split the plots with one half fertilized, so that farmers could assess each variety's performance with and without fertilizer. Adaptation trials were conducted in villages with four or more farmers interested to conduct this type of trial. The farmers needed to agree on the specific objective for their trials, e.g., finding varieties with good performance (even if they were having Striga infestation), late or early sowing, more or less weeding, or in a specific intercropping situation. As demand for these trials was very high, for several years, trials were only given to those villages where a group of at least four women conducted a variety trial in their own fields. The trials were designed with three, four, five or sometimes six varieties, always including a common local check widely grown in the village. Farmers recorded their observations directly or with help of village facilitators, and each group of farmers jointly discussed and documented their varietal choices. Researchers visited some of the trials and assisted some groups, particularly women's groups, with harvest and weighing of plot yields. Yield data from these trials, extracted from the above-mentioned field books, permitted broad assessments of the relative performance, profitability, and risks of not recouping investments in seed of improved open-pollinated varieties and hybrid varieties and fertilizer relative to the farmers' local varieties over diverse environments for men and women farmers (Weltzien, et al., 2018).

6 Developing seed system activities with farmer organizations

Although several varieties were identified through the above-described process and registered in the national variety catalogue, the spread of seed of newly identified varieties was very slow within villages conducting the on-farm trials, and even slower to surrounding villages. A commercial seed system for staple food crops, such as sorghum, does practically not exist in Mali; in addition, cultural norms make it largely unacceptable for individual farmers to buy or sell seed to others on a regular basis. Seed dissemination was further hampered by the introduction of the regional seed legislation of the Economic Community of West African States (ECOWAS) in 2008, to which Mali as a member state is committed. According to this law, variety registration and seed certification are mandatory requirements. In practice, there was widespread insecurity regarding future modes of implementation at the national and regional levels and prospects for farmer seed marketing.

However, there was interest among certain farmers and farmer organizations collaborating in the participatory trials to start larger scale seed production, compliant with the emerging seed marketing rules. With training and support by the breeders and technicians from the research stations, several groups of farmers launched formal seed production of the preferred varieties identified in the trials. These groups included the (initially) very small cooperative Coprosem, which was started by just 8 farmers and less than 10 hm^2 of seed production per year (Dalohoun, et al., 2011) and a very large union of farmer cooperatives (Union Locale de Producteur Cereales, ULPC) engaged in collective marketing of their grain and interested in new higher yielding varieties for their members. The choice of which varieties to produce was made by the individual farmers and seed-producer groups. The prior season test-results and discussions at the Annual Feedback and Planning Meetings were used to formulate their list of varieties for seed production. IER and ICRISAT sorghum breeding program jointly conducted training in commercial seed production and certification for farmer groups involved in seed production.

The number of farmer-seed producer cooperatives as well as the amount of seed produced and marketed by them has constantly increased since then, making these cooperatives important “new players” in the seed systems of several West African countries (Christinck, et al., 2014). Since each cooperative can make their own decision on which varieties from the breeding program to produce, based on their members’ preferences and needs, this system is responsive to diverse agroecological and socioeconomic conditions. Seed production and marketing is embedded in the collective activities of the cooperatives, thus serving “the common good” . For this reason, it has become much more acceptable for individual farmers to engage in seed production and marketing, or to buy seed of specific varieties.

7 Policy impact

The collaborative breeding program of ICRISAT, national research and farmer organizations contributes to several overarching goals that form part of international, regional and national policies addressing food security and nutrition as well as resilience of farming and food systems and adaptation to climate variability and change. It shows exemplarily how agronomic, post-harvest and nutrition-related traits can be addressed simultaneously in a breeding program. The program’s approach to facilitating participation of women and men turned out to be a key success factor in this regard, enabling nutritional benefits for vulnerable groups, such as women and young children.

The approach can also serve as one example for the realization of farmers' rights as set out in Article 9 of the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA). Through manifold group-based and knowledge-exchange activities, farmers' traditional knowledge has been strengthened and put to active use. They participate in the sharing of benefits arising from the use of plant genetic resources by having access to a broader range of varieties that meet their preferences and needs as well as through income-generating activities relating to the production, processing, and marketing of seed. Through formal involvement as cooperation partners, farmers and their organizations also participate in decision-making at national level, e.g., by contributing to priority setting of national breeding programs. Farmers maintain far-reaching rights to save, use, exchange and sell seed, based on their enhanced capacity to produce and sell seed on a legal basis. Since seed of varieties developed by national and international breeding programs is not covered by intellectual property rights, farmers can continue to save farm-produced seed of newly developed varieties for their own use without any legal restrictions.

8 Conclusion

Capacities and skills of farmers as well as breeders contributed to achieving genetic gains for the objectives targeted. Certainly, every joint interaction and project with farmer-researcher collaboration advanced joint learning and effective farmer-oriented breeding. Important advantages of long-term farmer-breeder collaboration for achieving changes include:

- The possibility of systematic follow-up from understanding of farmer needs and conditions to changing the design and activities in the breeding program;

• Establishing synergetic roles and sharing responsibilities for breeding at larger scales;

• The decentralized design of the breeding programs helped achieve sizeable genetic gains despite the limited resources and the complex environmental and socio-economic contexts;

• The sustained collaboration of farmers and breeders resulted in detectable contributions to overarching goals, such as:

– Enhanced food security, with understanding of and breeding for traits required for reduced risk to climate variability (Haussmann, et al., 2012; Weltzien, et al., 2006b) and yield improvements expressed under poor soil-fertility and farmers' low-input management systems (Kante, et al., 2017; Leiser, et al., 2015, 2012; Rattunde, et al., 2013). This helped to reduce the share of sorghum grain that farmers purchased for food while increasing the portion of harvest they sell (Smale, et al., 2018);

– Improved nutrition, particularly in view of micronutrient deficiencies that are widespread among women and children in West Africa (Bauchspies, et al., 2017; Christinck, Weltzien, 2013). This included understanding the women's practice of preparing separate meals for children with the grain they produce, along with selecting for vitreous grain and reducing micronutrient losses during decortication. It provided a pathway by which the benefits of bio-fortified varieties reach vulnerable groups, especially children;

– Empowerment of farmers: women and men initiated their own variety and cropping-system experimentation as well as methods of marketing seed and facilitating communication about seed among farmers and farmer cooperatives based on their learning and access to novel types of varieties (Weltzien, et al., 2018). They became co-owners of the variety development and dissemination process;

– Conservation and sustainable use of agro-biodiversity: our approach makes extensive use of local germplasm in breeding programs to produce a wider range of variety types that are made available to farmers through a decentralized system for variety development, seed production and delivery. This approach involves and responds to different types of farmers within and across contrasting agro-ecological zones (Weltzien, et al., 2018).

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Farmer field schools and participatory plant breeding in Zimbabwe

Hilton Mbozi, Joseph N. Mushonga, Patrick Kasasa

1 Introduction

Community Technology Development Organisation (CTDO) was established in 1993 as a non-government organization with a head office in Harare, Zimbabwe. Over the years, it has grown and now has offices in Zimbabwe and Zambia with a total staff of over 90 people. Its mission is to achieve poverty alleviation and sustainable development of marginalized communities by building farmer and household livelihoods capacities through research, technology innovation, technology packaging and dissemination, policy advocacy and lobbying, and knowledge management, through gender-sensitive and people centered approaches. It works on four major themes: food security; environment; agrobiodiversity; policy and advocacy. CTDO was one of the pioneers of community seed banking in Africa and globally; it established its first community seed bank in 1996. For more information: http://www.ctdt.co.zw.

Since 2014, CTDO together with its development partner organization Oxfam Novib, has established more than 150 Farmer Field Schools with funding support from the Swedish Development Agency (CTDT, 2019). The funds were made available through the Sowing Diversity = Harvesting

Security (SD=HS) program managed by Oxfam Novib. Farmer Field Schools (FFS) were established with the primary objectives of strengthening farmers' role in plant breeding and to broaden the genetic base of crops so that farmers have access to a wide diversity of crop varieties that have preferred traits. Farmers focused on four major crops of importance: sorghum, pearl millet, groundnut and maize.

Plant genetic diversity provides resilience to changing socio-economic realities and agro-ecological conditions. FFS and plant genetic resources entail a process where farmers learn and strengthen their engagement in crop improvement. Local and indigenous knowledge are combined with modern and institutional knowledge, making the in situ improvement of varieties more effective.

2 Methodology

Farmers use Participatory Plant Breeding (PPB), Participatory Variety Selection (PVS) and Participatory Variety Enhancement (PVE) to achieve their breeding objectives.Through the Farmer Field Schools, farmers are gaining access to "new" crop and varietal diversity from other communities, the Crop Breeding Institute, national and international genebanks and CGIAR centers. Together with CTDO, these institutions provide technical backstopping to the Farmer Field Schools. Experimental cycle after cycle, farmers then store the best performing varieties in the community seed bank. Best performers are selected from a number of experiments:

- Diversity plots: crops or varieties lost or new to the community are planted side by side and evaluated on performance according to criteria decided by the farmers (e.g., early maturity, which is increasingly demanded by farmers to cope with changing climatic conditions). The national gene bank plays a key role in the restoration of lost crops: it has repatriated more than 100 accessions of key crops including cowpea, finger millet, groundnut, pearl millet, pigeon pea and sorghum;

- Participatory variety selection: of segregating and stable lines/varieties of open-pollinated varieties and hybrids. For example, lines of open pollinated maize varieties, advanced lines of pearl millet, finger millet, groundnut and sorghum;
- Plant variety enhancement: of farmers' varieties and locally adapted modern varieties;
- Participatory plant breeding: farmers' deliberate crosses to generate new diversity. To date, two new varieties have been released as PPB varieties, although they were not registered with the inclusion of farmer or community names.

3 Partnerships

CTDO's operational approach is to build strong collaboration with other stakeholders through joint planning, implementation, monitoring and evaluation. Partners include communal authorities, ward councils, government departments (e.g., responsible for youth, women), members of parliament, ministers and other key government decision makers, AGRITEX (the national agricultural extension service), the national genebank, the Crop Breeding Institute, universities and CGIAR centers (CIAT, CIMMYT, ICRISAT). They all join forces for a common goal: to improve the livelihoods of farmers and contribute to seed and food security.

The SD=HS programme, through its collaboration with the national breeding program, and the international research centers ICRISAT and CIMMYT, managed to introduce a number of breeding materials since the 2015/2016 agricultural season. For example, in the 2016/2017 season, FFS received 33 lines of maize from CIMMYT, seven lines of sorghum from ICRISAT. In 2017/2018, 18 populations (F_3) of pearl millet were provided by ICRISAT to four FFS, the Crop Breeding Institute (CBI) provided 18 populations (F_4) of sorghum for PPB, nine advanced lines of both sorghum and pearl millet. In the 2018/2019 season, FFS received over 70 breeding materials from these institutions. From these introductions, farmers were able to select those lines that met their local needs. Two sorghum varieties were repatriated from the National Genebank, the Department of Research and Specialist Services of the Ministry of Agriculture, and from farmers in other communities or within the same community.

4 PPB results

The CTDO approach of crop improvement is leading to changes in the conventional breeding approach in Zimbabwe. The use of tools like the diversity wheel opened new avenues and created new thinking in terms of how farmers develop new varieties. For example, farmers set their breeding objectives based on the most preferred traits that make the varieties more adaptable to their agro-ecological conditions through selection. More than 70% of the objectives set by FFS focus on drought tolerance, early maturity and high yield. Breeding of crops is becoming more demand driven–a direct result of the FFS approach. PPB is a very empowering "tool" for farmers because farmers lead the research.

It is also a good tool for advocacy in favor of more farmer centered agricultural policies and laws.

Using the FFS methodology, smallholder farmers regularly interact with scientists and breeders from the Ministry of Agriculture's Crop Breeding Institute to evaluate the performance of stable lines of sorghum and pearl millet (Box 1). To date, this has resulted in the release of two pearl millet varieties (PMV4 and PMV5) by the Crop Breeding Institute based on the PPB process.

Farmers select the best performing materials and start to produce them in their own fields. Equally important, the programme made significant progress in restoring five popular farmer varieties of maize (garabha), pearl millet (nyati), sorghum (gokwe, cimezela) and groundnut (kasawaya) using Participatory Variety Enhancement, a component of PPB. Crop diversity grown per household has also increased from an average of five to eight varieties.

BOX 1 **Two examples of the crop improvement work** (Vernooy, et al., 2019)

The Chimukoko Farmer Field School is doing PPB on pearl millet. The Crop Breeding Institute provided 16 segregating populations and the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) provided a F_3 generation. Farmers set the following breeding objectives: early maturity, large panicle size and large grains. Selections started in the 2017/2018 season. For the second season, farmers selected the best performing plants as per the breeding objectives.

The Batanai Farmer Field School (15 women and 3 men) is in its third year of operations. The group started with seed from a group member: the local sorghum variety (Gokwe) is common in the ward and has been grown for more than 20 years without enhancing its performance resulting in low yields. It increasingly became susceptible to diseases. The group set the following breeding objectives: large heads (which have a bearing on yield), drought tolerant, pest and disease resistant, early maturity to "escape" the increasing occurrence of mid-season droughts, and ease to process. The FFS members have been selecting and harvesting the sorghum plants with large heads that matured in less than 90 days for the past three seasons. The FFS is now in the final year of selecting sorghum. They will then start multiplication and distribution seed within and outside the community. The FFS members are depositing seed of this sorghum variety (plus many others) in the Nyamarodza community seed bank.

5 Other action research results

CTDTO stimulated farmer seed production and distribution in the 1990s, but initial attempts were not very successful. Only after the establishment of the first community seed bank in Uzumba-Maramba-Pfunwe (UMP) district in 1999, more systematic work was done which was further improved through the Farmer Field Schools using the so-called cluster method. In this method, farmers take responsibility for producing seed of one to four crops on an area ranging from 0.2 to 0.6 hm^2. Right now, crops include Bambara nut, cowpea, groundnut, pearl millet, finger millet, maize (open pollinated varieties and in some cases, hybrids) and sorghum.

In many communities, seed produced through this method is sold locally, via the community seed bank, at seed fairs and during field days. CTDO and AGRITEX provide technical support. Farmers from the UPM community seed bank explained that this form of seed production has first a social function: to make sure that everyone has access to good quality seed of crops important for smallholder farmers and neglected by the large seed companies.

However, to expand farmer led seed system development on a larger scale, CTDO in partnership with Oxfam-Novib, recently also developed another initiative: the establishment of the Champion Farmer Seeds Cooperative Company (formally registered in 2016, launched in 2017). Champion Seeds is both a commercial and social enterprise, with farmers as stakeholders, producers (on a contract basis) and buyers of high quality, certified seed of highly adaptable and high yielding varieties of dryland grains and legumes. Now still benefiting from donor support, the company is making good progress toward organization and financial sustainability. In its first two years of operation, the company produced almost 150,000 tons of certified seed (CTDO, 2018).

6 Gender (analysis) and women empowerment

The PPB research has empowered women who are now able to make decisions about what to grow, where to grow the crops and more importantly, what to eat. The diversity wheel tool used in the PPB FFS has created awareness about which crops are important for what reasons and how gender preferences influence crop choices. For example, in terms of traits preference, men like traits related to yield and economic value, but women usually prefer traits such as easy to process, color, aroma and taste.

The PPB now takes these gendered preferences into account.

7 Policy influence

The PPB FFS are linked to several institutions including the Department of Crops Research (notably the Crop Breeding Institute) within the Ministry of Lands, Agriculture, Water, Climate and Rural Resettlement in Zimbabwe, ICRISAT (in Bulawayo and Nairobi, Kenya), CIMMYT in Harare, the National GeneBank of Zimbabwe and to community seed banks. These institutions are key sources of the breeding materials which farmers within the SD=HS supported project sites have accessed. CTDO signed a Memorandum of Understanding (MoU) with the Ministry of Lands, Agriculture, Water, Climate and Rural Resettlement; and has accessed breeding materials from CIMMTY and ICRISAT under a Standard Material Transfer Agreement (SMTA).

PPB is relatively new concept among farmers and breeders in Zimbabwe. Previously, all crop breeding was the domain of breeders who would only share stable materials for multi-locational testing in farmers' fields before carrying out distinctness, uniformity and stability (DUS) tests for selected (preferred) lines and presenting the results to a national variety release committee for their consideration and official release (or rejection). With the introduction of PPB under the SD=HS project, the thinking among breeders has started to change: they now see value in involving farmers in evaluation of the performance of segregating populations. PPB ensures that farmer preferences are considered at a very early stage in the crop breeding process. Farmers and breeders interact from the start of the process leading to decisions made by farmers to select for traits that they prefer. The fact that breeders are seeing value in involving farmers through PPB has started to bear policy influence as they are availing segregating materials under strict conditions to farmers working in FFS to contribute to the breeding processes.

On the other hand, the use of seed stored in community seed banks as a second source of breeding materials in the FFS is another avenue to influence policies. When policy makers attend seed fairs, farmers of the FFS and community seed banks always advocate for their rights to save, use, exchange and sell seed (Mushita, et al., 2015). The combination of PPB and FFS has a great potential to change the policy landscape in favor of smallholder farming.

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Participatory plant breeding in Honduras: Past successes and future challenges

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1 Introduction

Honduran farmers' involvement in organized agricultural research, participatory plant breeding and seed production, can be traced back to 1993. At that time, the first farmer research teams, commonly known by the Spanish acronym CIALs, or local agricultural research committees, were set up in Honduras by the International Centre for Tropical Agriculture (CIAT) with the support of local agronomists. Over a period of 25 years, the CIALs have become hubs of farmer research in the hitherto-neglected hillside regions of Honduras. Today, there are 153 CIALs spread across hillsides in eight of the country's 18 departments. Two Honduran non-governmental organizations, the Foundation for Participatory Research (FIPAH) and the Program for Rural Reconstruction (PRR), each supported by a team of farmer facilitators, work with and provide support to most of these CIALs. Backstopping the work of these NGOs are formal sector plant breeders, particularly those at the Panamerican Agricultural School, Zamorano. They have supported farmer experiments with access to germplasm in beans and maize, provided expertise in seed crossing and selection of disease-free lines, and offered regular technical advice. In Honduras, farmer participation in seed research and production is part of an organizational network that has served to foster a culture of innovation in seed diversity and food security for the benefit of the country's poorest rural inhabitants.

2 Methodology

The CIAL methodology was developed by Dr. Jacqueline Ashby and her team in the Hillsides Program at CIAT in the early 1990s. The methodology provides a framework for the selection of farmer researchers (women and men), identification of research priorities for each community, and the research tools for planning and assembling small-scale agronomic trials using controlled comparisons. The stepwise CIAL approach allows communities to make informed decisions about meeting their needs for seed and food security. The CIAL methodology and adapted versions of it have been used in various countries in Latin America, e.g., Nicaragua, Ecuador, Guatemala, in addition to Honduras, as well as in sub-Saharan Africa (e.g., Sanginga, et al., 2006). What stands out in the Honduran context is the faithfulness with which both FIPAH and PRR have adhered to this approach over a very extended period. In the case of FIPAH, a research foundation, it is at the core of what the NGO does (http://fipah-hn.org): the CIAL methodology is the organizing principle around which all its activities are structured. Nevertheless, FIPAH has made changes in the way that the methodology developed by CIAT, is now practiced in Honduras.

At the outset, the public process of electing CIAL committee members led to the exclusion of women and of more marginalized community members; people tended to vote for the usual leaders, most of whom were men. By introducing secret ballots and by making CIAL membership open to anyone interested in joining the group, the CIALs became more inclusive and better able to represent the goals of different communities. Impact studies undertaken in 1997 and 2004 showed how membership in the CIALs supported by FIPAH had shifted in the intervening years from one dominated by local elites who sought to capture the rewards of research for themselves, towards one that served community interests. Moreover, this shift was gendered in nature–a trend that has continued up to the present. Thus, while there were no women present in the first CIALs, by 2018, women made up 50.3% of the membership and occupied 67% of the leadership positions in the CIALs, and related organizations (savings and credit and micro-business) that make up the regional CIAL associations supported by FIPAH (FIPAH annual report, 2018).

3 Partnerships

In the mid-1990s, CIAT trained a dozen Honduran NGOs in the CIAL methodology. Only PRR, and FIPAH (the latter of which emerged from CIAT's program) have continued to utilize the CIAL methodology; other NGOs either failed to survive as organizations, or they have not persisted with this approach. FIPAH and PRR are both supported by Canadian NGOs, USC Canada, and World Accord respectively. Unlike many Honduran NGOs, they have had access to regular funding over an extended period. This has allowed for the uptake of the CIAL methodology and for early problems to be worked out. United in a shared approach, the two NGOs have collaborated as sister organizations, attending each other's events and celebrating each other's advances and successes. They have also both worked with breeders at the Pan American Agricultural School, Zamorano.

Initially, breeders at Zamorano provided support to CIAL trials in the form of previously released varieties to try to find materials that might outperform those of the farmers. The primary problem identified by hillside farmers was food insecurity. Farming families would commonly run out of maize and beans several months before the next harvest came due leading to hunger and indebtedness. With the goal of raising yields, the Zamorano breeders supplied the CIALs with formal sector varieties of maize and beans to use in controlled comparisons against farmers' traditional varieties. However, over a period of about four years, it became clear that this approach was not the solution. On average, the scientist-developed varieties performed poorly under hillside conditions against farmers' own materials. It was at this stage, supported by the Development Fund of Norway, that Zamorano, FIPAH, and PRR switched focus. Together, they moved towards participatory plant breeding (PPB) in an effort to find new varieties for the marginal conditions confronting most CIALs. The partnership between these three organizations has been instrumental in moving the CIALs towards collective solutions for food insecurity.

4 Participatory bean breeding

The process of varietal development in beans is summarized below through two narratives. The first provides an example of localized PPB in early generations (Macuzalito); the second (Cedron) is an example of varietal selection in advanced generations. Parts of the Macuzalito and Cedron narratives were originally published in *Agriculture and*

Food; both have since been updated. In the first case, CIAL members, supported by FIPAH, determined the criteria for improving their local landrace. Members drew up a list of the characteristics they liked, and those that they wanted to improve. This information, along with local seed, was passed onto the Zamorano breeders. In the second case, the CIALs participated in the evaluation of advanced lines as part of broader regional adaptation and yield trials led by Zamorano. The decision to go for one option over another depends on many factors, including the capacity of specific CIALs to manage genetic materials in early generations, the expressed germplasm needs of specific CIALs and the capacity of FIPAH and Zamorano to support whichever process is selected by the farmers.

4.1 Macuzalito

Macuzalito was the first PPB bean released in Honduras. It was developed with the support of Zamorano, at the request of CIAL members and FIPAH, in the upland area around Yorito. The variety was derived from one of the most widely used local trailing landraces, Concha Rosada. The improved landrace has gained broad acceptance amongst both CIAL and non-CIAL members.

At Zamorano, scientists selected five elite lines for crossing with Concha Rosada seeking to improve disease resistance, yield and architecture while retaining the desirable traits of the landrace. Amongst these was early maturity. Fast maturing varieties are highly valued by poor farmers, especially by women, because they shorten the hungry period and provide food at an earlier date than later maturing materials. Earliness, farmers tell you, allows the variety to "escape poor weather", such as drought or heavy rains, depending on the growing season. However, farmers recognize that this benefit is offset by lower yields than those provided by later maturing varieties. Therefore, hillside farmers typically include both early and late maturing varieties in their seed portfolios.

The development of Macuzalito involved 53 members (30 men and 23 women) from four CIALs over four years. Originally, the process had been conceived by Zamorano as being centralized in one upland community. However, to ensure adaptation to local conditions, the four participating CIALs decided to decentralize it. They selected materials amongst (F_3) lines from 120 families for planting in their own communities, located at between 1,350 and 1,650 metres above sea level (masl). The ten best results from the individual community trials subsequently underwent replicate trials (F_6) in the four communities, along with five materials selected on-station by Zamorano, plus the local check. At that stage, farmers selected four lines for multiplication (F_7), followed by verification trials from which they selected one line, Macuzalito, for local varietal release. None of the lines selected by Zamorano featured amongst those identified by farmers. This reflected the very different environmental conditions of the two participant groups, as well as differences in preference criteria used by farmers compared to those typically employed by the scientific community. Macuzalito, named after the highest point in the municipality, had the best traits on average of the finalist materials: good yields (but not the highest), including moderate maturity; medium disease tolerance and good commercial value. It was released in the municipal government seat of Yorito in 2004.

A sister-line of Macuzalito was released nationally in El Salvador in 2012 by the government agency, Centro Nacional de Tecnología

Agropecuaria y Forestal (CENTA; the National Agricultural and Forestry Technology Centre), in collaboration with Zamorano, with the variety name Centa Cpc. However, Macuzalito was excluded from Honduran national multi-locational validation trials in May 2018 due to lack of seed availability.

4.2 Cedron

Cedron was the product of a double-cross using four scientist-generated materials. It was selected by CIAL Chaguitio from 16 advanced lines (F_6) that were part of a Central American Regional Adaptation and Yield Trial (known by the Spanish acronym, ECAR) provided to FIPAH by Zamorano in 1999 with a view to involving the CIALs in bean varietal selection. Line EAP 9508-93 was chosen by CIAL members for its high yield, high tolerance to disease and drought, its upright bush architecture and its adaptation to high altitude zones (1,000-1,400 masl). The members named it Cedron after the mountainside where local farmers cultivate beans and where the research had taken place. However, the dark red colour of the bean reduced its commercial value. Zamorano subsequently improved the colour, increasing its marketability and broadening its appeal. Cedron was released at the municipal level in Yorito in 2007 and since then has been used widely, both locally and regionally. It has demonstrated consistently high yields in more than 32 communities in five municipalities at high altitudes. It also demonstrated high yields, even in lowland areas, in trials conducted between 2011-2015, across the country. For this reason, the Food and Agriculture Organization (FAO) has promoted Cedron extensively in the western departments of Intibucá and Lempira.

In 2014, Cedron was amongst six PPB materials included in a Triadic Comparison of Technologies (TRICOT) evaluation developed by Bioversity International (Steinke J, van Etten J, 2016). The PPB materials, including Cedron, outperformed the formal sector check on the majority of criteria; neither altitude nor zone explained any differences, except on the criterion of vigor. In 2016, in another TRICOT evaluation, Cedron was judged to be the best variety based on yield, commercial and culinary criteria by 65 farmers who assessed a set of nine materials (which included three nationally released varieties), under different conditions in different regions of the country.

In 2018, Cedron was one of five PPB varieties placed in national validation trials at 200 locations in the major bean areas of Honduras with a view to national release. However, these trials are opposed by some branches of government, and the validity of these trials are questioned.

The two narratives reveal the potential of PPB varieties to meet not only the needs of local farmers, but also those of farmers in other regions, and even in other countries. Farmers' selection criteria are a response to local conditions, but, with the support of Zamorano, genetic improvements have been incorporated into the materials to broaden disease resistance and to include traits that allow for coverage of wider geographical areas. Breeders have worked in an iterative manner with NGO partners and CIAL members to improve disease resistance, grain colour, etc., using a variety of methods, including molecular markers, to enhance broad spectrum adaptability. It is this collaborative nexus between breeders, NGOs and farmer research teams that has helped to deliver an ongoing flow of new bean varieties to hillside farmers across Honduras over the past 12 years. However, as we discuss in the section on Policy Influence below, registration of PPB varieties and certification of seed are prevented.

5 Gender analysis

As mentioned, women have become key participants in the CIALs, presently making up just over 50% of total membership. This is a surprising statistic given the perception that in Honduras agriculture is a male activity and that women's rightful place is in the home. This perception is dominant in the rural areas, but also evident more generally within the culture. Studies using mixed methods (quantitative, qualitative, life histories, participant observation) conducted between 2004 and 2011 (Classen, et al., 2008; ASOCIAL, Classen, 2008; Humphries et al., 2012) show that women's participation in the CIALs is perceived to have had a significant impact on their relative freedoms, and on their decision-making roles, within their households and their communities. These perceptions are largely attributable to women's self-confidence, and the confidence that their spouses have in them, due to their participation in the CIAL. Thus, women CIAL members were significantly more likely to have made changes in their level of available freedoms in the five years prior to the survey. These changes include freedom to occupy positions in the community, take on paid employment, attend workshops outside the community, administer household finances, visit with neighbours and friends, and work on the farm with husband, when compared to non-CIAL women. Similarly, CIAL-women were perceived to exercise significantly more decision-making in key areas: sale of farm products, what crops to plant and where to plant them, household food purchases, spending of household money, association with local organizations (Humphries, et al., 2012). In the case of CIAL women's association with local organizations, this increased from a position where only half of women CIAL members participated in even one organization prior to joining the CIAL, to having an average of four memberships once they became CIAL members. From a position of extreme marginalization in their communities, CIAL-women have emerged as organizational joiners at rate above that of non-members and indeed, above the rate of male CIAL members. CIAL membership for both men and women, but particularly for women, has presented members with an opportunity to develop social capital in their communities. They are perceived to be leaders with specialized expertise and, therefore, are frequently invited to participate in other community organizations. This in turn, increases members' self-confidence, particularly that of women given their subordinate role in local communities and, more generally, in Honduran society.

6 Capacity development

The CIAL methodology teaches farmers the scientific method of using controlled comparisons and randomized plots, replicated across multiple sites. Farmers learn to plan experiments, set them up, evaluate them, and analyze the findings. This sequence is represented as a series of connected steps, the so-called CIAL ladder. Given that educational levels in the rural areas of Honduras are very low, it is not surprising that many CIAL members struggle initially with learning the CIAL approach. Average years of primary school for women (CIAL and non-CIAL) and non-CIAL men were found to be in the range of 2-3 years. Only amongst men was there a significant difference in educational attainment (4.03 years for CIAL vs. 2.37 years for non-CIAL men), suggesting that the methodology appealed to those men who had stayed longer in primary school. However, the methodology has not been a deterrent to adoption, even for those with fewer than three years of primary school, given support from farmer facilitators who make inclusiveness their priority (Classen, et al., 2008).

CIAL members will often tell you how the CIAL methodology has affected them in all areas of their lives. Learning through randomized, controlled comparisons allows CIAL members to better make social decisions too, such as assessing one familial decision against another, or for planning ahead. The latter has proven particularly important in the area of food security. When families regularly ran out of food several months prior to the next harvest, or when they were forced to give up a large portion of their harvest to a moneylender to pay back a previous loan, planning was not a regular household activity. Farmers knew their harvest would not last them through the year, so there was little point in trying to plan. However, once yields were raised through better crop management and improved seeds, families began to budget food supply on a monthly basis with a view to meeting their needs throughout the year.

FIPAH has supported CIAL members through budgeting exercises—both of food supply and household expenses. Such capacity development explains why CIAL members tell you that they no longer think as before. They are forward-looking, or futuristas in Spanish (futurists), as they call themselves, in comparison to conformistas (conformists), whom they describe as fatalists: those who believe that they will die poor, just as they were born, and that the life course cannot be altered. Through the CIAL approach, its members firmly believe that the life course is not immutable.

7 Policy influence

As mentioned earlier, some branches of government bureaucrats strongly reject the decentralized approach inherent in PPB seed generation. The decentralization inherent in PPB challenges centralized authority over seed regulation. With the support of Zamorano, FIPAH and PRR, all of whom receive funding for PPB research from overseas donors, seed production is effectively bypassing the traditional channel of nationally-authorized government release of new seed. However, while farmers' networks, particularly through the CIAL regional, and national associations, can deliver seed to CIAL members in different parts of the country, this supply chain nevertheless limits who can access seed outside the CIALs. It also affects the price that producers can expect for their seed. Without national release, farmers' seed must be sold as "grain", at a price below that of seed. This affects the growers' incentive to produce seed. Under current seed legislation, certified seed requires that the variety be registered. Registration depends on prior national release involving results from trials across the major bean producing regions of the country. The cost of organizing these trials is clearly prohibitive for small NGOs and CIALs.

Recently, the private sector has become interested in selling PPB seed, both domestically and internationally. However, it cannot do this without prior seed certification. This interest on the part of the private sector has stimulated the organization of a National Bean Chain to promote the supply and marketing of beans, as well as helping to promote discussions about the regional release of bean varieties. Support to accept the idea of regionally approved varieties has been forthcoming from agricultural government agencies across the spectrum, except from the one agency that controls national varietal release, seed registration and certification. Centralization has historically limited hillside farmers' access to adapted seed and negatively affected the food security of country's poorest inhabitants.

What is evident from this discussion is that PPB poses a threat to traditional policy around seed and those interests that are vested in maintaining the status quo.

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Participatory crop improvement for promoting conservation and sustainable use of crop genetic resources in Nepal

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1 Introduction

Commonly used participatory crop improvement (PCI) methods in Nepal include: i) informal research and development, ii) participatory variety selection (PVS), iii) participatory plant breeding (PPB) and iv) grassroots breeding or landrace enhancement. In all these methods, the participation of farmers and stakeholders in the decision-making process of new variety development, testing and dissemination is central. PCI began in the early 1990s and resulted in many successes. PPB started in 1992 in a highland village by giving F_3 population of three crosses of cold tolerant rice varieties to a few interested farmers. The main objective of the PPB programme was to develop new cold-tolerant rice varieties; the community only had a few landraces to work with. After a few years of selection in farmers' fields by farmers and researchers and testing in the national yield trial, a new rice variety named *Machhapuchhre 3* was released by the national system (Joshi, et al., 1997). Later, the PPB method was replicated in the high yield potential production system in the *terai* (lowland) region; as result, a number of additional new rice varieties were developed, released and registered by the national system. In the late 1990s, this method was applied to promote conservation and use of local rice varieties in Kaski and Bara districts and to improve local maize varieties in Gulmi district.

Another variety development method practiced was collection of germplasm in farmers' fields, assessment at the research station and release by the national system. The aim of this method, however, was not to promote conservation and use of local crop diversity *per se*, but to bring promising local varieties in the formal system. Once such local varieties are released or registered by the National Seed Board (NSB), they are categorized as improved varieties. A systematic method for landrace enhancement led to the development of *Pokhreli Jethobudho*, a popular aromatic rice landrace in Pokhara valley (Gyawali, et al., 2010). Applying more or less the same method, *Kalonuniya* rice landrace in Jhapa district, *Rato Kodo* (a finger millet landrace) in Jumla, *Dudhe Chino* (a proso millet landrace) in Humla, Panhelo and Khairo Simi (common bean landraces) in Dolakha and Tilki rice landrace in Dang districts, were identified and assessed. These varieties are now in the final development stage and for some, variety release/registration proposals have been submitted to the NSB. Community seedbanks or community-based seed producer groups are established or strengthened to making the newly developed varieties easily and continuously available to farming communities in the locality.

Local Initiatives for Biodiversity, Research and Development (LI-BIRD) applies two types of participatory crop improvement methods: i) use of selected local varieties as a parent for PPB crossing and ii) enhancement of landraces through a selection process, also known as grassroots breeding for promoting conservation and sustainable use of crop genetic resources in Nepal. This chapter discusses these methods in more detail and reflect on the achievements to promote conservation and sustainable use of crop genetic resources.

2 Partnerships

In PCI, farmers and scientists work together from step one (setting the breeding goal) to the registration of the newly developed variety and local seed system development. Farmers may or may not be organized in groups or cooperatives at the early stage, but it is essential to have a legally registered farmers' group or cooperative to develop a local seed supply system of the varieties developed using the PCI method. For LI-BIRD, farmers and farmer groups are the key actors. Similarly, it is important to work with commodity programs under the Nepal Agricultural Research Council (NARC), such as the National Rice Research Programme (NRRP) in the case of PPB rice, the National Maize Research Programme (NMRP) in the case of maize, and so on. The nearest Regional Agriculture Research Stations under NARC are also consulted. Some of the grassroots breeding work has been carried out in collaboration with the National Genebank of Nepal. The agriculture extension agencies were mobilized as well. Technical support from Bioversity International and financial support from various agencies including DFID, CIMMYT, IDRC, IFAD, UNEP/GEF, SDC and the Development Fund have been instrumental for the continuation of PCI work in Nepal.

3 Participatory plant breeding

To start PPB, a rigorous appraisal is conducted through group discussion, participatory four-cell analysis and positive and negative trait analysis of local varieties to identify the best local varieties for using as PPB parents. Complementary parents are selected by plant breeders based on the negative trait(s) or traits to be improved. In this step, a clear breeding goal is defined. Crossing of the selected parents is done at the research station or by a trained person in the farmers' field. Because of the limited number of seeds obtained from crossing, the first generation (F_1) is cultivated carefully by the researchers at the research station or in the farmers' field, but fully controlled by the researcher. In the second generation (F_2), the population is given to a few interested farmers who have been trained in PPB methods. They will observe likely variations in the PPB plot and plan the subsequent selection step. Once the crop comes nearer to maturity, plant breeders and farmers jointly select the farmer preferred lines, based on the breeding goal agreed upon. This process is repeated for a few years or until a few uniform, farmer-preferred lines are obtained.

The uniform lines are then tested for various qualitative and quantitative traits, screened for diseases and other agronomical and morphological traits as determined by the researchers. Seed multiplication of farmer-preferred lines takes place to make seeds available to many farmers for testing and dissemination. At this stage, women farmers are engaged to look at post-harvest traits, such as milling recovery, cooking quality, taste. Market demand for farmer-preferred varieties is also assessed so that varieties are not rejected due to poor marketability. Then, the best performing variety according to these combined traits is proposed for release or registration by the NSB. The farmers or the farmer group involved in the breeding together with the plant breeder and other stakeholders involved in the process are considered the variety owners. The farmers or farmer group then produce seed and apply for the certification of the released/registered or pre-released/registered variety according to the provisions of the National Seed Regulation responding to demand in or outside the community.

4 Grassroots breeding

To initiate grassroots breeding, the local crop diversity that plays an important role in local food security or income generation is identified. Often, the local diversity is under stress. Breeding goals for selected crop(s) and variety/varieties for breeding are determined based on in-depth discussion with the community. Then, seed samples are collected; sometimes a few, sometimes a several hundred or more. While collecting seed samples, a minimum population is maintained to capture the heterogeneity of the population. Collected samples are evaluated in terms of cultivation challenges; the lines with no or little problems are identified for further evaluation. Such screening is done for two to three years. Once the preferred lines are identified, the same process as described for PPB is followed for qualitative and quantitative assessment, registration, seed production and distribution.

5 Results

5.1 PPB case: Maize

In 1999, a farmer-led PPB program on maize was launched in the mid hill area of Gulmi district where maize is cultivated mainly on sloping terraces as main staple crop under rain-fed conditions. Program funding support came from the CGIAR System-Wide Program on Participatory Research and Gender Analysis. In Gulmi district, farmers were facing problems of excessive lodging, leaf diseases and low maize yields, but they did not have other options than cultivating landraces. Therefore, the breeding goal of the program was to develop new maize varieties to address these problems. A Farmers' Research Committee (FRC) was formed to lead the process representing Resunga Shrijanshil Farmers Group of Darbar Devisthan and Malika Farmers' Group of Simichaur. Later, these farmer groups were registered as independent cooperatives and considered owners of the new varieties developed. To start the PPB, a small population of F_1 seed of five randomly crossed maize varieties, namely Rampur Composite, Rampur 1, Across 9331, Narayani and Rampur were obtained from the NMRP, Rampur, Chitwan. The F_1 population was given to two farmers in the two mentioned villages. After a few years of mass selection, a population was identified as the best and named Resunga composite. It was released at the NSB. Resunga is a well-known religious place in Gulmi district. In parallel, as second cross was made between the local Thulo Panhelo and the released variety Rampur Composite. Form this population, another variety Gulmi 2 was identified as the best and registered by the NSB. The variety was named after the district where the variety development took place. This variety has all the positive traits of the local Thulo Panhelo, according to farmers' perceptions. Two cooperatives do yearly seed production and source seed production of these two PPB varieties supervised by LI-BIRD plant breeders.

5.2 PPB case 2: Rice

Under the in situ conservation project jointly implemented by LI-BIRD, NARC and Bioversity International from 1998 to 2006 in the three agroecological zones, several crosses of local and improved rice varieties took place. Local varieties were identified by farmers and exotic complementary parents identified by plant breeders of LI-BIRD, NARC and Bioversity International. One of the crosses was Dudhisaro (landrace) and Harikatha 1 (exotic) in Kachorwa village of Bara district in the central terai of Nepal. Crossing between the selected parents was done by the researcher and selection of segregating materials right from the F_2 generation was done jointly by farmers and the researcher in farmers' fields. After a few years of selection, a few farmer-preferred lines were developed; line "4" was highly preferred and given the name Kachorwa 4. At the community level, the activity was led by a farmers' organization called Agriculture Development and Conservation Society (ADCS). The variety was submitted to the NSB for registration, but it did not meet the required criteria. Notwithstanding this setback, the ADCS operated community seed bank has continuously produced about a ton of source seed to sell to farmers in the locality every year since 2003.

5.3 Grassroots breeding case: Enhancement of rice landraces

LI-BIRD has carried out landrace enhancement work in three rice landraces one each in Kaski, Jhapa, and Dang districts of Nepal. The first case was Pokhareli Jethobudho in Kaski district carried out under the In situ Conservation project from 1999 to 2006. Jethobudho was a popular aromatic rice landrace in the Pokhara valley, but some farmers and consumers started complaining about its quality. Blast disease and lodging problem were also reported. Therefore, the project team decided to work on the enhancement of this variety and collected 338 samples from seven different villages of the Pokhara valley. The collected lines were evaluated for a few years and selection was done to address the complaint of farmers and consumers. After a few years of careful evaluation and selection in farmers' fields, six lines were identified as superior in terms of disease resistance, level of aroma, nonlodging and high yielding. These six lines were then proposed as Pokhareli Jethobudho for release as a bulk, which was accepted by the NSB. Every year, a few farmers' groups produce about 10 ton seed of Pokhareli Jethobudho with technical support from LI-BIRD. Later, the same method was applied for the enhancement of *Kalonuniya* rice landrace in Jhapa and *Tilki* rice landrace in Dang in the eastern and western *terai* of Nepal respectively. While Kalonuniya is in the final stage of getting registered, the proposal of Tilki is being developed for submission to the NSB. Both Kalonuniya and Tilki were about to disappear from Jhapa and Dang, but as a result of the enhancement efforts and the availability of quality seeds from community seedbanks, both of these varieties have again become common in the respective area.

5.4 Grassroots breeding case: Assessment of two bean landraces

The Local Crop Project (LCP) jointly implemented by LI-BIRD, NARC and Bioversity International with financial assistance from UNEP/GEF, conducted research on eight mountain crops including bean (*Phaseolus vulgaris*) from 2015 to 2019. Dolakha was one of the four project districts where the local project team identified two promising local bean varieties locally known as Panhelo and Khairo. These varieties were being cultivated by just a few farmers in a small area in 2015. Together with farmers, the project team decided to include these two promising varieties in the bean research. All the required data for variety registration has been collected and a proposal is in the process for submission to the NSB. The Jugu community seedbank is already producing and selling seed of both varieties, which are being cultivated by many farmers in Jugu and surrounding area and in other neighboring districts. This is an example of how a rare variety can become common after a few years.

5.5 Grassroots breeding case: Assessment of millet and minor millet landraces

The Local Crop Project also conducted an assessment of finger millet landrace called *Rato Kodo* in Jumla district, proso-millet called *Dudhe Chino* in Humla district and foxtail millet called *Bariyo Kaguno* in Lamjung district for the registration by NSB. Among these, the finger millet landraces, *Rato Kodo* is commonly grown in Jumla district and no other varieties can compete with it in terms of yield and other traits. It has a high potential for dissemination in other districts once registered. The proso-millet variety *Dudhe Chino* in Humla is also a commonly cultivated variety. Until now, no variety of proso-millet has been registered by NSB. The foxtail millet variety "*Bariyo Kaguno*" was about to disappear from the community in Lamjung. While discussing the nutritional value of the crop, farmers renewed their interest in it. An assessment of this variety was carried out with the aim to register it by the NSB. In Nepal, the

Seed Act does not allow the commercialization of any crop variety if not registered/released by the NSB. The recently established Crop Development and Agrobiodiversity Conservation Center has a program to promote these crops, but unless registered, the center cannot provide any support for seed production and promotional activities. The LCP team is about to submit the variety registration proposal of these varieties. The Ghanpokhara Community Seedbank is promoting a local delicacy, pudding of *Bariyo Kaguno*, at local and national fairs. This product is in high demand. Farmers cultivating foxtail millet are also making a good amount of money from this renewed mountain crop.

5.6 Grassroots breeding case: Collection and assessment of amaranth landraces

With financial assistance from IFAD through Bioversity International, LI-BIRD carried out a study on the varietal diversity of amaranth in Nepal to identify and promote accessions suitable for grain and leafy vegetable use. Altogether, 435 accessions from various sources including the collection of the National Genebank were obtained for varietal characterization and evaluation. These accessions were grouped into two categories, vegetable type and grain type, and assessments were conducted in Jumla, Kaski, Dolakha and Nawalparasi districts. Seed of promising accessions was provided to farmers for testing and understanding farmers' preferences. Some vegetable and grain types have been selected for registration and dissemination. Among the selected accessions, a vegetable type accession collected from Ramechhap district has been registered as "Ramechhap

Hariyo Latte" by the NSB. It is now disseminated through the formal and informal systems. This is the first amaranth variety ever released/registered in Nepal. A few other varieties of grain type are in the process of getting registered. The release of the amaranth variety should encourage more research on hundreds of other neglected and under-utilized, but nutrition dense and climate resilient crop varieties.

6 Impact on farmers' seed systems and rural livelihoods

All the varieties developed through PCI are registered or released as jointly owned by a farmers' organization, LI-BIRD and other stakeholders involved in the variety development process. The farmers' organization takes charge of PPB seed production (including source seed) with technical support of LI-BIRD and the relevant government entity. The seed produced by farmers' organizations and community seedbanks is primarily sold locally. This process directly contributes to the improvement of farmers' seed systems and promotes the exchange of seed. Every year, the cooperatives in Gulmi involved in the variety development process of *Resunga Composite* and *Gulmi* 2 maize variety, produce about 10 ton of seed per variety and sell it locally. A farmer group in Kaski district produces nearly 10 ton seed of *Pokhareli Jethobudho* and markets it through a network including the municipality, extension agency and private seed entrepreneurs. The seed production and dissemination of PPB varieties are directly contributing to enhancement of the local seed system and income of the farmers involved in seed production activities. The *Kalonuniya* rice landrace in Jhapa was about to disappear from the community, but now, after the enhancement process, many farmers cultivate it in a large area, obtaining a 250% higher price compared to other improved varieties.

7 Capacity development and women empowerment

The PCI process contributes to capacity development of farmers, farmer groups and women empowerment. Various trainings, exposure visits, discussions and interactions are conducted throughout the process and men and women take part equally. In the variety development process, men are more involved in the selection in the field, but the postharvest assessment is usually done by a group of women. Some farmers who were involved in the variety development process are also invited in the variety registration proposal sharing meeting at the Seed Quality Control Center (SQCC). Thus, they learn about the procedure and can make their views heard to the Variety Release and Registration Sub Committee (VRRC). The capacity of community seedbanks and farmer groups involved in the PPB process is developed concerning quality seed production, seed storage and marketing, and legal aspects of seed transactions. The capacity building of farmer group and community seedbanks is key as the PPB programs carried out with financial assistance from external agencies is available for limited time.

8 Policy influence

A noticeable policy change due to LI-BIRD's PPB efforts was the revision of the variety release and registration format with some provisions for accepting data collected using participatory methods. This was possible through the evidence-based policy advocacy approach of LI-BIRD. LI-BIRD and the National Genebank steered another policy change, although likely more indirectly due to PPB: the SQCC has developed a separate format for the registration of local varieties with relaxed provisions. The varieties–two bean landraces, millet and minor millet landraces, mentioned in the grassroots breeding cases above will be registered following this provision.

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Foundation of sustainable food production: Experiences from farmer breeding in Southeast Asia

Normita G. Ignacio, Norminda P. Naluz

This chapter draws on more than two decades of experience of the Southeast Asia Regional Initiatives for Community Empowerment (SEARICE) of working together with farmers and plant breeding institutions. It highlights how participatory plant breeding (PPB) can contribute to sustainable food production and livelihood. It also presents the challenges that restrict farmer breeding from contributing to agricultural development towards sustainable food production systems.

1 Journey to agricultural biodiversity

Concerned by the dwindling state of agricultural biodiversity globally and in Southeast Asia in particular, SEARICE embarked on a plant genetic resources conservation programme in the early 1990's. The programme, which implemented a curatorship or seed keeping approach, distributed traditional seeds of staple crops, vegetables, and root crops to farmers as part of on-farm conservation. During implementation, SEARICE noted that farmers discarded varieties that did not perform well and retained only those that addressed their needs. From this experience, a very important lesson was learned: not all farmers can be curators. Purely conservation of plant genetic resources cannot and should not be imposed on farmers, particularly smallholders, as they need every square centimeter of their land to provide food and livelihood for their families. In 1997, SEARICE changed focus from mere conservation work to crop improvement/development (SEARICE, 2005), with support shifted to farmer breeding as a way of conserving some of the genes of traditional varieties while improving the overall farmer plant genetic resources system. Farmers' technical capacities were strengthened, mainly through Farmer Field Schools (FFS), enabling the conservation and development of (new) varieties that address farmers' specific needs and preferences.

2 Lack of steppingstones

The challenge for SEARICE at the initial stage of PPB implementation was to find examples on which to anchor its work as there was a dearth in PPB knowledge and experience. Despite some studies showing that decentralized selection was a key factor in increasing response to selection (or the adoption of varieties), (Ceccarelli, Salvatore, 2015), existing PPB programs then involved farmers only at the later stage of the breeding cycle. SEARICE's work was guided by a strong belief that farmers should be able to decide what kind of varieties they want and how they should be involved in developing such varieties from beginning to end to ensure on-farm adoption. Almekinders and Hardon (2006) argued that formal plant breeding cannot adequately meet the demands of the farming population, and that there is a need therefore to strengthen the capacity of local farming communities to continually develop their seeds. A dynamic farmer seed system is essential to ensuring a country's food security. SEARICE also banked on the reality that only a few varieties developed by the formal breeding system eventually were used by farmers in their fields, due to their unsuitability to local conditions or inability to meet farmers' preferences. This situation motivated some researchers to try PPB (SEARICE, 2009).

3 Missing element in implementation

Changing conventional breeding practices was difficult. In the beginning, SEARICE country partners tapped the nearest plant breeding institution or genebank as source of materials for breeding and field trials and later as partner in some of the field implementation, but in most cases the commitment remained at the individual level through the supply of *ad hoc* pre-breeding materials to farmers. To make PPB work, this practice had to change and SEARICE believed that the best way to do this was to develop institutional partnership with plant breeding institutions. This was done in Bhutan, Laos, and Vietnam. Initially, there were biases and prejudices to be corrected, unlearning and learning to be facilitated. Farmers were worried that the new varieties they had successfully bred could be misappropriated. For their part, plant breeders were unwilling to share their breeding lines because they were not convinced that farmers could handle early generation materials. Through many open discussions between the two "parties" and adoption of a collaboration protocol, initial fears diminished. The use of a participatory process provided many opportunities for partners to recognize the valuable contributions of each other and learn from each other; thus, mutual trust and respect developed.

4 Bountiful harvest

From the implementation of plant genetic resources conservation through development and use (PGRCDU) in four countries (Malaysia, Philippines, Thailand and Vietnam) in the 1990s, SEARICE activities expanded to five other countries in Asia (Bhutan, Cambodia, Laos, Myanmar, and Timor Leste). Where possible, institutional partnerships with plant breeding institutions were forged. Over the years, technical interventions were strengthened, tools and methodologies were refined, and learning materials like curricula, FFS manuals and field guides were continuously developed and improved. Crop production expanded from rice to maize and currently to some legumes and vegetables. It has been more than two decades since the pilot implementation of PGRCDU and the initiative has yielded remarkable results.

4.1 Empowered farmers and farming communities

Most notable among the accomplishments of SEARICE and its partners are the numerous farming communities that have been able to keep their local seed systems functional. To date, SEARICE has worked with around 1,000 communities and more than 30,000 farmers, of which 40% were women, in nine countries. The capacity building interventions and activities have created positive changes in farming practices. Farmers trained not only their fellow farmers, but also agricultural extension agents. Likewise, farmers were invited as resource persons/speakers in primary, secondary and even tertiary schools to share their experiences with students. Along with the technical aspects, enhanced social skills led to more self-confidence among farmers. This was evident in the way they managed agricultural biodiversity and participated in resolving issues concerning their rights and welfare (SEARICE, 2012).

A notable demonstration of empowerment are the Seed Clubs and farmers' groups which farmers themselves organized. Currently, there are 342 Seed Clubs in the Mekong Delta in the south of Vietnam. These support systems solidified farmers' collective interests with a common voice in negotiating legal recognition from local, national, and international policy-making bodies.

The achievements were further validated by several of external programme evaluations conducted during program implementation:

- The Biodiversity Use and Conservation in Asia Program (BUCAP) provides a clear illustration that farmers in farmer seed systems are capable of playing a part in improving crops, managing agrobiodiversity and, especially in the diverse environments characteristics for the tropic and sub-tropics, ensure local adaptation and variety diversity in sustainable agricultural production systems (Hardon, 2005);
- The self-assessment and our review also clearly show that by promoting agro-biodiversity, farmer-based seed supply systems and diversified and integrated farming systems, the programme has produced multiple, substantial and important benefits to farmers in project areas in terms of addressing several different dimensions of poverty: income, food security and empowerment (Eklöf, 2009);
- The team saw impressive gains at the farmer level in all sites, including: reinforced capacity in plant genetic resources conservation, management and development; improved crop production due to availability of stable varieties, knowledge in pest management and timing

of planting; reduced production costs per cropping season; improved access to government extension services; evolution of local seed markets that facilitates exchanges of farmer varieties and enhances diversity of plant genetic resources at the community level (Quitoriano, et al., 2011);

- The programme in the three countries has been able to contribute to farmers' empowerment, in particular the technical capacities and rights as well as the increased awareness of seed policies and the communities' capacity to engage in and influence local to global food, agriculture, and climate change policies. Moreover, the programme has been able to address gender equality and women's empowerment (Berg, 2015).

4.2 Capable farmer breeders providing communities with locally adapted varieties

In the Mekong Delta, there are 65 skilled and innovative farmer breeders who continuously develop varieties that respond to the needs of farming communities in the region. As of 2017, 400 rice varieties have been released proving the capacity of farmers to create new varieties adapted to their local conditions. All these varieties, at some point in time, became popular in the communities.

Two farmer-breeders, Mr. Nguyen van Tinh of Kien Giang province and Mr. Tran Thanh Hung of An Giang province, developed HD1 and NV1, respectively and had these certified through the formal seed certification process. The accomplishment was a breakthrough for farmers, in particular in a country that is oriented towards the global rice market (Figure 1). Significantly, this opened the door for other farmers who have no formal training in agriculture to have their varieties recognized and accepted at the national level (SEARICE, 2013).

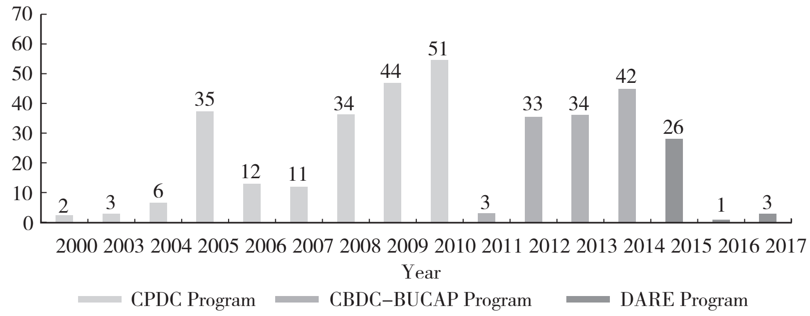

Figure 1 Farmer's varieties released in the Mekong Delta of Vietnam

Source: Data provided by Dr. Huynh Quang Tin of the Mekong Delta Development Research Institute (MDI).

4.3 Empowered women ensure household seed security

Women farmers play a crucial role in PPB. Through its earlier program on PGRCDU, SEARICE and its partners conducted studies to determine the PPB contributions to uplifting the lives of women. Using the findings of these studies, SEARICE and its partners developed tools and methodologies that would ensure women have meaningful participation in PPB and that benefits would accrue to them. Among the tools used are those that describe the roles of men and women in PGRCDU, access and control over agricultural resources (seeds most importantly), gender disaggregated data on trait preferences, and breeding objectives. Specific indicators on benefits gained by women in the communities where PPB is implemented, are also integrated as part of program monitoring and evaluation.

Across the Philippines, Thailand and Vietnam, women who engaged in SEARICE's PPB program activities gained access to trainings and opportunities to participate in decision-making processes in program activities. These women learned skills which were traditionally the domain of men – crop breeding, varietal selection, and even teaching fellow farmers' new techniques in conserving and developing plant genetic resources. Eventually, they were able to participate in the decision-making process in their households, particularly on the kind of varieties to plant, where to plant, and how to plant crops.

In addition, the women learned the value of plant genetic resources, found ways to ensure the steady supply of seeds for the next planting season, increased their income, and earned the recognition and respect of their local communities. In the process, they became more secure in their abilities and gained self-confidence (SEARICE, 2011). In some communities, women took leadership roles as heads of farmers' groups like in the case of Bhutan. In the Philippines, women were equally responsible in lobbying and establishing community seed registries intended to protect crop varieties in their communities from biopiracy and the possible application of IPR's by vested interests (SEARICE, 2012).

4.4 Increased access to and steady supply of diverse good quality seeds

With empowered communities came enhanced on-farm plant genetic resources diversity and farmers' increased access to good quality seeds at affordable prices. Using the Mekong Delta as an example, it can be seen clearly how much farmers contribute significantly to the local seed supply system. The Seed Clubs can produce around 180,000 ton of good quality seeds per year. This translates to supplying about 35% of the total rice seed requirement in the region, a very significant contribution considering that the formal system (including both public and private sector) can supply only about 15% of the seed demand in the region. This demonstrates the important gap that farmers can fill if given the opportunity. The Seed Clubs also produce seeds with a diverse genetic base. In 2015 for instance, they were able to produce and distribute seeds of 92 different rice varieties, 17 of which were formally released and 75 were farmers' varieties. They continue to develop crop varieties to address varying needs of farmers as environmental changes and new challenges emerge. In recent years, the Seed Clubs have developed nine rice varieties that are tolerant to salinity, seven varieties that are tolerant to drought, two that are suitable for flooded conditions, and one that is resistant to blast.

As demonstrated by the certification of HD1, NV1, and recently, TZ7 and AG1, farmer-bred varieties can have the same qualities, if not better, as those of certified seeds and therefore have the potential of becoming part of the supply that support the seed requirements in the country. HD1 was bred with the aim of obtaining a rice variety that is tolerant to acid sulphate and saline soils. This objective was achieved and the resulting variety has a good yield of 4.8 tons/hm^2 during wet season and 6.3 tons/hm^2 during dry season; good quality non-chalky grains, resistant to flooding and lodging; and is tolerant to grassy and rugged stunt diseases, blast, and brown plant hopper (SEARICE, 2013).

4.5 Cadre of advocates and supporters of PPB

Through the years, more than 500 development practitioners including agricultural extension agents, researchers, plant breeders, technicians, have become PPB facilitators. The FFS provided opportunities for different stakeholders to interact intensively with farmers and participate in collective analysis of problems and identification of solutions. Through this process, they were able to experience how the knowledge and experiences of both farmers and extension agents/development workers are valued and respected. This process of learning and unlearning brought about transformation to these development practitioners. From teachers who impart knowledge and skills they became facilitators who enable mutual learning through exchange of experiences, joint analysis of experimental results and processing of experiences into concrete learning.

The experience in the Mekong Delta demonstrates that with government support PPB can go a long way. In Vietnam, the law prohibits selling of uncertified seeds. However, local government authorities who have been directly involved in program implementation have recognized that the quality of varieties and seeds that the farmers are developing and producing can respond to the seed needs of many farmers in the country. They believe that by working closely with farmers and supporting them, the process of developing locally adapted varieties and producing good quality seeds for distribution to other farmers in Mekong Delta will continue. One manifestation of support to farmers is the granting of the use of the logo of the Mekong Delta Development Research Institute (MDI), SEARICE's institutional partner in the Mekong Delta, for the packaging of farmers' seeds as a guarantee of its quality. Likewise, the Department of Agriculture and Rural Development (DARD) and the Seed Centers at the provincial level, gave recognition to farmer varieties, sanctioning their production at the commune, district and provincial levels. Local government support ranges from financial (costs of FFS and training of FFS facilitators) to technical assistance to provision of materials for breeding to awarding of certificates to Seed Clubs so they can produce and sell seeds locally. The potential of farmers' varieties and seeds to reach more communities and provinces even outside the Mekong Delta gained support through the national certification of farmers' varieties with the assistance provided to farmers in technical documentation and coverage of the costs of certification.

5 Challenges

PPB has produced significant results and various effective implementation models. However, it remains in the periphery because of major challenges that prevents PPB from going mainstream despite its huge potential.

5.1 Breaking stereotypes

The first bottleneck is the outdated belief that farmers cannot do breeding, that at best they can test almost stable materials on-farm for local adaptation. In all countries where SEARICE implements PPB, there was initial reluctance among scientists/plant breeders to provide farmers with segregating materials. To demonstrate that this is a false belief, the FFS methodology puts farmers in charge to run experimental breeding trials with the use of cross breeding. When the scientists saw how effective farmers were in handling segregating materials and in managing early generation materials, they recognized the capacity of farmers and started entrusting them with breeding lines.

5.2 Ownership of PPB products

Not all plant breeders are willing to share their breeding lines with farmers, even though they know that farmers can manage the materials well.

At the heart of this is the issue of ownership of the resulting variety. In one of the countries where SEARICE implements PPB, plant breeders within the same government institution are protective of the information about their individual breeding work because they worry that their colleagues may beat them in developing new varieties. In another country, plant breeders are unwilling to share their breeding lines with farmers, because they are selling those breeding lines to private seed companies. Since the plant breeding institution does not receive funding from the government, they resort to selling their breeding lines to survive. This development is unfortunate given that the breeding work conducted by government plant breeding institutions is supposed to be for the public and not for private good or to benefit the private sector.

5.3 Seed policies and legislation

The national certification awarded to HD1 and NV1 demonstrates that farmer varieties can meet the stringent requirements of seed certification and nullify the misconception that farmer varieties cannot be considered "varieties," because farmers cannot conduct breeding activities. However, the procedures that varieties need to go through before they are granted national certification status as well as the financial costs are too stringent for farmer-breeders. With such a system, obtaining national certification remains unattainable for farmers despite the potential of farmer varieties to support the country's national production (SEARICE, 2013).

In recent years, the intense pressure put on countries to integrate in the global trade have prompted national policy makers to double their efforts in reviewing policies or creating laws, which could have major impacts on farmers' access to seeds. Policies and legislation which embrace integration can easily quash the gains made at the local level leaving farmers with limited or no control over their seed systems.

5.4 Intellectual property rights

Intellectual property rights (IPR), which are argued to spur innovation by rewarding innovators with ownership of their innovation, have found their way in national seed laws of many countries. In most cases, distinctness, uniformity, and stability (DUS) standards used to maximize market potential of the varieties, are the same ones used in national certification of new varieties. Multi-location trial or value for cultivation and use (VCU) tests, another seed certification requirement, is basically a market optimization strategy which aims to maximize profit.

Most trade agreements between developing and developed countries require the former to amend their law and apply strict IPR on seeds. This move undermines farmer seed systems, which provide 80%-90% of the seed requirements in most developing countries. In some cases, farmer selling of uncertified seeds becomes a criminal offense.

Another form of IPR on seeds is plant variety protection (PVP), which limits the potential of farmers to create new varieties that can respond to new challenges such as those caused by climate change. Just like patents, PVP is an artificial monopoly on a public good. Although economists rarely come to a consensus, they agree on one thing: monopolies lead not just to inequities but also to major distortions in resource allocations. As a society, we tolerate this distortion in the hope that it will promote innovation that would, in the end, lead to social benefits that would outweigh the costs (Stiglitz, 2008). Plant breeders are given incentives through privatization of property not only to compensate them for their efforts and investment, but ultimately, to give society the benefits of new discoveries and the expansion of our collective knowledge. The ultimate question that must be answered is this: does the social benefit outweigh the social cost? Given the important role of farmers in innovation and the adaptation pressures posed on them and our food supply by climate change, the costs to society of limiting farmers' ability to create new varieties using protected varieties would be devastating and would far outweigh the benefits. For the regular consumers, the farmers and breeders, it is just not worth it (Ignacio, 2013).

6 Conclusion

Farmers have a huge potential to contribute to crop improvement and to meet the diverse seed needs of other farmers, based on present and future challenges such as those of climate change. PPB provides a working model, wherein genuine partnership among key stakeholders can be achieved. Experiences demonstrate that this paradigm is not only effective, but also more efficient as compared to conventional plant breeding. PPB allows farmers to develop varieties which cater to their specific preferences and criteria and are well-adapted to their specific niches and agro-ecological conditions. This translates to significant savings in resources and promotes resource-sharing among key stakeholders. This is even more important given the decreasing public funding for agriculture research and development (Shapit, Rao, 2007). Farmers are an indispensable part of the innovation system that sustains formal breeders. Cutting off farmers from this process by restricting their right to freely generate much needed varieties from a protected variety is inequitable and unwise.

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Part 2

Chinese cases

From participatory plant breeding to integrated rural development: The case of Upper Gula, Guangxi

Lanqiu Qin, Kaijian Huang

1 Introduction

Participatory Plant Breeding (PPB), also known as collaborative plant breeding, is a method that requires researchers to work closely with farmers and other interested parties to achieve plant genetic improvement, while Participatory Varietal Selection (PVS) is a method in which researchers work with farmers and other interested parties to identify and select promising crossing combinations(Nie Zhixing, et al., 2008). The concept of participatory plant breeding was developed in the 1980s in response to the reality that modern breeding could not meet the production needs of farmers in developing countries. It is a means of technical assistance to farmers in remote areas to sustain their livelihoods, and a complement to modern breeding techniques. In Upper Gula, Guzhai Village, Mashan County, Guangxi, participatory breeding methods for participatory selection of maize have been used since 2000. It is one of the first communities in China to use participatory plant breeding methods for maize breeding.

Upper Gula is 23 km from the town of Mashan, and close to the

Guzhai Village. It is located in the subtropical region. It has a south subtropical monsoon climate, sufficient sunshine, mild climate, abundant rainfall, annual average temperature of 21.3 °C, average frost-free period of 343 days, and an average annual precipitation of 1,667.1 mm. Upper Gula is a boulder mountainous region, the flat land below the mountains is dry land, the foothills are villages, and all the village houses are lined up along a main road. There are 89 households in the whole canton, with a total population of 359 (2011), of which one third are Yao ethnic groups and two thirds are Zhuang ethnic groups. In 2014, there were 142 people working full-time in the village, with 9 hm^2 of cultivated land. Before 1974, there were water fields in the village; due to climate change and other reasons, the creek in the canton ran out of water or had less water in the second half of the year; since then, all the water fields have been converted to dry land, of which 6.67 hm^2 are planted with maize (two seasons a year), accounting for 74% of the total cultivated land, while the rest are planted with beans and vegetables. The villagers have always been consuming maize as a staple crop until 2010, when the economy began to develop gradually, life improved and rice consumption increased.

Prior to the 1980s, maize cultivation was mainly dominated by old local varieties, including four varieties: local yellow maize, local glutinous maize, little hearted white, and white horse teeth. In the early 1980s, some of the Open Pollinated Varieties (OPV) varieties introduced from Mexico were planted, such as Mexican white and locally bred interspecies hybrids; in the 1990s, a few hybrids were planted, mainly top crosses.

In the late 1990s, there was a systematic separation between formal and farmers' seed systems, and varieties bred by scientific institutions were seldom used by farmers in remote mountainous areas, not only because of the limitations of promoting hybrids to adapt to local microclimates, but also because some poor people lacked the funds to purchase hybrid seed. With the development of society and the opening of the seed market, the entry of domestic and foreign seed companies, and the diversification of hybrids, more choices are available to the farmers, notably the emergence of Zhengda 619 in 2002, which increased the proportion of maize hybrids planted in Upper Gula to 80%-90%. The planting pattern is going to another extreme, planting varieties tend to be homogenized, and local varieties face the risk of extinction.

In 2000, a project led by a team of the Center of Chinese Agricultural Policy introduced participatory maize breeding in Upper Gula to allow farmers to grow varieties that produce better yields with little or no cost, and to preserve the diversity of local varieties. By supporting a local farmer folk art group and setting up community development funds, farmers (mostly women farmers who stay behind while husband migrate to urban areas for work) were organized to carry out participatory community resource registration of varieties, farmers' participatory seed and local culture exchange meetings, participatory variety comparison tests and local variety improvement activities. While protecting and improving local maize varieties, the technical and resource advantages of researchers are combined with farmers' local knowledge and local varieties to cultivate excellent varieties that are adapted to local cultivation and affordable to farmers. At the same time, in response to the needs of society at different stages of development, the project team encouraged the establishment of local seed and crop produce businesses in conjunction to promote the comprehensive development of the Upper Gula village.

2 Action Research Methods

2.1 Variety improvement and selection

PPB and PVS are the two main methods used to improve the selection, purification and rejuvenation of local maize varieties and screening of introduced varieties, to obtain varieties suitable for the local ecological environment and farmers' needs.

The basic process includes:

- Communication with participating farmers to understand the purpose of PPB and PVS and to equip them with certain breeding techniques through training;
- Community resource registration to understand the genetic variation and diversity of local maize;
- Survey to understand the selection criteria of maize breeding traits needed by farmers to set reasonable breeding objectives: resistance, high yield, high quality;
- Selection and breeding of new varieties from mutant populations;
- Variety identification and trait description;
- Good breeding, marketing and integration with conventional breeding systems.

2.2 Integrated community development

The participatory approach was adopted, and after discussions and consultations among the parties concerned at different stages of development, a consensus was reached on the appropriate development and establishment of farmers' organizations, and through the adoption of an organizational management model, the integrated development of community-based ecological agriculture and rural construction was promoted.

3 Project partners

The main partners include farmers from the Upper Gula (from 8 to 36), breeders from the Maize Research Institute of the Guangxi Academy of Agricultural Sciences, maize breeders from the Chinese Academy of Agricultural Sciences, researchers from the Center for Chinese Agricultural Policy of the Chinese Academy of Sciences, and participatory research expert Ronnie Vernooy, then at the International Development Research Centre (IDRC) of Canada. Financial support was provided by the International Development Research Centre, the Farmers' Seed Network, Oxfam Hong Kong, and others.

4 Results of participatory plant breeding

4.1 Participatory improvement and selective breeding of maize varieties

In 2000, participatory maize breeding was started in Upper Gula, and at different stages, extensive participatory maize testing and identification were carried out, and 10 maize varieties adapted to the local climate were selected and bred through improvement, identification and screening (Table 1). The four varieties of Guinuo 2006, Xinmo No.1, Local Mobai, and Local Mohuang miscellaneous, were selected and utilized as cases to share with other farmers.

Table 1 Participatory selection of maize varieties

Participatory Plant Breeding	Breeding varieties and sources
Scientist-led	Guinuo 2006: Selected by the Guangxi Academy of Agricultural Sciences Maize Research Institute, introduced after successful local breeding trials Xinmo 1: Improved variety of Mobai 1 Zhongmo 1: A combination of three varieties: Mohuang 9, Xinmo 1 and Suwan 1 Guisuzong: Improved variety of Suwan 1
Farmer-led	Local Mobai: Xinmo 1 planted with local white maize and retained after years of selection Local Mohuang: Zhongmo 1 mixed with local yellow maize and planted after years of selection Mobai and Yellow Hybrids: Interspecies hybrids of native Mobai as the parent and native ink yellow as the parent Improved Guinuo: Black and white maize as the parents, Guinuo 2006 as the parent for hybridization, spike selection mixed seed Local Yellow: Recovered and rejuvenated from local farmers' stock Local Glutinous: Recovered and rejuvenated from local farmers' stock

4.1.1 Selection and utilization of Guinuo 2006

Guinuo 2006 is a glutinous maize hybrid selected by the Guangxi Academy of Agricultural Sciences and improved from 2004 to 2006 in Upper Gula through the participatory testing and comparison of the selected glutinous maize hybrids suitable for local cultivation, with high yield, good taste, and popular among farmers.

From 2004 to 2006, under the leadership of Rongyan Lu, 10 participating farmers in Upper Gula formed a participatory maize breeding group and used about 5 mu of land to conduct participatory planting, identification and evaluation of 12 to 20 new maize varieties (Guinuo 2006 is the only glutinous maize, all other varieties involved are common maize). The main activities included: at each stage of maize growth, local farmers, including the participating farmers, were organized to evaluate the participating varieties by scoring or throwing maize nibbles, the traits evaluated include plant height, ear height, shape, ear baldness, seed appearance, yield, pest resistance, etc. Among them, the trial yields results in 2006 were shown as follows:

Yumeitou 102 (346.5 kg/mu) > Guiyu 505 (322.7 kg/mu) > Guinuo 2006 (297 kg/mu) > Nongda 108 (273.6 kg/mu) > Zhongmao No. 1 (265 kg/mu) > Guishan 22 (257.1 kg/mu) > Guishan 216 (252.7 kg/mu) > Guishan 30 (252.1 kg/mu) > Local Yellow (251 kg/mu) > Guishan 168 (248.3 kg/mu) > Gui A339 (243.3 kg/mu) > Mobai (236.5 kg/mu).

Guinuo 2006's yield ranked No.3 of the 12 varieties. It combines both good taste and quality. It ultimately excelled among many test varieties and was selected by farmers as the local main glutinous maize variety to be used for production. At the same time, the participatory maize breeding group started seed production trials in 2006-2007 and expanded Guinuo 2006 seed production and sales in 2008.

The total recorded gross sales value of Guinuo 2006 produced from 2009 to 2017, minus self-consumption, amounted to 72,350 RMB. In terms of seed production and marketing: in 2007, the Guangxi Academy of Agricultural Sciences' Maize Research Institute provided the parental seeds to start seed production trials, that year there were four farmers involved in seed production trials, an area of 0.14 hm^2, but due to flooding, only 0.06 hm^2 could yield seeds, a total of 41.3 kg of seeds were harvested, with a total of 991.2 RMB of sales revenue. By 2015, the total area of seed production was about 2.38 hm^2, with a total yield of 1,331.3 kg, and total sales income of 40,046.2 RMB. The total number of participating farmers was 66 households. See Table 2 for details.

Table 2 Guinuo 2006 seed production (PPB): Guzhai Village, Mashan County, Guangxi

Year	Households	Area (hm^2)	Yield (kg)	Sales (kg)	Price (RMB/kg)	Total income (RMB)	Remarks
2007	4	0.14	41.3	41.3	24	991.2	Due to flooding, only 0.06 hectare could yield seed
2008	11	0.37	223.5	205	24	4,920	
2009	11	0.33	127.5	127.5	33.6	4,290	
2010	8	0.43	0	0	0	0	Total loss of yield due to flood
2011	6	0.20	165.5	150	36	5,400	
2012	9	0.20	153.5	153.5	30	4,605	
2013	6	0.20	250	250	32	8,000	
2014	6	0.31	160	160	32	5,120	Lost approximately 250 kg of seed due to rodent infestation
2015	5	0.20	210	210	32	6,720	
Total	66	2.38	1,331.3	1,297.3	—	40,046.2	

In 2013, Rongyan Lu of Upper Gula shared Guinuo 2006 and its two parental varieties with Baoshan Stone Village, Yunnan Province, and since then, Guinuo 2006 has taken root and sprouted in Baoshan Stone Village, bringing benefits to local farmers and a new chapter of participatory maize breeding in Baoshan Stone Village.

The introduction and sale of Guinuo 2006 has not only met the needs of local farmers for their own consumption, but also brought some cash income to local farmers, notably to the women. After meeting the needs of local farmers, the seeds produced are then sold externally. They are generally purchased by cooperatives and then sold uniformly. Seeds are sold 1.5% cheaper than the market price, which reduces the input cost of seed, and at the same time, generates a certain amount of cash income, so that local seed producing farmers could benefit from it. More importantly, through participatory plant breeding trials, production, and sales, the breeding team has gained a more systematic understanding of the key aspects and basic skills of maize breeding, identification and evaluation, accumulated knowledge and experience for the wider development of participatory breeding in the future and laid the foundation for the promotion of local participatory plant breeding.

Due to the protection of the right of use and the isolation conditions of local seed production, the yield of this variety is limited, which restricts the large-scale development of this variety in the local area.

4.1.2 Mobai-Mohuang hybrid breeding and utilization

The Mobai-Mohuang hybrid is an interspecies hybrid with Local Mobai as the father variety and Local Mohuang as the mother variety. It was selected by two female farmers, Jin Yuan Lan and Aimei Lan of Upper Gula, in 2013. The local varieties of maize, such as Local White and Local

Yellow, have always been planted in Upper Gula. In recent years, the annual area planted is about 20-30 mu, and some of the fields are flooded land. In addition to planting to reduce the cost of seeds and reduce the risk, another purpose of the planting is also for food safety (farmers have a fear of genetically modified varieties), as well as for taste and development of ecological agriculture (local varieties are more used as food for porridge rather than feed). To increase the yield of local varieties, the Participatory Plant Breeding Team has been conducting stock-reinforcement screening and seed retention and using them as parental and commercial hybrids for cross-improvement or interspecies hybridization trials.

The hybridization method of this variety is simple and easy. One only needs to plant two rows of Local Mobai in the Local Mo Huang plantation, remove the Local Mobai male flowers before the male flowers lose their powder, and collect the Local Mobai female rows during the harvesting period to keep the seeds; at the same time, the flavor of the Local Mobai is partially retained, and the seed color turns yellow after hybridization, which meets the farmers' requirements on seed color and taste. At the same time, the planting yield of this variety is higher than the two parents: Mobai-Mohuang hybrid (550-650 kg/mu) > Local Mohuang (500-550 kg/mu) >Local Mobai (450-500 kg/mu).

This variety currently has a large area of local production applications. From 2013 to 2018, the total area of seed production was 1.0 hm^2, involving 63 farming households; due to the simplicity of seed production, although the area of seed production has not changed much, the number of farming households participating in seed production has increased year by year; the total area of production use was 9.57 hm^2, involving 137 farming households. See Table 3 for details.

Table 3 Summary of the seed production and yield of Mo Bai-Mo Huang Hybrid from 2013 to 2018

Category		2013	2014	2015	2016	2017	2018	Total
Seed Yield	No. of Households	2	8	9	10	13	21	63
	Area (hm^2)	0.23	0.11	0.12	0.13	0.15	0.26	1.00
Yield	No. of Households	15	16	18	12	17	59	137
	Area (hm^2)	0.29	0.48	0.2	0.73	1.00	6.87	9.57

It could be seen from the table that the planting area of the Mobai Mohuang hybrid variety reached a peak in 2018. "It's either pouring rain for three days straight or smoking sunny for three days straight." This proverb is a true reflection of the local meteorological disaster. According to farmers, the strong winds and floods in Upper Gula have caused significant losses to local maize production (including local maize varieties, commercial hybrids); and some of the lost farmers could not even recover their seed money. In addition, the commercial seed price in recent years has remained high, which reached RMB70 yuan/kg in 2018, while the yield of planting commercial varieties was only 75-100 kg/mu higher than their own variety, the Mobai-Mohuang hybrid. Therefore, farmers choose to plant their own Mobai-Mohuang hybrid, which saved them money on the purchase of seeds, while it matured earlier than commercial seeds. If planted in the second half of the year, planted early and harvested early, it can also avoid the drought. That was why the acreage of this variety was expanded in 2018.

The Mobai-Mohuang hybrid is a farmer-led, participatory breeding variety. It sufficiently shows the real needs of farmers for varieties and the dynamic power of participatory breeding in addressing climate change. It has played a positive role in farmers' productive livelihoods and ecological farming and has also greatly encouraged their confidence to engage in participatory plant breeding.

4.2 Participatory domestication of selected vegetable varieties

Like many other villages, in Upper Gula each family has a tradition of growing vegetables to meet their own needs. They plant both their own varieties and seeds purchased from the market. In 2008, due to the entry of a NGO, organic vegetable cultivation began in the community. To meet the needs of the NGO for diversification of vegetable varieties and organic cultivation, the participatory plant breeding team, led by Rongyan Lu, gradually began to introduce and domesticate wild vegetables, from which they selected suitable varieties to adapt to the local climate and ecological growing requirements. Varieties selected were distributed to other farmers, and training was provided on relevant cultivation techniques. Pumpkin seedlings, sweet potato leaves, hollow cabbage, leeks, scallion, ginger, garlic, wolfberry leaves, chayote shoots and 18 other varieties were tested through the process.

The scale of vegetable production also expanded from the small organic vegetable garden in 2008, which had 5 households of farmers and 2 mu of vegetable land, to 39 farming households and a total of 27 mu of organic vegetables in 2012. With the supply to restaurants totalling 21,689.25 kg, market sales of RMB 21,069, and a total income of RMB153,402.4. Because the group members are the non-primary workforce of the family, these incomes, while modest, solved part of their daily spending needs.

Due to the decline in the demand of restaurants and other reasons, vegetable cultivation in 2013 began to be more affected. To solve this problem and adapt to market problems, Rongyan Lu and the villagers found a new way—focusing their attention on the development of chayote shoots' organic planting. The chayote shoots were brought in from the mountains by Yan Rong to be domesticated and then production expanded. Chayote has a long fertility period, long harvesting period, extra-low need for care, and high yield, which is very suitable for industrial development in the current state of an insufficient rural labor force. As a result of the opening of new market demand, in 2016 the planting area of chayote shoots increased to 32 mu, its annual sales reached 17,700 kg, with a total income of RMB120,900; and in 2019 the planting area of chayote shoots reached 60 mu. At the price of 5 yuan/kg, the annual output of 1,750-2,500 kg / mu, chayote shoots alone generated an annual income of RMB 525,000-75,000 yuan for the community and attracted a group of young people to join. For the poor households, in addition to the income they get from planting vegetables, they can also get more than RMB 100 yuan each day by helping others to harvest vegetables.

Participatory selection and introduction of vegetable varieties has enriched the biodiversity of the community, promoted the development of ecological vegetable cultivation, and played a catalytic role in poverty alleviation and rural revitalization.

5 Results of other action research

5.1 Application of participatory seed selection in the establishment and operation of community seed banks

In Upper Gula, through participatory training and learning, participating farmers have increased their awareness of the importance of community germplasm conservation and have learned and started to conduct a community plant genetic resource registration. As of 2018, a total of 93 species have been registered in the Mashan Upper Gula Resource Register, including 6 varieties of maize, 3 varieties of wheat, 11 varieties of bean, 6 varieties of sweet potatoes, 9 varieties of melon, 13 varieties of fruits, 18 varieties of vegetables, 25 varieties of Chinese herbs, and 2 others. At the same time, a community seed bank was established in 2017 for seed conservation, exchange, and display of some of the registered varieties. Farmers initiated participatory seed selection to expand the community seed bank collection.

5.2 The role of participatory seed selection in community seed display exchanges

Since 2005, the conservation of the diversity of local varieties in Upper Gula has been enhanced through the organization of or participation in farmers' participatory biodiversity seed fairs and local cultural exchanges, which have expanded the range of local varieties planted and enriched local biodiversity through the exchange of new varieties. "I never thought there would be so many varieties of crops here" and "I've never seen this kind of maize seed," were remarks that can be heard from time to time during the exchanges. A Participatory Plant Breeding and Biodiversity Exhibition and Traditional Cultural Exchange was held in Luocheng, farmers brought a total of 210 varieties, while Upper Gula brought 16 varieties, including 4 maize, 5 bean, 5 vegetables, and also brought cotton and other crops. They took home the Mobai maize, red rice bean, bitter gourd from Jiuwei, and the Wuming old captain's 7 kinds of herbal medicine.

5.3 Fostering new types of farmer organizations that meet the farmers' needs

5.3.1 Establishment of a farmers' folk-art group

Upper Gula village belongs to the Yao ethnic group, whose women love to dance the hammer dance on festive occasions. Ronnie Vernooy saw the hammer dance for the first time in 2005 when he visited Upper Gula for participatory breeding training and other activities. In 2006, he invited the village's farmers' folk-art group to perform at the China Agricultural University (CAV) in Beijing in May of that year. To increase the attractiveness of the program, on 15 February 2006, the community decided to set up the Masan County Guzhai Yao Township farmers' folk-art group. The number of members has increased from 10 to 31 (based on the former Participatory Plant Breeding Women's Group) and has gone from purely female to having 7 men. A total of eight programs were scheduled and performed since 2006. With the support of the project team, the show was performed at the School of Humanities and Development of China Agricultural University, which was attended by 1,200 people. It turned out to be a great success. The event has greatly promoted the development of the farmers' folk art group, attracted the attention of the local government, and enabled the hammer dance to be passed on. The dance won the title of Intangible Cultural Heritage of Nanning City in 2014, and the title of Intangible Cultural Heritage of Guangxi Zhuang Autonomous Region in 2015. Rongyan Lu, the group's leader became the inheritor of intangible cultural heritage. At the same time, as a result of the establishment of the farmers' folk-art group and its activities, the number of people involved in gambling has reduced, and the number of people taking part in collective activities and their motivation has greatly increased.

5.3.2 Establishment of the community development fund

With the support of the project, a community development fund was set up in 2004, with Rongyan Lu as the head of the fund. The start-up fund was RMB 20 thousand, mainly for small farmers to borrow money for the input of ecological farming and production materials, and for children from poor families to attend school. With the support of the Community Fund, the development of organic vegetable farming and organic pig farming has led to a total of 13 farmers participating in organic farming by 2011, with annual sales exceeding RMB 100,000. To date, the fund has helped more than 70 farmer families, some of whom are poor, to pay for health and education. The fund serves both as a loan facility (with lower interest rates than commercial banks) to support individual cooperative farmers and as a fund for collective investments and activities, such as the purchase of breeding materials or pumps. The fund also benefits non-cooperative members and has so far provided loans to 34 non-cooperative families.

5.3.3 Establishment of professional organic breeding cooperatives

Upper Gula combined participatory vegetable introduction testing with organic vegetable farming. The total farmers and land involved went from the initial 5 households and 2 mu of land in 2008, to 39 farmers and 27 mu in 2012. To seek better management and development, in March 2012, they officially registered the Mashan County Yan Rong Organic Growing and Raising Professional Cooperative; the cooperative has 36 households, and in 2019 the organic vegetable cultivation has developed to 60 mu. The Mashan County Yan Rong ecological breeding professional cooperative has become the leading industrial development of Mashan County Guzhai Township. It has made great progress in the vegetable sales, cultivation, and other aspects, providing an excellent platform for farmers to alleviate poverty and become well-off.

5.3.4 Establishing a community seed bank

Rich and diverse plant genetic resources are the foundation of participatory plant breeding. After more than a decade of registering, collecting, exchanging and conserving community crop varieties, the participating farmers' awareness of the importance of protecting local varieties of resources has increased. At the same time, the economic development and the expansion of the seed industry, and the rapid renewal and dissemination of new commercial varieties in the market, has led to a partial loss of local varieties (e.g., the local maize variety Xiaoxin bai). To protect and enrich community's plant genetic resources, a community seed bank was established in 2017 in Upper Gula. While enhancing the conservation of variety diversity among farmers, it also facilitates seed exchanges and knowledge exchanges among farmers. Currently, the number of varieties on display in the community seed bank is 27, including 15 for bean, 2 for maize, and 10 for melon and vegetables.

5.4 Establishment of an incentive mechanism

Local development has benefited from providing technical incentives to ordinary cooperative and community seed bank members, through technical guidance to cooperative members, such as techniques for the purification and refining of traditional varieties, maize hybridization, vegetable variety selection and cultivation, etc. Another incentive has been providing financial support: through the community development fund, in form of small loans to farmers in need of financial support (about 7.2% annual interest); and a third incentive has been providing for marketing local products. The latter has been used to pay for the transportation of vegetables (RMB 15 each time), to reward group members responsible for harvesting vegetables and recording, and occasional rewards for farmers who are active in growing vegetables; incentives for managers are mainly invisible, such as inviting members such as Rongyan Lu, the head of the cooperative, to attend various exchange activities.

6 The development of women's capacities and self-confidence

Women over 35 years of age in Upper Gula stay at home because they are too old to find jobs and need to take care of their children, while men tend to work outside in the cities. As a result, activities such as participatory plant breeding, farmer's folk-art group and organic vegetable farming and sales are basically carried out by the women who are said to be "left behind". Through their participation in relevant activities, communication, exchange and training, women's production skills, interpersonal skills and economic income have been greatly improved, and they have played an increasingly important role in community building and development. Take Rongyan Lu as an example. When the project was launched in 2000, Rongyan Lu started as a team leader of the hammering team, and through going out for training, setting up a participatory breeding women's interest group, she became the leader of the group. She became the head of the participatory breeding team, then the head of the community development committee in 2004; followed by becoming the deputy director of the village committee in 2005. A few years laters, She set a cooperative and became the president in 2012, finally becoming the head of the village committee and the village branch secretary in 2015. Each role change is a process of growth, and her overall competence and self-confidence are greatly improved.

7 Community capacity building

Through the implementation of various activities, more opportunities are provided for community farmers, in particular women farmers, to participate in community activities, which plays an important role in community organization building, capacity building and community bonding, and provides a strong assurance and support for community development. For example, farmers' field schools have been organized to promote communication within the community; outreach activities have been carried out to improve farming techniques and skills and management through learning exchanges; and farmers have become more cooperative with each other and fostered social networks as a result of their participation in the PPB process.

8 Policy influence

8.1 Agreement on in situ maintenance and improvement of maize and rice of farmers in Guangxi

In 2010, to maintain the agricultural genetic resources in the southwestern mountains and support the livelihood development of small farmers in the southwest, the Participatory Action Research Project Team of the Center for Chinese Agricultural Policy of the Chinese Academy of Sciences developed a novel agreement for the in situ conservation and improvement of farm varieties through an approach agreed upon by all stakeholder. The agreement was named the *Guangxi Maize and Rice Farm Seeds In Situ Conservation,* *Improvement and Utilization Agreement*. On 21 June 2010, in Nanning, Guangxi, the agreement was signed between the scientific institutions and the participating project sites. The engagement was also signed by farmer representative Rongyan Lu, on behalf of the project villages in Upper Gula.

The specific terms of the agreement are as follows:

• The maintenance and improvement of farm seeds will be carried out on a voluntary basis, with freedom of participation and withdrawl.

• The project team's emphasis on the conservation and improvement of farm varieties does not exclude the selection and adoption of hybrids.

• The project team will work with the Guangxi Maize Research Institute and the Guangxi Rice Research Institute to provide technical and information support on technical needs in the planting process (e.g. through the improvement of old varieties through participatory breeding).

• The project team compensates the farmers involved in the inoculation trials for the varieties and technical risks that may be encountered in the normal planting process, taking into account the average local production of common varieties in the current season.

• For farmers, farmer groups and farmer organizations that are active in the process of maintaining and improving farmer varieties, the project team supports the community through year-end competitions and awards.

• The cost of project activities will be covered by the Participatory Action Research Project Team; for communities with community development funds, compensation or incentives for the conservation of farm seeds will be discussed between the project team and the fund management committee to form an incentive mechanism; for communities that have not yet established funds, compensation and incentives will be covered by the project team.

• The collection of local farmers' seeds from the project villages by scientific research units requires the payment of subsidies and recognition of the source of the seeds (the source is registered at the time of submission to the State); the natural village where the seed is collected needs to be specified, for the purpose of reporting variety sources in the validation of hybrids. The distribution of benefits within the community is not part of the agreement, but the project team will make recommendations in the project community on organizational activities and incentive compensation mechanisms for farmers.

• The agreement shall be renewed every three years; the agreement will become effective on the date of its signing by all parties.

The signing of this unique agreement maximized the encouragement for farmers to continue their work on participatory plant breeding and conservation of farmer seeds. It led to the development of another agreement (see 8.2).

8.2 Agreement on the Use of Farmers' Maize and Rice Seeds for Crossbreeding in Guangxi

The Participatory Maize Breeding Project (led by CCAP), which started in Guangxi in 2000, witnessed the continued recognition of farmer varieties by formal institutions and their use in the selection of hybrids. On the other hand, since hybrid selection is a long process with a lot of uncertainty, germplasm resources are constantly screened and recombined during this process. Therefore, it is difficult to see the specific contribution of farmer germplasm directly from a one single hybrid. Technical difficulties do not justify ignoring the contribution of farmer germplasm and its conservators. Based on years of cooperation, the Participatory Action Research Project Team intended to assist and support the cooperative breeding institutions: Guangxi Maize Research Institute, Guangxi Rice Research Institute, and the project village communities through a benefit-sharing engagement. Thus, an Agreement on the Use of Farmers' Maize and Rice Seeds for Crossbreeding in Guangxi was established. On June 21, 2010, in Nanning, Guangxi, the agreement was signed by Rongyan Lu on behalf of Upper Gula, which is involved as one of the project villages.

The specific terms of the agreement are as follows:

• As public breeding institutions, the Guangxi Maize Research Institute and the Guangxi Rice Research Institute, recognize the contribution of farmer seeds collected from project villages to hybrid breeding.

• In terms of the selection itself, if the farmer group improves and selects the maize farmer species directly involved in crossbreeding as one of the parents, the farmer/group will receive up to 25% of the seed rights proceeds; if it is a conventional species, the farmer/group will share the seed rights proceeds with the project team in a proportion agreed on a case-by-case basis.

• From the point of view of the selection itself, farmers/groups will receive up to 25% of the varietal rights benefits if the improved and selected rice-farmer seeds are directly available as one of the parents of the hybrid rice; if they are conventional varieties, they will receive full varietal rights benefits.

• After the public breeding institutions, Guangxi Maize Research Institute and Guangxi Rice Research Institute, have directly or indirectly used farmers' seeds as breeding materials to produce varieties, the villages/ communities where the farmer seeds are collected have the right to share economic benefits and property rights (e.g. joint application for variety validation and variety rights application).

• In the process of participatory plant breeding, farmers who have made significant contributions to the application for breeding rights for the resulting varieties may apply for breeding rights jointly with the institution as "co-breeders"; if the approved varieties are not directly marketable, the two parties cannot share the economic benefits.

• Benefit-sharing is not only at the economic level, but also in the exchange and sharing of technology, knowledge and experience, etc., and the institution will continue to strengthen relevant benefit-sharing with the project community through the project platform.

• The distribution of benefits within the community is not part of the agreed consideration, but the project team will advise and support the farmers' organizational activities and incentive compensation mechanisms in the project community.

• For the varieties produced by participatory plant breeding, the project team and project village farmers/groups will share the profit and naming rights in agreed proportions.

• The agreement shall be renewed every three years; the agreement will become effective on the date of its signing by all parties.

The signing of this agreement, while protecting local varieties, has encouraged community farmers to actively carry out participatory variety improvement and variety selection; in addition, the agreement has further promoted the production and marketing of Guinuo 2006 in the community and contributed to community development.

9 Conclusion

Upper Gula, by using participatory breeding as the entry point, and the conservation of local varieties, biodiversity conservation, community capacity building and integrated rural development as its objectives, has carried out extensive community crop resource registration, participatory variety selection, field trials, skills training, exchange visits and other related activities since the project was established in 2000. Farmers' organizations such as the Community Development Fund, the Eco-Culture Cooperative and the Farmers' Theatre have been established. More than 90 local resources have been registered and more than 10 varieties of maize have been introduced, improved and cultivated. Community leaders or community workers as Rongyan Lu, Haiqing Lan, Aimei Lan and Jin Yuan Lan, were trained and became champions of rural development. The community has made great progress in crop conservation, cultural development, livelihood improvement, and ecological restoration, which has contributed greatly to the conservation and utilization of local varieties, value addition to local agrobiodiversity, and the integrated development of community and village.

10 Outlook

Crop varieties, biodiversity conservation and utilization based on participatory plant breeding platform have been the driving force and solid foundation for the development of agricultural industry and rural revitalization in Upper Gula and will be in the future. The future of Upper

Gula will be better with the continuation of activities to protect, introduce, innovate, cultivate and sustainably utilize local varieties, and promote the comprehensive development of the countryside in conjunction with the local culture.

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In situ conservation of farmers' seed systems: Smallholder farmers and scientists join forces to enhance conservation and sustainable use of traditional varieties*

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1 Introduction

40 million years ago, the Indian and Eurasian plates collided, triggering a sharp squeeze, rises and cuts of the Transverse Mountains, the mountains and rivers alternately spread out, forming the world's unique natural wonders of the three rivers, the Jinsha River, Lancang River and Nu River, flowing 170 km in parallel. Located at the crossroads of East Asia, South Asia and the Qinghai-Tibet Plateau, the Three Rivers' Merging Region is the richest geological and geomorphological museum in the world, known as the "Natural Alpine Garden" by the botanical community, and one of the richest regions in the world in terms of biological species, known as the "World Biological Gene Bank".

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The Jinsha, Lancang and Nu Rivers start from the Qinghai-Tibet Plateau and go hand in hand across the mountains. The Jinsha River starts from the Getotuo River in Tanggula Mountains, passing through Qinghai, Tibet, Sichuan, and Yunnan, turning away at Yunnan Lijiang Shigu and flowing east to the sea. The Jinsha River is the headwaters of the Yangtze River civilization and one of the origins of agriculture in Asia, where farming and nomadic culture fused and developed. Just upstream of the Jinsha River from the Zhimen of the Yushu region of Qinghai Province to Yibin City, Sichuan Province, a total length of about 2,300 km, where the influence of special geotypes, and nearly direct intersection with the southwest monsoon, directly blocking the warm and wet airflow from the Bay of Bengal, forming a typical dry hot river valley climate, is one of the more typical dry hot areas in China, known as the "inland tropical enclaves". The region's harsh climate and soil conditions, coupled with prolonged anthropogenic disturbances, make the ecosystem fragile and the soil erosion severe, making it a typical ecologically fragile zone.

Stone Village, located in the dry hot Jinsha river valley, is part of Baoshan Administrative Village, Baoshan Township, Yulong County, Lijiang City, Yunnan Province. Stone Village is northeast of Lijiang City, 126 km away, so named because it resides in a mushroom-like boulder. The village consists of 6 groups of villagers, 247 households and 814 residents, including 794 Naxi. Stone Village is an agricultural-oriented Naxi mountain village with 1,026 mu of terraced fields and 92 mu of dry cultivated land. The per capita cultivated land is 1.26 mu. The main crops grown on the terraces are wheat, barley, maize, soybeans, broad beans, pumpkins, cucumbers, sorghum, peanuts, sweet potatoes, etc. The water source for agricultural irrigation comes from the nearby Baoshan River, which is irrigated by the "open ditch and culvert" irrigation system that dated back for thousands of years. Good agricultural production conditions continue to be challenged by local climate change, which has been characterized by "ten years, nine droughts" in recent years.

Stone Village is located in an ecologically fragile area, despite the combination of natural resources and traditional environmental protection techniques; how to cope with water scarcity remains a challenge that the people of Stone Village cannot avoid. The busiest season of the year is from March to May, when the "big spring" seeds have to be planted before the "grain in ear" (one of the 24 solar terms). But in recent years, Stone villagers believe there have been more droughts in the last decade, with the rainy season postponed by 10 days to half a month, sometimes followed by flooding and heavy rains. The combined effects of industrial agriculture, migrant workers and climate change have led to significant changes in the farming practices, planting structures and crop varieties of the people of Stone Village, and to the erosion of genetic resources. There has been a shift from traditional rice cultivation to planting maize in "the big spring" and wheat in "the small spring". With the constant spread and promotion of modern varieties, there are fewer and fewer local varieties in farmers' fields. The diversity of crop variety resources is a major factor in resistance to harsh climatic conditions. The more homogeneous the variety resource is, the more vulnerable the agricultural production is to extreme weather. Villagers are using traditional ecocultural knowledge and changing farming techniques to cope with climate change, but they still feel the threat from outside.

In September 2013, Yiching Song, a researcher at the Center for Chinese Agricultural Policy of the Chinese Academy of Sciences, led her participatory action research team[1] over the mountains to this Naxi village on the mushroom boulder. They wanted to find out how much of the agro-germplasm resources were preserved in this hidden-away farming village on the edge of the Jinsha River. A few weeks of questionnaire visits revealed a downward trend in the total number of varieties planted by farmers; notably since 2007, there's a rapid decline. There is also a downward trend in the proportion of native species and introduced improved species, while the proportion of hybrids is on a rapid upward trend (Figure 1) . Mountain communities 126 km from the city are also suffering from genetic erosion, but it is encouraging to note that some women have shown a fondness for seeds.

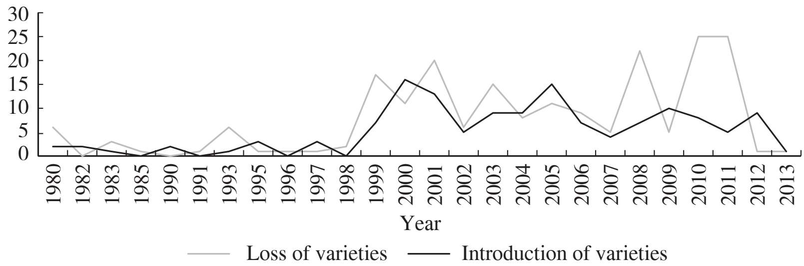

Figure 1 Loss and introduction of varieties in Stone Village from 1980 to 2013

At that time, the participatory action research team had been studying farmers' seed systems in Guangxi for 15 years, breaking the vacuum between farmers' seed systems and public breeding institutions' technical research and discovered the complementary cooperation model of Participatory Plant Breeding (PPB). In December 2013, the "Farmers' Seeds and Traditional Culture Exhibition Exchange Fair" was held in Lijiang and Stone Village, Yunnan Province. Representatives of the community, research

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① This team joined UN Environment Programme-International Ecosystem Management Partnership (UNEP-IEMP) in 2018.

institutions and government, from domestic and overseas regions who are involved in participatory seed selection came to Stone Village. Farmer Breeder Rongyan Lu, from Upper Gula, Guzhai Township, Mashan County, Guangxi Zhuang-ethnic Autonomous Region, shared her experience and results of participatory breeding selection together with her sisters from the cooperative. Her sharing inspired and attracted several villagers from Stone Village, who decided to join the participatory action research team with the expectation of exploring a development path for in situ conservation and sustainable use of agricultural seed systems with Stone Village characteristics.

2 Action research

2.1 Participatory methods

Through a participatory approach, villagers become the center of community development and develop a sense of ownership among them. After an international exchange workshop in December 2013 in Stone Village, five villagers from Stone Village, Shanhao He, Xiuyun Zhang, Ruizhen Li, Wenchuan Mu and Yichang Mu, formed a community participatory group. With the assistance of the Participatory Action Research Team, the farmers were linked to the Guangxi Maize Institute, where they were accompanied by field teaching and remote mentoring to teach them hands-on techniques such as Participatory Plant Breeding, Participatory Variety Selection, purification and rejuvenation and seed production. The group made an inventory of the community's biodiversity assets, compiled a register of community resources, and organized farmers' field schools to share the result and experience of planting in the field and teach other fellow villagers their selection and breeding techniques. They established a village seed bank in the community public space to raise awareness about local crop resources and motive local people to conserve community germplasm resources. The participatory team sows seeds from the seed bank in the seed field each year and then harvest seeds adapted to local climate change, to be returned to the village seed bank.

2.2 Community links and delivery

When the community of Stone Village joined the participatory action research team, it became a sister community with the community of Upper Gula, Guzhai Township, Mashan County, Guangxi Zhuang Autonomous Region. Through this link, they introduced Guinuo 2006 maize variety, the result of PPB in Upper Gula, to Stone Village, to learn from the seed production experience and participatory seed selection experience shared by the sisters of Upper Gula. After several years of hard work, the Stone Village community returned the fruits of their efforts to their sisters in Upper Gula.

The five team members in Stone Village passed on the virtues of sister communities, sharing the results and experiences of participatory breeding to their mothers' families and surrounding villages, and to the upstream villages of the Jinshajiang River Basin, Yomi Village, Lakaxi Village, and the downstream village of Wumu. On January 1, 2019, these four villages formed the Naxi Mountain Community Network, sharing their results and experiences with each other and exploring the possibility of sustainable community development in the context of climate change.

3 Project partners and processes

The approach used combines the traditional ecocultural systems and scientific knowledge systems, with smallholder participation, external assistance and led by the community.

3.1 Farmer-oriented community-based participatory plant breeding

The five members of the participatory team of the Stone Village community, Shanhao He, Wenchuan Mu, Yichang Mu, Ruizhen Li and Xiuyun Zhang, are composed of elderly people, women and village officials. Shanhao He is the head of the village's Senior Citizens Association and hopes to lead the senior citizens of Stone Village to help the community develop in a civilized and harmonious manner. Wenchuan Mu is the secretary of Stone Village and Yichang Mu is the village chief of Stone Village, who themselves have an innate pride in Naxi culture and an interest in the traditional germplasm resources preserved by their ancestors. Ruizhen Li is the captain of the Women's folk-art Team of Stone Village. She grew up in Stone Village, claiming that "this is my revolutionary base" and was always accompanied by the land every day. Influenced by his father, Xiuyun Zhang has a keen interest in seeds and dares to be innovative. Wenchuan Mu's wife and Xiuqin are village health workers and often share the results of participatory breeding through the village health network. Stone Village's participatory breeding initiative has attracted the attention and support of other rural officials. Participatory group members share experiences and results of participatory breeding through their community networks.

3.2 Traditional knowledge combined with modern science

The technical support force behind the participatory action in Stone Village came from the Maize Institute of the Guangxi Academy of Agricultural Sciences. Scientists such as Weidong Cheng, Kaijian Huang, Lanqiu Qin and Hexia Xie were invited to the terraced fields along the Jinsha River several times for field instruction. The villagers of Stone Village shared traditional farming techniques, such as ancestral breeding and planting experience with experts who had come from far and wide to exchange seed selection ideas. These experts also do not mince words to teach breeding techniques, such as purification and rejuvenation, and at every critical moment of breeding, they come to Stone Village to give follow-up guidance and to teach the villagers hybrid breeding techniques. The experts answer questions in WeChat groups and oversee the growth of the local team members.

3.3 Action researchers and NGO assistance

Participatory action in Stone Village is also inseparable from the assistance of action researchers and NGOs. The action research teams invited from 2013 to date are the Center for Chinese Agricultural Policy of the Chinese Academy of Sciences, the Kunming Botanical Research Institute of the Chinese Academy of Sciences, and the Yunnan Lijiang Alpine Station, the team of Professor Qingzhong Sun of China Agricultural University, Professor Yunyue Wang and the research team of Yunnan Agricultural University, and Professor Xueli Chen of Yunnan University. The combined innovation of experts and scholars has contributed to the development of present Stone Village. Stone Village has also received support from national and international agencies and NGOs, including the

Farmers' Seed Network (China), UN Environment Programme-International Ecosystem Management Partnership (UNEP-IEMP), Oxfam Hong Kong, the International Institute for Environment and Development (IIED), United Nations Development Programme (UNDP), Global Environment Facility Investing In Our Planet (GEF), The GEF Small Grants Programme (SGP), the NGO ANDES of Peru, Brot fur die Welt (Germany), International Development Research Centre (IDRC) of Canada, Bioversity International (now the Alliance of Bioverisity International and CIAT), and the International Network of Mountain Indigenous peoples (INMIP).

3.4 Community farmers are beginning to value farmers' seeds and traditional culture

In April 2014, members of the Stone Village Participatory Research Team, represented by Wenchuan Mu and Xiuyun Zhang, traveled to the Potato Park in Cuzco, Peru, never dreaming that they would be able to go abroad and see that on the other side of the Pacific Ocean, there is an even more "primitive" placed compared to Stone Village, where people have the technology to improve economic conditions, but traditional farming tools and farming methods are always used and prefered. The land is home to the world's largest variety of potatoes, and the traditional culture lives on in the community in strict adherence to community conventions. Xiuyun Zhang, who was interested in seeds, was stunned by the dazzling variety of potatoes, and Wenchuan Mu began to recall those traditional cultural activities he had participated in as a child. After a few days of communication and experience, they saw faith in the eyes of this group of Andean people and felt the respect for the seed.

Wearing sackcloth during funeral and mourning is a tradition in Stone Village, due to the complicated weaving process, sackcloth is easily available from the market, and the seeds of sisal disappeared. In 2015 Wenchuan Mu recovered the seeds of traditional weaving sisal, sisal seeds again grew on the land of Stone Village. Wenchuan Mu called on the village weavers to revive their traditional weaving techniques.

"One who never travels will not know the comfort of his home", in September 2015, Ruizhen Li and Yichang Mu took Stone Village's spirit liquor and preserved meat to Beijing to attend the China Delicious Ark Products Exhibition and Summit Forum held by the International Slow Food Association Greater China, where Stone Village's traditional handcrafted spirit liquor and preserved ham were selected for the International Slow Food Association China Delicious Ark Directory. Traditional breeding methods and handed down wine recipes are recognized by the public and being "down to earth" is not a bad thing. Upon his return, Yichang Mu began to follow the herbalist to the mountains to identify Chinese herbs, and from time to time made his own medicinal liquor. Through their actions, they are expressing their awareness of the urgency of preserving farming and traditional culture.

4 Results of participatory breeding

4.1 Direct achievement of PPB and PVS

In 2013, the participatory action research team set foot in this mountainous area, and since then they have been connected to this Stone Village on the edge of the Jinsha River, a village that is quietly changing: the seeds of diversity are gaining resilience in the face of climate change, and traditional ecosystems are being restored and developed through the combined efforts of the villagers.

After several years of participatory breeding initiatives in Stone Village, community biodiversity is beginning to enrich. Members of the participatory group made bold attempts based on their own interests, with 64 varieties successfully introduced in Stone Village as of December 2018 (Table 1). In 2013, we introduced maize test varieties Guizongnuo, Guisuzong, Guinuo 2006 and Moyinuo from our sister community Upper Gula. Xiuyun Zhang began to study Guinuo 2006 under the guidance of Guangxi Academy of Agricultural Sciences in 2014. She introduced a total of 14 varieties of maize for PVS testing and selected 8 kinds of varieties adapted to the local climate and retained them. The three women, Wenchuan Mu, Ruizhen Li and Yichang Mu, began to purify and rejuvenate, and Shanhao He began to collect old varieties of vegetables. In 2015, Xiuyun Zhang taught Guinuo 2006's breeding techniques to Ruizhen Li, and after they mastered hybrid breeding techniques, they produced the desired varieties according to their preferences.

Table 1 Seed-related achievements: Enriching community biodiversity

Sources	Varieties
A total of 40 varieties have been successfully introduced from outside Stone Village	Guinuo 2006, Guizongnuo, Guisuzong, Moyinuo, DPR905-2, DM91 DR901, P12, P11, P9, Zhong-mo 1, Yellow maize, Huaiyuan glutinous, Peruvian purple and white maize, Peruvian big white maize, Peruvian red maize, Peruvian purple maize, Peruvian yellow maize, Peruvian black maize, Guangxi yellow maize, fruit maize, Kyrgyzstan Sakhar (yellow) maize, oil rice glutinous maize, Oumu glutinous maize, nettle, Kyrgyzstan wheat, Indian pumpkin, quinoa, oil rice beans, Mexican beans, lupine, Peruvian broad beans, Peruvian peas, white eyebrow beans, Li beans, Guichun 15, Guichun 13, Guichun 11, Guichun 8, Lijiang Kuzi soybean, Meizuan big yellow beans and 24 traditional varieties of Mexican maize.

continued

Sources	Varieties
A total of 4 varieties introduced from Guladun, Mashan, Guangxi	Guinuo 2006, Guizongnuo, Guisuzong, Moyinuo were all successfully preserved.
A total of 14 varieties were introduced from the Guangxi Maize Research Institute	PR905-1, PR905-2, PR901, PR501, PR619-1, PR619-2, Black Glutinous 601, Black Glutinous 518, P12, P11, P9, China-Mexico 1, Yellow maize, Huaiyuan Glutinous Eight of these have been adapted to the climate of Stone Village and remained in production DPR905-2, DM91 DR901, P12, P11, P9.CM1,Yellow maize, Huaiyuan glutinous

In 2015, the community attempted to retrieve old farmyard varieties of soybean. Yichang Mu took the lead in soybean PVS testing. By identifying the local adaptability of each tested variety, their economic traits, yield potential, yield stability, resilience, and other characteristics, after three years, eight satisfactory varieties were selected from the 37 varieties introduced to be planted by the villagers. The villagers will use the harvested soybeans to make soymilk and tofu. In 2014, Wenchuan Mu's wife and Xiuqin He distributed the introduced Guizongnuo to more than 30 farmers through a network of village doctors. Today, many families still grow Guizongnuo in their vegetable gardens, and because of its good taste, the villagers have consciously started to save its seed. After several years of experimentation, Guinuo 2006 and Guizongnuo have become the signature ingredients to serve tourists.

Due to the severe loss of farmer varieties, experimental varieties were introduced to produce seeds adapted to the climatic environment of Stone Village. An inventory of the community's biocultural household products was started, and a community resource register was compiled. As of December 2018, 63 varieties were registered, of which 4 are maize, 4 rice, 8 wheat, 10 bean, 2 peanut, 2 sweet potato, 5 melon, 1 fruit, 12 vegetables, 4 Chinese herbs and 11 others. Since then, the Stone Village community has had its own genealogy of biocultural resources.

To raise the villagers' awareness to protect the old varieties, a village seed bank was established in 2015 at the site of the former Stone Village Elementary School (formerly the center of Baoshan county). The seed bank serves as a public exchange platform for the community to showcase its germplasm resources and rally more villagers to participate in protecting the old varieties and build a seed sharing platform for villagers to encourage them to save as much seed as possible for breeding. There are seven displays in the Stone Village Seed Bank, namely: Stone Town old varieties, Stone Town old vegetable seeds, Stone Town herbs, Lijiang local plants, PPB (Participatory Breeding) trial varieties, PVS (Participatory Variety Selection) soybean varieties, and varieties exchanged within the seed network. There is a total of 109 varieties, including Stone Village rice, maize, sorghum, vegetables and 69 other local varieties, plus 22 PVS soybean trial varieties and 17 PPB trial varieties. With the assistance of the Farmers' Seed Network, experts from the Lijiang Alpine Botanical Garden of the Chinese Academy of Sciences provided technical support and conducted research on the environment and endangered wild species resources of the Stone Village Ecosphere. They arranged the "Vertical Distribution Map of Jade Dragon Snow Mountain Plants" in the seed bank and set up a separate display case of Lijiang native plants, with 25 local plant species. The seed bank is shared by the villagers, and managed by the villagers themselves, who discuss the rules of use and management together. It is now mainly managed by Ruizhen Li and the two sisters of the women's literary team, Ping Li and Shugui Mu.

In response to climate change, Ruizhen Li took out 16 seeds from the seed bank in June 2017, including seven species of beans and nine species of maize, and used a piece of her own land as a test field for adaptive breeding. She said, “What’s it like to not have a field to try planting the seeds!” She wrote the name of each crop and seed provider on a cardboard and inserted it in front of the crop. She has sent out photos of herself with seed fields and test varieties in the “breeding group” WeChat group to share their growth, and to show the seed owners and breeders in Guangxi how the varieties have taken root and blossomed in the Stone Village.

4.2 Innovations by farmer breeders

The results of the participatory group’s efforts were something they had not expected before, nor had they expected to work together with scientists, let alone to become “breeders” themselves. In 2014, Xiuyun Zhang tried Guinuo 2006 seed production, and in 2015, she brought her sisters together to do Guinuo 2006 seed production, strengthen the power of the Stone Village seed production, and reduce the risk of the trialing. When Xiuyun Zhang first started trying to produce seeds, he was affected by the weather in Stone Village. The seeds of Guinuo 2006 were sent from Upper Gula for seed production in the following year. But again, bad weather affected the crop. Xiuyun Zhang said, “One after another, I was let down, but I will make you stand up straight again!”.

In the end, under the patient guidance of scientists at the Guangxi Academy of Agricultural Sciences Maize Research Institute, Xiuyun Zhang mastered the 2006 Guinuo seed production technology. The traits have been stable for four years, with the crosses of Peruvian purple-white maize with

Guinuo 2006 and Guizongnuo. Due to Xiuyun Zhang's keen interest in seeds, up to 54 varieties have been introduced. She named her Guinuo 2006 hybrid Xiuyun No.1 and Peruvian purple-white maize dumpling Guinuo 2006 as Xiuyun No.2. The 2006 hybrid of Guinuo 2006 bred by Ruizhen Li was named Ruizhen No. 1, and the breeding of Guizongnuo bred by Wenchuan Mu, which was adapted to Stone Village, was named Stone Village No. 1.

5 Building women's capacity and confidence

After several years of participatory breeding action, a new type of local talent has emerged in Stone Village, "farmer breeding experts" Xiuyun Zhang, Ruizhen Li. These Naxi women are known for their hard work, good communication, learning, and cooperation. Awareness, pride and ownership of the indigenous knowledge system are also enhanced, as they get out of the mountains, meet different people, expand their horizons and network.

In 2016, Xiuyun Zhang and Ruizhen Li traveled to Mexico to represent mountain indigenous women at the 13th Conference of the Parties to the Convention on Biological Diversity. They shared their experiences and experiences of farmer's participatory breeding selection and represented the voice of Chinese women at the conference, bringing the Naxi tune to the international stage and showcasing the Naxi ethnic culture. In 2014 and 2017, Xiuyun Zhang and Ruizhen Li went to Cusco, Peru, as representatives of the Naxi mountain farming culture. At the "Potato Park", they shared mountain farming knowledge with indigenous mountain people from around the world and discussed challenges and opportunities for indigenous and modern knowledge systems. In 2016, Xiuyun Zhang took the traditional cuisine of Stone Village to Turin, Italy for the International Slow Food Conference. Xiuyun Zhang brought the white spirit liquor of Stone Village and confidently stood in front of the crowd to introduce the recipe of the liquor passed down from the ancestors. By travelling overseas and meeting with partners of Farmers' Seed Network, they shared their experiences and doubts, encouraged fellow members, and grew together.

After going out to see the world many times, they also began to have a dream in their hearts. In 2018, Xiuyun Zhang took her sisters and registered the Baoshi Ecological Agricultural Cooperative, expecting to promote their own experimental results with the sisters, adopt traditional ecological cultivation methods, spread the concept of conservation of agricultural seeds, build a local brand in Stone Village, and increase economic income and improve family economic level by adding added value to the development of results.

6 Community capacity building

Through five years of participatory breeding trials, the skills, competencies and awareness of the group members have improved, bringing them closer together for common goals. They set up community fund management groups to jointly develop management mechanisms and mutual compliance. Together, they organized one international conference, two workshops, one annual meeting of the Farmers' Seeds Network. In May 2016, the South-South Cooperation Conference welcomed friends from Peru, Tajikistan, Kyrgyzstan, Nepal and the farmer communities in China to present their traditional knowledge and farming culture as hosts, with confidence and to share village rules and regulations and management systems. With the support of village officials, the Elderly's Associaition has revived traditional rituals and encouraged more men to participate. The memories of the once childhood joys have also returned to everyday life in 2018, with men, women and children gathering in the square every evening, the Naxi trilogy playing, and men, women and children gathered around a campfire to begin dancing.

Realizing that the power of one village is limited, they formed a network of Naxi mountain communities with the upstream and downstream Naxi villages of the Kinshasa River basin—Youmi, Lakaxi and Wumu villages. The members of Stone Village shared the results and experiences of participatory breeding, Wumu Village and Youmi Village share the preservation and transmission of traditional Naxi culture, and Lakaxi Village shares the experience of leading the villagers in economic development and discussing the sustainable development of the community.

7 Policy implications

The results of the efforts of the Stone Village community are also being replicated through various platforms to promote the recognition of farmers' seed systems and the importance of biodiversity conservation.

In May 2016, villagers in Stone Village welcomed the visit of the INMIP members, where nearly 40 scholars, policymakers, experts from international organizations and 35 representatives of farmer communities from different countries around the world came together for a workshop on the theme "Ecocultural Systems in Mountain Indigenous Communities, Poverty Reduction and Sustainable Development". The meeting resulted in the Stone Town Declaration of the International Mountain Indigenous

Network, whose policy recommendations were presented at the 22nd Conference of the Parties to the United Nations Framework Convention on Climate Change in Marrakech, Morocco, in November 2016, in order to raise awareness of the situation and needs of indigenous mountain people and call attention to the ecosystem and livelihood activities of mountain communities to address climate change impacts. In December 2016, Ruizhen Li and Xiuyun Zhang spoke out for mountain women and local seeds at the International Conference on Biodiversity in Mexico. The "seed trail" of Stone Village has been engraved all over the world, and these people, who live in a corner of a big mountain and a big river, have attracted the attention of the world with their hard work and wisdom.

Smallholder farmers and scientists in the Stone Village community have joined forces, and after many years of work, crop variety resources are being enriched, enhancing the conservation and sustainable use of older varieties, as an effective strategy to adapt to climate change.

The case of the Hani ethnic group of Yunnan: Community–based biodiversity management

Yunyue Wang, Chunming Lu, Guangyu Han, Yifan Zhu, Bo Jiang, Ling Huang, Hongsong Wang, Xiang Li

1 Introduction

Hani terraces are located in the southern part of Yunnan Province, the southern section of the Ailao Mountain, spanning over the Honghe State's four counties; Yuanyang, Honghe, Jinping, Luchun, with a total area of 820,000 mu. It is an agricultural miracle reclaimed by the ancestors of the mountain people of the Honghe state, who are mainly of Hani ethnicity. They took full advantage of the special geographical and climatic conditions of the Xiaojuan Mountain with their wisdom and ingenuity. With a recorded history of over 1,300 years, it is the essential way of survival and development of these mountain peoples; it provides them with all the necessities of livelihood, and to them it also has a deep sentimental value. On 22 June 2013, at the 37th World Heritage Conference held in Cambodia, the Hani Terraces were inscribed on the World Heritage List by UNESCO, becoming the 45th World Heritage Site in China and the first World Heritage Site in China to be named after an ethnic group, marking the recognition and affirmation of its value by human civilization.

The Hani Terraces mark the highest level of achievement and agricultural paradigm among the world's mountain peoples, a classic case of overcoming the limits of cultivated land and water resources. The Hani terraced rice farming system is the soul of the Hani terraces and is both the origin of Hani culture and a cultural carrier. All the activities of the Hani people revolve around rice farming, while traditional rice varieties are the central focus of traditional rice farming. For over 1,300 years of Hani farming history, natural and artificial selection has gradually produced a large number of farm varieties adapted to the Hani Mountain ecosystem, and these rich local rice seed resources and their genetic diversity are the basis for ensuring the sustainable development of Hani terraced rice system.

The Hani have developed a relatively scientific and rigorous system of terraced farming procedures and a system of land, forest and terraced management in the spirit of their traditional culture through indigenous knowledge for the conservation of biodiversity and ecosystem functions. The system involves farmland construction, irrigation, cereal seed selection, field management, etc. to meet food, agricultural, socio-economic and cultural needs and maintain local ecosystem service functions. It has resulted in a large number of rice varieties adapted to the local geographical climate during its long history of rice farming.

In order to better protect the Hani Terraces, uncover traditional knowledge of Hani mountain rice management and sustainable farming, and promote the conservation and sustainable use of traditional rice varieties, we analyzed the role of the Hani Terraces seed system and traditional seed exchange in maintaining local rice seed diversity by starting with seeds. At the same time, we raised the awareness and capacity of local communities to conserve and sustainably use biodiversity through research, interviews, training, building community seed banks, farmers' field days and biodiversity days.

2 Action research methodology and project partners

Systematic and continuous research on the Hani rice seed system has been carried out since 2008, using questionnaires, semi-structured and household interviews, rice seed collection and evaluation, survey and evaluation of agronomic traits and pest resistance of rice varieties, field trial demonstrations, community seed bank construction, farmer training, farmer field days and biodiversity days.

Project partners include Yunnan Agricultural University, International Biodiversity Center, Yunnan Academy of Agricultural Sciences, Yuanyang County Agricultural Science Institute, Yuanyang County Agricultural Extension Center, Yuanyang County Seed Station, Yuanyang County Xinjie Township.

3 Results of participatory plant breeding

The Hani people use traditional rice as the core of their farming, however, in the southern section of the Weijuan Mountains, in the areas of Yuanyang, Honghe, Jinping and Luchun, the majority has little land. Thus, here the Hani people had no choice but to reclaim land from the mountains in order to cultivate rice. After hundreds of years of continuous reclamation, the Hani terraces have an elevation difference of more than 1,000 m. In the process, the Hani people have also been breeding diverse varieties of rice to adapt to different ecological environments and they have developed a unique culture of seed retention, seed swapping and participatory breeding and farming of rice. As a result of long-term selection and cultivation by the Hani people, the Hani terraces retain an unusually rich diversity of local rice varieties, with over 100 rice varieties still under cultivation. These varieties are named with local characteristics, suitable for cultivation from 960 to 1,946 m above sea level, rich in genetic diversity in both agronomic phenotypes and at molecular level, with a wide range of resilience and stable adaptability, showing good buffering capacity when encountered by major pests and diseases, climate and environmental changes. Many varieties are rich in various trace elements and high levels of 16 amino acids with high nutritional value. To meet the demand for manual threshing, local rice varieties are also generally better in shattering. In addition, the Hani people have diversified the selection and cultivation of rice varieties in order to meet the diversified needs of worship, mushroom-shaped roofing, silage production, and the raising of fish, ducks, loach, and crabs in the rice fields.

From 1956 to 1982, Yuanyang County has conducted four seed censuses, the county has 196 traditional varieties, of which there are 171 kinds of indica rice, 25 kinds of japonica rice, 47 kinds of land rice. In 1999, Qinghua Wang mentioned in his book “On the Culture of Terraces”, that the Hani tribe has more than 180 rice varieties.

A study published in 2010 showed that there are 135 rice varieties with different names in 30 villages in the core area of the Yuanyang Terraces, but we also found that with socio-economic development, the diversity of rice varieties and the culture of rice farming in the area are facing serious challenges. First, most farmers do not have a clear understanding of the value of the rice varieties and culture they have, while infrastructure and socio-economic development have led to the gradual disappearance of some of the needs (e.g., roofing). The emigration of young people and changes in cultural practices have also led to the abandonment of the rice culture, with more and more farmers preferring modern varieties with consistent high yields or other crops with higher economic value. Therefore, in order to promote the conservation and sustainable use of traditional rice varieties and rice culture in the Yuanyang terraced rice fields, and to raise the awareness and capacity of local farmers and government departments for the conservation of rice genetic diversity and germplasm resources, we launched the Yuanyang Hani community germplasm bank in 2015. So far the germplasm bank has collected and preserved 104 local traditional rice varieties and conducted seed registration for them. The composition of the Yuanyang Community Seed Bank includes a seed conservation cabinet and a breeding base. The seed preservation cabinet is a room temperature seed storage facility set up at the Agricultural Science Station in Xinjie Town, Yuan Yang County, using seed bottles for sealed storage. An archive of agronomic traits, yields, resilience (pests, low temperatures, frost), uses and utilization values of rice seeds was also established. The breeding base is located in Qingkou Village, Xinjie Town, at an elevation of 1,660 m. Its role is breeding for the seed bank, field display and collection of variety-related data information. The seed bank management team, comprising community farmers, rice scientists, local agronomists, and staff from relevant government departments, is responsible for activities such as identification and evaluation of rice seed collection, development of seed bank management regulations and seed acquisition procedures, and organization of training and staff training.

The first priority of the Wanyang Community Rice Seed Bank is to provide quality traditional rice seeds to local farmers. There are two ways in which farmers can access seeds at community rice seed banks: seed exchange and seed borrowing. Seed exchange, whereby farmers exchange their own varieties with community seed banks for seeds they need; seed borrowing is mainly for farmers who do not have a seed bank and lack a source of seed. They can borrow seeds from the community seed bank free of charge at the time the rice is sown, subject to an agreement to return the same seeds after the rice harvest. All farmers participating in the Hani terraced community rice seed bank seed exchange and seed borrowing must mark information, such as variety, harvest land and planting management when returning seed.

4 Results of other action research

4.1 Yuanyang Terraced Rice Farmers' Seed System

Between 2010 and 2014, we conducted a five-year continuous study on the seed system for farmers in the Hani terraces of Yuanyang, covering nearly 450 households in 10 villages in the core area of the Yuanyang terraces. The survey found that there are four sources of seed for farmers, namely self-sowing, inter-farm seed exchange, seed from the government (programs such as good seed promotion), and seed purchase from commercial enterprises.

Although the proportion of seed received by farmers from these four channels varies somewhat from year to year, the amount of seed from the two channels of self-sowing and seed exchange has remained consistently above 80%. This means that the farmers' seed system has been dominant in rice seed in the Yuanyang terrace. The proportion of farmers keeping their own seeds and exchanging seeds varies considerably from year to year, for example, over 70% in 2010-2011 and only 45% in 2012-2013, due to the fact that about three quarters of local farmers are accustomed to changing seeds every three years and that there is some tendency to bandwagon by farmers.

Farmers in the Yuanyang terraces also have preferences on the choice of rice seed source when switching to a new variety. Most farmers would choose seed sources within a horizontal distance of 1,000 to 4,000 m and a vertical elevation difference of 200 m, with no obvious preference for seed sources from higher, same or lower elevations. This swapping approach ensures the genetic stability and uniqueness of traditional rice varieties while maintaining genetic diversity within and among local rice varieties. In the inter-sowing period, terraced farmers generally prepare rice seeds for the second year by self-seeding, and there are three main methods of seed retention and selection, namely, field selection, block selection and ear selection. Field selection means that farmers mix the seeds of all the plots after harvesting and select the full and good seeds from them as the seed source; block selection means that farmers observe the growth of the fields before harvesting and select the plots with good performance and high fertility and collect the seeds from them as the seed source; ear selection means that farmers select single plants with good growth, healthy and full seeds from the fields before harvesting and thresh them individually as the seed source. About 50% of the farmers in the Yuanyang terraces chose block selection as the seed retention method, and the proportions of field selection and ear selection are about 25% each. The way farmers choose to retain seeds is influenced by several factors. Farmers with a large field area will generally use field selection and block selection, while small area farmers tend to use ear selection to retain seeds. Farmers with a lack of labor force will generally not choose ear selection, while farmers with a high level of education and high purity requirements for rice varieties will use ear selection to retain seeds.

The rich diversity of rice seeds in the Yuanyang terraces has benefited from the well-developed local folk seed system and diversified methods of seed exchange and seed retention. Through centuries of continuous selection and exchange by the Hani, Yi and other ancestral peoples, the unique rice variety system and terraced rice culture of the Yuanyang terraces have been gradually formed, and a balance has been achieved between the introduction of new external genetic germplasm and maintaining local genetic stability.

4.2 Rural livelihoods

The Hani terraces, which closely link the Hani traditional rice culture, terraced landscape and rice, especially after the success of the UNESCO World Heritage listing, attract a large number of tourists every year. The terraced red rice (Yunnan quality rice), terraced loach, and other products created through rural cooperatives have also won the approval of many consumers for their organic, environmentally friendly and healthy qualities, as well as the inner-qualities of the Hani farming culture. The rice is sold to major cities, bringing considerable income to local communities and farmers.

5 Gender analysis and the development of women's capacities and self-confidence

Women play an important role in the traditional rice culture of the

Hani Terraces, participating in decisions on seed selection, seed change, cultivation, etc. Special emphasis has also been placed on the role of women and building their capacity and self-confidence in activities such as community seed bank building, variety demonstration, community capacity building, including inviting women to submit and display rice seeds, registering varieties and describing traits, participating in field trial demonstrations, participating in field days and biodiversity days. Hani women have been proactive in these activities, demonstrating the important role and place of women in agricultural activities.

6 Community capacity building

Community capacity building is key to the conservation and sustainable development of the Hani Terraces and its rice culture. Since 2008 we have conducted a series of capacity building activities in more than 30 communities in the Hani Terraces, including training for farmers and community opinion leaders, participatory surveys and interviews, rice seed collection, agronomic trait and pest identification, field trial demonstrations, farmers' field days and biodiversity days, and community seed bank building. These activities have effectively raised community awareness and capacity for conservation and sustainable use, promoted farmers' awareness of the value of the rice varieties they own, and nurtured farmers' sense of identity and confidence in their traditional knowledge and rice culture. Field days, for example, focused on showcasing dozens of rice varieties from the Hani terraces, making farmers aware of the rich diversity of rice varieties. Visually comparing the differences between varieties, motivating them to participate in the conservation and sustainable use of rice diversity and helping them to make better use of community seed banks.

7 Policy implications

We have used a wide range of multi-layered channels, such as through the "Two Sessions", i.e. the National People's Congress (NPC) and the Chinese People's Political Consultative Conference (CPPCC), CPPCC research, CPPCC consultations, thematic consultations, proposals for consultation, etc., to submit research reports and proposals to the Yunnan provincial government. The party and government functional departments have arranged for the implementation of RMB 215 million funds for the protection of the Hani terraces.

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A case of conventional rice in the Guangxi Academy of Agricultural Sciences Rice Research Institute

Chuanhua Chen

1 Introduction

Rice is the main food crop of nearly half of the world's population, in particular in developing countries, and is the number one food crop in China, with a sown area of 30.18 million hectare in 2016 and a yield of about 207 million tons, accounting for about 40% of total food production. Guangxi's rice cultivation area and production rank among the top in the country, with an annual sowing area of about 2.1 million hectare, accounting for 60% of the region's grain sowing area.

Drought is a worldwide agricultural problem and is one of the major impeding factors affecting rice production. Drought in rice is the second yield limiting factor worldwide, after pests and diseases, of all biologically adverse environments.

In recent years, with the continuous deterioration of the ecological environment and the frequent occurrence of catastrophic weather, the hazards are becoming more and more serious. For example, in the extreme drought suffered by five provinces in southwest China in the spring of 2010, more than 50 million people were affected, nearly 5 million hm^2 of crops were affected, of which 400,000 hm^2 of fertile land had zero yield, 78 counties (cities) in Guangxi suffered varying degrees of drought, including 5 particularly dry counties (cities), 16 heavy drought counties (cities), and Nandan County, Fengshan County as regional drought-prone areas. That is why there is a greater need to apply resilient varieties in agricultural production to resist disasters such as drought.

In 2007, the Research Office of the Rice Research Institute of the Guangxi Academy of Agricultural Sciences (GAAS) started the breeding work related to drought-resistant high quality rice, such as the combination hybridization of varieties, initial screening of drought resistance, selection of agronomic traits, etc., and subsequently natural screening of materials for drought resistance will also be conducted.

Our project site is Namo Village. The entire village has 43 households and a total population of 228, pure Zhuang ethnic group. It currently has over 200 mu of cultivated land, of which 6 hm^2 are cropland, with yellow and red soils.

The villagers' houses and cultivated land are located on the hillside at an elevation of about 830 m, with an average annual temperature of 19℃ and a large temperature difference between day and night, with hot days, cool nights and mild seasons. The staple grains produced are rice and maize, as well as miscellaneous grains, such as red rice and millet.

Due to unique factors such as climate and soil quality, food crops' growth period is longer than normal, and the rice produced is more fragrant, chewy and more nutritious than normal. However, there are many local fields without irrigation, which are threatened by year-round drought and are well suited for natural screening against drought.

Partners for Community Development (PCD), a Hong Kong based foundation with the mission of restoring people's inner connection with nature and exploring ways and means to achieve sustainable living, began the first phase of cooperation with the Guangxi Academy of Agricultural Sciences in 2011 to introduce conventional rice varieties such as Guiyu No.7 in Nandan, and found that conventional rice varieties such as Guiyu No. 7 are more drought-resistant than hybrid rice. PCD hopes to carry out the second phase of cooperation, through natural screening of drought-resistant breeding materials obtained by GAAS in the target community of Fengshan, Guangxi, with the goal to screen out some drought-resistant rice varieties adapted to local ecological conditions, and promoting their application locally to improve the resilience of local farmers to drought disasters. At the same time, involve farmers in screening trials and train them in practical techniques such as purification and rejuvenation, to reduce the local cost of rice cultivation.

2 Action-research method and project partners

We conduct natural screening of drought-resistant breeding materials obtained in the rice fields of farmers in the target community, Fengshan, Guangxi. Farmers will participate in the seed selection process and will train in practical techniques for seed selection, purification and rehabilitation through training courses and field exchanges.

Project partners include the Rice Research Institute of GAAS, PCD, Namo Village: Yongzhong Huang and Caiyi Ban.

The project partner, the Rice Research Institute of GAAS, was established in 1981, formerly the Academy's Department of Food Crops, Plant Crops and Plant Physiology. It has been engaged in long-term research on rice seed resources, conventional and hybrid rice breeding, high-yielding rice cultivation and supporting technology research, research and promotion of rice computer expert system, application of biotechnology and rice germplasm innovation, etc. The institute has a physiological and biochemical laboratory, standard seed testing room, rice quality analysis laboratory, artificial climate room and rice original seed and original seed production base. It has formed a variety selection, testing, demonstration research and fruit development and application system.

Since the establishment of the Institute, a total of 104 new varieties (combinations) of rice have been bred. 13 varieties have obtained the State variety rights protection, the cumulative area of promotion has reached more than 300 million mu and have won 86 awards for scientific and technological achievements. It is a professional rice research and development organization with the strongest overall strength in Guangxi.

The project partner, Partners for Community Development (PCD), was established in May 2001 by the Hong Kong Kadoorie Foundation. Its mission is to restore people's inner connection to nature and to explore ways and means to achieve sustainable living.

PCD works within and between communities to promote a culture of wholeness and sustainable development and to strengthen community self-esteem, participation and cooperation. The projects include enhancing participatory and research skills, learning about local culture, good rural governance management, eco-agriculture, community supported agriculture, extension of voluntary work, capacity building of civil society organizations and community groups, etc. During this period, PCD has carried out a total of 50 development projects in Yunnan, Guizhou, Sichuan, Guangxi, Guangdong, Shanghai, Beijing, and other provinces and cities. In addition to funding community projects, PCD also responds to issues of justice, equity, sustainable development and multiculturalism through training, information exchange, networking, etc.

Since 2009, PCD has been supporting the development of eco-agriculture in Namo Village, with the aim of restoring farming techniques to the traditional manner and in harmony with nature, while making reasonable use of technology.

Since 2012, the villagers' meeting reached a consensus to ban the use of chemical fertilizers, pesticides, herbicides; only animal manure and green manure will be used for rice planting, and follow the tradition of plowing three times, harrowing three times, and make one to two cultivation care, while gradually restoring more than a dozen traditional varieties, through conventional planting. The village has since embarked on a path of sustainable development.

In 2012, PCD and GAAS collaborated on the project "Drought Tolerant Variety Selection and Supply of Nandan and Fengshan Rice in Guangxi", which included the Zhuang-ethinic Namo Village as a pilot site.

The project will mainly take place at the home of Production Captain Zhongyong Huang, and villager Caiyi Ban.

3 Results and achievements of participatory breeding

For farmers, three conventional rice varieties with good drought tolerance, Guiyu No. 7, Guiyu No.8 and Guiyu No. 9, which are suitable for local use, were selected after a three-year selection process for drought-resistant varieties (or strains). Before the project, the community mainly planted three varieties of hybrid rice, namely Xianyu 63, Zhongzheyou and Danuo, two varieties of small glutinous rice, two varieties of black rice, two varieties of japonica grain and dry grain.

These three varieties are all soft rice varieties with excellent quality, and most of the rice quality indexes have reached the national standard levels 1 and 2, with high yield comparable to hybrid rice, good field resistance, and good performance in local rice cultivation, which is suitable for local use and has improved the yield of local ecological rice cultivation. Farmers are involved in the selection process and select the relevant traits according to their own needs, so that the selected varieties are better suited to the local growth environment and market demand. By participating in breeders' training courses on drought resistance and on-site teaching of seed selection, purification and re-strengthening, local participating farmers basically mastered simple purification and re-strengthening skills. With this skill farmers can effectively retain seeds of conventional rice varieties grown at home, maintain the excellent seed quality of the original varieties, and effectively reduce the cost of rice seeds caused by the purchase of seeds.

For breeding facilities, the project provides access, on the one hand, to a group of excellent drought-tolerant monocultures that have shown good resilience and good yield trait indicators for cultivation in local fields and can be used as intermediate breeding materials. On the other hand, breeders, through exchanges with farmers, clarified the requirements of local farmers for varieties. Farmers need varieties with good qualities: good-looking rice, crystal clear, high rate of whole grains; good taste, soft and smooth; easy to grow, can maintain a high yield even without the application of chemical fertilizers and pesticides, and show little yield reduction in dry weather. The goal of variety selection and breeding is now clearer.

4 Other action research results

4.1 The continuation and protection of local cultivation practices and the preservation of the local ecological environment

Namo farming techniques have evolved hugely with the Chinese society. At the time when chemical agriculture was on the rise, the villagers used to follow suit. Not only did they consider fertilizer pesticides as an important means of increasing yields, but they also took it as a fad. After many years, they discovered that the soil was getting harder and leaner and more difficult to grow; the fields were becoming less and less populated with small animals and insects, which even became extinct, and the pests were increasing. A phenomenon of "three highs" appeared in the area of growing food, namely high seed costs, high fertilizer and pesticide inputs, and high ploughing and harrowing. What is even more incomprehensible is that two or three households in Tuen Mun have kept their traditional methods of cultivation, without the use of fertilizers and pesticides. These households have not seen any decline in food yield, pests and diseases did not occur much. These findings made it clear to them that increasing yields from fertilizers and pesticides alone is a monolithic and deformed view of farming techniques that is not worth replicating, and that while there is a little yield improvement, there is more to be lost. As a result of the comparison, the villagers changed their simplified view of farming technology, gradually reverted to traditional farming practices, and reduced the use of chemical fertilizers and pesticides year by year.

After the community partners introduced the concept of "harmonious coexistence between people and nature", they are now more confident to follow the path of ecological farming. The cultivation of fields without chemical fertilizers, pesticides and herbicides has become the consensus and action of all villagers in recent years. In the planning process, hybrid rice varieties are expensive seeds, the yield of farm varieties is low, farmers want to seek some high yield, good rice quality and relatively cheap rice varieties to improve the efficiency of rice cultivation and promote the sustainable development of local agriculture. In this participatory selection process, the breeding unit recommended Guiyu No.7, Guiyu No.9 and other excellent conventional rice varieties as organic rice varieties to local farmers, which increased local organic rice production. At the same time, the simple technology of seed selection, purification and re-strengthening taught in the field enables farmers to plant conventional high-quality rice can be very good seed retention, effectively reducing planting costs. All the planting processes are organic, fertilizer-free and pesticide-free, which help to continuously protect the local planting habits and the local ecological environment.

4.2 Expanded local variety pool

Protecting old varieties and implementing multi-species farming is one of the key points of local ecological farming techniques. Protecting old varieties is a need for cultural transmission and is the basis for realizing diversity of varieties, while at the same time allowing farmers to control their own autonomy and choice. Multi-species planting increases disaster resilience and reduces risk. Through this participatory breeding activity, the local seed bank was expanded, and the current seed bank rice varieties includes three varieties of japonica rice, three varieties of glutinous rice, two varieties of black rice, small glutinous rice, dry valley, Zhongshan Red, Guihong No. 1, Guiyu No. 7, Guiyu No. 9; maize varieties include white maize, yellow maize, white glutinous maize; miscellaneous grain varieties include millet, duck's feet rice, sweet potato, taro, pumpkin, sesame, fire hemp; and bean varieties include small yellow beans, rice beans (bamboo beans) and other varieties.

Conclusion

Trends and highlights: Seeds that continue to give

Ronnie Vernooy, Yiching Song

The 11 cases offer a rich panorama of the evolution, results and challenges of participatory crop improvement since the publication of *Seeds that give* in 2003. In this conclusion, we first present an overview of the major trends that can be discerned from the combined cases. We then summarize the major features of the cases based on the same key elements included in the comparative cases of the original publication: methods and tools, partnerships, breeding results, other results, policy impact. The Appendix presents the mainfindings of the cases included in the 2003 *Seed that give* book and the new book.

1 Trends

Analyzing the cases altogether time wise (historically, between 2003 and 2019), several major trends emerge.

1.1 From pilots to scale

• By involving more farmers, women farmers in particular (including specialized plant breeders), but also farmers other than the usual leaders in communities

- By partnering with farmer organizations in the breeding and seed productions efforts
- By application to more crops (e.g., from a focus on maize in China to include rice, soybean, vegetables) including crops of low priority to NARS (e.g., high mountain crops in Nepal) and to high value crops like organic vegetables for niche market consumers (e.g., Southwest China)
- By expansion in area (number of ha), to more provinces and various geographies (favorable and less favorable environments)
- By increasing the complexity of the experimental breeding design and process, based on emerging needs due to socio-economic and climate changes
- Through use of farmer varieties and modern material and the crossing of both in different ways, based on emerging local needs
- Through take up in organizations, (government) departments or units (including local government), and international, regional (e.g., Southeast Asia), subnational and national networks (e.g., China Farmers' Seed Network)
- Through inclusion in some capacity development/training curricula in farmer field school training (e.g., Zimbabwe) and formal university/college training.

1.2 Methodological innovations

- Seeds for needs: crowdsourcing/citizen science for PVS piloted in several countries by Bioversity International and partners; in Ethiopia now involving more than 30,000 farmers through collaboration with the Integrated Seed Sector Ethiopia program managed by the Wageningen Center for Development Innovation of Wageningen University and Research

- Evolutionary crop breeding piloted in several countries (e.g., new IFAD supported project)
- Developing long-term collaboration throughout the whole breeding cycle.

1.3 From plant breeding to holistic and dynamic seed systems research and development

- Through linkages with seed production and distribution
- Trough linkages with conservation and sustainable use of crop diversity
- Building capacity for seed production and dissemination on a cooperative basis
- Empowering women, often as groups to engage in selection, seed production and seed dissemination.

1.4 From improved crops to holistic and dynamic improvement of livelihoods

- Through attention to nutrition and health, e.g., nutritional requirements of vulnerable groups (e.g., West-Africa)
- Through increased consideration of traits relating to post-harvest processing and reduction of food losses
- Through connections with (urban) consumers and restaurants, for example, through community-supported agriculture initiatives
- Through complementarity with agro-ecological management/ practices and movements (e.g., Southwest China, Europe).

1.5 Empowerment of farmers beyond the breeding process and significant benefits for women

• For example, women's decision-making in research and breeding has spilled over into decision-making in crop planting and sales, community leadership, etc.

• Concretizing the recognition of farmers' rights to seed and the significant contribution to the realization of the right to food.

1.6 Stronger connections made with efforts to bring about policy change

• Through coalition building at national level in particular (Honduras, Nepal, Vietnam, Zimbabwe)

• Through the assignment of research sites as demonstration cases of good practice to follow, e.g., the Hanni terraces in Yunnan, China as a Globally Important Agricultural Heritage System (GIHAS, promoted by FAO) as an outstanding landscape of aesthetic beauty that combines agricultural biodiversity, resilient ecosystems and a valuable cultural heritage; and Guzhai in Guangxi, China for its novel circular farming and organic agriculture

• Through national or regional networking (e.g., China, Europe, Southeast Asia)

• Through direct lobbying (Europe, Southeast Asia)

• However, policy and legal bottlenecks continue to exist in similar ways across countries, e.g., concerning the difficulties of allowing farmer seed production and marketing

• While some policy space has been created in support of participatory crop improvement, e.g., Nepal's new and more flexible procedure to register farmer varieties, and the EEC's time-bound approval of the use and marketing of evolutionary population of four crops.

2 Highlights

These are several of the key features of the cases.

2.1 Methods and tools

PVS and PPB are combined (all cases) and, more recently, crowdsourcing/citizen science and evolutional plant breeding have been introduced as major methodological innovations. Grassroots breeding has gained more strength in some countries (China, Nepal): enhancement of landraces through a selection process to promote conservation and sustainable use of crop genetic resources. In Southeast Asia and Zimbabwe, Farmer Field Schools have evolved to be key means to guarantee continuity and sustainability. In West Africa, new methods have been developed for priority setting with farmers; recurrent selection for population improvement has taken place and BC1F1-populations with local varieties have been developed together with farmers (China, West Africa). All forms of participatory crop improvement are increasingly connected to local seed saving efforts through community seedbanks and increasingly linked to the development of farmer cooperatives or enterprises investing in seed production and dissemination (China, Europe, Nepal, Middle East, West Africa, Zimbabwe).

2.2 Partnerships

In all cases, much broader and stronger coalitions have been built of collaborating partners bringing different but complementary knowledge and skills to the field. Some institutionalization has taken place (China, Middle East, Honduras, West Africa, Zimbabwe), but perhaps not as strongly was hoped for. The financial and technical support and collaboration of international organizations has remained important, but, overall, the role of the international CGIAR centers as PPB champions has diminished. Some regional networking has taken place, but not very strongly. In China, the national Farmers' Seed Network has been established as a multi-stakeholder platform to advance research, capacity development and policy development in support of farmers' seed systems. This has been a significant achievement, based on two decades of commitment to sustainable rural development, participatory plant breeding and the conservation and sustainable use of agrobiodiversity. No global network has developed, likely influenced by high costs/limited financial support and lack of organizational leadership.

2.3 Plant breeding results

Large numbers of varieties of different crops have been improved and adopted by thousands of farmers. Adaptability has been achieved with regard to multiple factors, including to climate change (becoming more and more a constraining factor around the globe). For example, in West Africa, the result has been a portfolio of improved sorghum varieties with traits required for i) reduced risk and yield improvements expressed under poor soil-fertility and farmers' low-input management systems; ii) improved storage and processing quality; iii) enhanced nutrition, especially of women and young children.

Several participatory bred plant varieties have been officially registered and released at national or sub-national level (China, Honduras, Nepal, Philippines, Vietnam, Zimbabwe). Through grassroots breeding, improvement and promotion of farmer varieties/landraces is taking place, e.g., Nepal (rice, bean, millets, Amaranthus). In a similar vein, in Zimbabwe, progress has been made in restoring five popular farmer varieties of maize (garabha), pearl millet (nyati), sorghum (gokwe, cimezela) and groundnuts (kasawaya).

2.4 Other results

Farmers, in particular women, have been empowered to lead the crop experimentation process, become better crop and seed producers, seed custodians and entrepreneurs, and make better livelihood decisions. This has resulted in increased productivity due to enhanced access to locally adapted good quality seeds. It has also led to new income generation opportunities, e.g., seed clubs in Vietnam, community seed businesses in Nepal, organic production and healthy foods (China, Nepal, Europe), and multi-purpose farmer cooperatives in China. In Zimbabwe, it gave rise to the establishment of the Champion Farmer Seeds Cooperative Company (2016). Local seed systems have been enchanced: more seed diversity, better quality, larger quantities, improved access. In Southeast Asia alone, more than 500 development practitioners have become PPB facilitators. The young generation of plant breeders and agricultural researchers has joined the efforts (e.g., China).

2.5 Policy impact

In Honduras, support to accept the idea of regionally approved varieties has been forthcoming from many agricultural government agencies, except from the one agency that controls national varietal release, seed registration and certification. Uptake of PPB in Algeria and in Jordan by National Center for Agricultural Research and Extension (NCARE) – now NCAR (National Center for Agricultural Research); in national agricultural programs (Zimbabwe); and by a number of research organizations in China. In Nepal, farmers have a say in the Variety Release and Registration Sub Committee. In several countries, PPB varieties have been registered and released by national authorities.

On the legal front, in Nepal, the variety release and registration format with some provisions for accepting data collected using participatory methods has been accepted; in China, the New Seed Law (2021) in China provides some degree of legal protection for farmers' rights and interests; space has been created in the national certification system in Vietnam to accept farmer-bred varieties and provincial certification in Laos; local ordinances have been approved that include provisions supporting farmer breeding, e.g. Sustainable Agriculture Code in Arakan Municipality, North Cotabato, Philippines, and community seed registries to protect farmer varieties from misappropriation in several municipalities in Bohol, Philippines; and in Europe, the use and experimental marketing of populations legalized in Europe for wheat, maize, rice and on 31th December 2021.In Yunnan, China, the provincial government has agreed to provide financial and technical support to the maintenance of the Hanni rice terraces (GIHAS site), including the PPB efforts led by Yunnan Agricultural University.

Last, but not least, PPB has now been recognized as contributing to the realization of Farmers' Rights as set out in Article 9 of the ITPGRFA.

Appendix

Selected key results of the PPB initiatives

	Methods and tools	Partnerships	Breeding results	Other results	Policy impact
Honduras	PVS and PPB, connected to community seedbanks	CIALs, FIPAH, PRR, Panamerican Agricultural School, Zamorano, University of Guelph (Canada)	Ongoing flow improved bean varieties; Macuzalito sister line released in El Salvador	Farmers empowered to make better livelihood decisions Women empowered	Very limited; some support to accept the idea of regionally approved varieties
Middle East	PVS and PPB; evolutionary plant breeding	Ministry of Agriculture in Syria, Jordan, Eritrea, Yemen, Morocco, Tunisia and Algeria; NGOs in Iran; Desert Institute in Egypt	32 varieties in 5 countries improved and adopted by farmers	Farmer seed production and marketing Women empowerment	Uptake of PPB in Algeria and Jordan by national agricultural research and extension
Nepal	Grassroots breeding; PPB and grassroots breeding linked to community seedbanks	Local communities, national crop programs, NARC stations, National Gene bank of Nepal, Agriculture extension agencies, Bioversity International	Several PPB varieties registered and released; improved landraces; promotion of local bean varieties, finger-, proso- and foxtail millet, Amaranthus	Farmer cooperatives, ADCS and community seedbanks produce and market seed Enhancement of local seed systems	Farmers in Variety Release and Registration Sub Committee; PPB varieties registered by NSB; revision of the variety release and registration format

continued

	Methods and tools	Partnerships	Breeding results	Other results	Policy impact
West Africa	PVS and PPB; recurrent selection for population improvement; post-harvest and sensory evaluations; farmer seed cooperatives	Seed producers coop of COPROSEM, Mali, Union of cereal producers, ULPC in Mali and others in Burkina Faso, ICRISAT, CIRAD, IER Mali, INERA Burkina Faso	Portfolio of improved sorghum varieties Conservation and sustainable use of agro-biodiversity	Empowerment of farmers; new methods of marketing seed; cooperative development	Contributions to policies related to food security and nutrition, climate-change adaptation, resilience, gender equality and Farmers' Rights
South east Asia	PVS and PPB Farmer Field Schools	National agriculture and extensions agencies in Bhutan, Cambodia, Lao PDR and Vietnam; Metta Development Foundation (Myanmar); Hug Muang Nan Foundation (Thailand); RAEBIA Timor Leste; local Government Units in the Philippines	Improved varieties of various crops in all partner countries; several PPB varieties released at national or local level	Empowerment of farmers in particular women; development practitioners have become PPB facilitators; farmer groups linked to public sector institutions; increased productivity and food security	Space created in the national certification system in Vietnam to accept farmer-bred varieties and provincial certification in Laos; local ordinances that include provisions supporting farmer breeding

continued

	Methods and tools	Partnerships	Breeding results	Other results	Policy impact
Zimbabwe	PVS and PPB through the Farmer Field Schools and connected to community seedbanks; diversity block	Farmer Field Schools, Crop Breeding Institute, AGRITEX, national genebank, CIAT, CIMMYT, ICRISAT, local authorities and communities, OXFAM-Novib	Improved varieties; progress in restoring five popular farmer varieties; release of two PPB pearl millet varieties (PMV 4 and PMV5) by Crop Breeding Institute.	More demand driven crop breeding; empowerment of farmers, women in particular; increased awareness about gender and seeds; farmer seed production/marketing; Champion Farmer Seeds Cooperative Company	Uptake of PPB in national agricultural programs PPB as advocacy tool in favor of more farmer centered agricultural policies and laws
Southwest China	Grassroots breeding, PVS and PPB, recently connected to community seedbanks Hybrid technology and seed production in hands of farmers	Farmer groups, CAAS, GMRI, Farmers' Seed Network	12 farmer-preferred varieties released locally; five CIMMYT varieties improved; 30 landraces improved; hybrid waxy maize variety registered and seed produced; conservation and improvement of farmer varieties	Multi-purpose farmer cooperatives established Women empowerment as farmers, breeders and seed entrepreneurs	PPB institutionalized by a number of research organizations; Farmers' Seed Network as national platform; new Seed Law (2021) in China provides some degree of legal protection for farmers' rights and interests

continued

	Methods and tools	Partnerships	Breeding results	Other results	Policy impact
Fengshan, County, Guangxi Province	PVS, recurrent selection for drought resistant rice lines, as well as BC1F1-populations with local varieties with farmers	Farmer groups, CCAP, GMRI, PCD, Farmers' Seed Network and national agriculture research agencies	Drought resistant rice varieties, landraces conservation, agroecological farming	More demand driven and participatory breeding; women and community empowerment; landraces and traditional knowledge recognized by scientists	PVS and community-based approach mainstreamed in rice research program; some changes in breeding strategy of the Academy
Guzhai Village Guangxi Province	Community based PPB and PVS for enhancement of landraces, seed production, linked to community seedbanks Women-led PPB and organic vegetable seed production	Women groups and local communities, GMRI, CCAP, national agricultural research agencies, Farmers' Seed Network	China's pilot PPB village; 10 PPB maize varieties including 1 PPB hybrid	China's first ever farmer-led PPB; empowerment of women farmers; awareness raised among scientists and policymakers; first ever access and benefit sharing agreement for hybrid seed production by farmers and scientists	Women leadership and local policy influence; first demonstration case of circular farming and organic agriculture in Guangxi; scaling to other villages (women group from Stone village in Yunnan)

continued

	Methods and tools	Partnerships	Breeding results	Other results	Policy impact
Hani Rice, in Yunnan province	PVS, recurrent selection for insect, disease and drought resistant rice lines, BC1F1-populations; in situ training; laboratory analysis of farmer varieties	Farmer communities, women groups, local government, agricultural and extension agencies, Yunnan Agricultural University, CCAP, Bioversity International, Farmers' Seed Network	Improved rice varieties, enhanced in situ agrobiodiversity conservation; enhanced farmer seed system	Empowerment of local extensionists and farmers; farmers adopted new seed management practices; linkages improved with formal seed sector	Policy influenced at provincial level (support for GIHAS); PPB and community seedbanks mainstreamed in university training
Stone Village, Lijiang, Yunnan Province	Community-based PPB and PVS, and grassroots breeding linked to community seedbanks Women-led PPB seed production	Local communities, women groups, GMRI, CCAP, national agricultural and extension agencies, Ntaional maize program, Farmers' Seed Network	Large number of PVS varieties selected (soy bean, bean, maize); PPB hybrid seed production and distribution; first farmer-led community seedbank established	Community-based farmer seed system enhanced; empowerment of women farmers; increased awareness about gender and seeds; farmer cooperative and agroecology for urban rural linkages	Local policy influence (Lijiang); demonstration case Scaling to other villages along the upper Yangzi River International outreach through networking

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