INDIGENOUS CROPS IN WEST AFRICA: OPPORTUNITIES FOR PLANT BREEDING TO ADVANCE AGROECOLOGICAL TRANSITIONS

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ALLY FOR A JUST WORLD

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Farmers and breeder comparing varieties for grain quality ▲

FOREWORD

Today, modern, high-performance agriculture relies on only twelve plant species and five livestock species to ensure our food supply. As a result, 99.6 % of the world's crop plants remain neglected. At the same time, four transnational corporations alone control over 50 % of the global commercial seed market, worth an estimated US$ 45 billion a year. Due to this concentration on a few species and companies, agriculture rests on a narrow base, while the increasing volatility of the climate and markets, the growing homogeneity of agricultural landscapes and the nutritional needs of populations require an increasing diversity on farmland and plates.

In Africa, by contrast, about 80 % of seeds are produced by farmers and have been continuously selected by farmers for generations. In recent decades, many efforts have been made to ensure that the seed standards of Western industrialised countries also apply in African countries. But the associated quality requirements are often too costly, making it virtually impossible for the African countries to meet them. At the same time, the decentralised seed production and distribution carried out by farmers has repeatedly been side-lined in legal provisions. This situation threatens the ability of farmers to freely reproduce, exchange and trade seeds, and may result in the loss of the valuable contribution of farmers and their organisations to crop improvement and adaptation.

African civil society has been opposing this development for years. It calls for the recognition of farmers' seed systems and their multiple benefits and for a rethinking of formal seed systems.

This publication aims to contribute to these debates. Based on a review of plant breeding in four Sahelian countries, the authors highlight the possibilities of breeding, seed provision and dissemination that involve farmers, men and women, and their organisations as equal partners and central actors in seed systems. The authors also point out the requirements for plant breeding to support sustainable, agroecological agriculture.

This brochure focusses on practical plant breeding options for recognizing farmers' skills and strengthening their opportunities to continue shaping the crop diversity of their production- and food-systems.

We wish you an enjoyable and informative read.

Dr Bernd Bornhorst
Managing Director
International Cooperation
MISEREOR

INTRODUCTION

Three indigenous crops, pearl millet, sorghum and cowpea, provide the foundation for food security in rainfed farming systems of West Africa. Their seed systems and their biodiversity are at the heart of discussions for coping with climate change and improving food security in view of political instability, urbanization and other socio-economic changes. How can the diversity of farmers, working in vastly contrasting, highly variable and poorly predictable agro-climatic conditions gain access to the crop diversity, varieties and seeds to achieve their goals and aspirations while facing these challenging scenarios?

The agroecology movement, social activists with practitioners and committed scientists, envisions a food system transformation with production- and seed systems driven by the social, environmental, economic and political goals of those concerned foremost – the farmers and food producers. Learning and action are inspired and guided by a set of principles rather than strict rules or pre-designed development trajectories. The principles address governance aspects, as well as social and environmental sustainability through innovation by co-creation and joint learning.

Harvested pearl millet panicles ready for transport ▼

Many international efforts are under way to support private sector investments in West African seed systems. Agroecology activists in contrast support seed legislation that recognizes farmers' skills and expertise. This brochure focusses on practical plant breeding options for recognizing farmers' skills and strengthening their opportunities to continue shaping the crop diversity of their production- and food-systems.

In West Africa, both farmers and researchers manage biodiversity, creating and sharing new varieties of these indigenous crops. How do they and how could they work together to support agroecological transitions of West African food, farming and seed systems? This brochure gives an overview of present plant breeding practices with indigenous crops in Niger, Burkina Faso, Mali and Senegal and highlights options for supporting agroecological changes.

An international panel of experts recently agreed on naming and describing 13 agroecological principles that apply at the scale of field, farm, agro-ecosystem or food systems. Plant breeding, both its products and how it is conducted, can contribute to advancing all 13 principles. This brochure focusses on three of these: biodiversity, co-creation of knowledge and participation in decision making to strengthen local management of agricultural and food systems.

THE 13 PRINCIPLES OF AGROECOLOGY (HLPE, 2019)

1 | Recycling.
Preferentially use local renewable resources and close as far as possible resource cycles of nutrients and biomass.

2 | Input reduction.
Reduce or eliminate dependency on purchased inputs.

3 | Soil health.
Secure and enhance soil health and functioning for improved plant growth, particularly by managing organic matter and by enhancing soil biological activity.

4 | Animal health.
Ensure animal health and welfare.

5 | Biodiversity.
Maintain and enhance diversity of species, functional diversity and genetic resources and maintain biodiversity in the agroecosystem over time and space at field, farm and landscape scales.

6 | Synergy.
Enhance positive ecological interaction, synergy, integration, and complementarity amongst the elements of agroecosystems (plants, animals, trees, soil, water).

7 | Economic diversification.
Diversify on-farm incomes by ensuring small-scale farmers have greater financial independence and value addition opportunities while enabling them to respond to demand from consumers.

8 | Co-creation of knowledge.
Enhance co-creation and horizontal sharing of knowledge including local and scientific innovation, especially through farmer-to-farmer exchange.

9 | Social values and diets.
Build food systems based on the culture, identity, tradition, social and gender equity of local communities that provide healthy, diversified, seasonally and culturally appropriate diets.

10 | Fairness.
Support dignified and robust livelihoods for all actors engaged in food systems, especially small-scale food producers, based on fair trade, fair employment and fair treatment of intellectual property rights.

11 | Connectivity.
Ensure proximity and confidence between producers and consumers through promotion of fair and short distribution networks and by re-embedding food systems into local economies.

12 | Land and natural resource governance.
Recognize and support the needs and interests of family farmers, smallholders and peasant food producers as sustainable managers and guardians of natural and genetic resources.

13 | Participation.
Encourage social organization and greater participation in decision-making by food producers and consumers to support decentralized governance and local adaptive management of agricultural and food systems.

INDIGENOUS CROPS IN WEST AFRICA

What does "indigenous crop" mean?

All crops were originally developed from wild species through their use by communities of farmers. Each crop is therefore "indigenous" to people who live in a geographic area where the crop originated. An indigenous crop is always linked to a specific culture and its agroecological context and history. Crop wild relatives still often grow as weeds in farmers' fields in these areas. Recent research with pearl millet shows the importance of genetic exchange between crops and their wild relatives for adaptation to changing growing conditions in these areas. Farmers' knowledge and culture for managing seed of their indigenous crops therefore continues to shape the genetic diversity of these crops.

Pearl millet (*Pennisetum glaucum*), Sorghum (*Sorghum bicolor*), and cowpea (*Vigna unguiculata*) are all indigenous crops in West Africa. Their wild relatives grow in or near production fields. West African farmers' deep-rooted knowledge and culture for managing seed of these crops are vital for successful production under climatic conditions that are among the world's most unpredictable and variable over years.

▲ Pearl millet and its weedy relative

Pearl Millet

Pearl millet is a cereal crop with small grains that form on long flowering structures called panicles. Pearl millet is a highly cross-pollinated crop. Each panicle can produce more than 1000 grains. Each plant can produce many tillers in response to good rains.

Pearl millet is extremely well adapted to sandy soils, high temperatures and drought, but it does not tolerate standing water. It is the dominant staple crop of the Sahelian region. Pearl millet is also grown further south in the more humid Guinea Savannah zone and in areas with residual moisture.

Pearl millet grains are nutritionally well-balanced, providing important minerals and vitamins and a diversity of oils, proteins and starches in West African diets.

▲ Farmers‘ sorghum crop approaching maturity

Sorghum

Sorghum panicles and grains vary greatly in size and form. Botanists use these differences to distinguish five different races of cultivated sorghum. Each race has its own specific adaptation to growing conditions and uses of the grain and stalks. The most common race in the Sudan Savannah zones of West Africa is the Guinea race. The Durra race is grown on sandy soils, and with residual moisture, whereas the Bicolor race is grown for its sweet stems. The Caudatum race is grown in the Sahelian zone, typically on heavier soils or where water logging occurs.

Sorghum plants in West Africa may grow very tall, sometimes more than 5m and can produce tillers. Each panicle can produce 500 grains or more. Sorghum is mostly self-pollinated, although up to 30% outcrossing is observed in the Guinea race.

Sorghum grain is used for preparing diverse food dishes. Sorghum, along with millet, are superior sources of micro-nutrients (iron and zinc) relative to maize and rice.

▲ Sole crop of cowpea

Cowpea

Cowpea seeds are larger than those of the indigenous cereals. Each cowpea plant may only produce 10-30 new seeds. The crop is highly self-pollinated.

Cowpeas grow in all agroecologies across West Africa and are often grown as intercrops with sorghum or pearl millet. As legumes they contribute nitrogen to the production system. The crop’s leaves and green pods are used as vegetables. The grains are an important source of protein, and the dried haulms are used and marketed as animal fodder.

WHAT DO FARMERS DO TO MAINTAIN AND ENHANCE CROP DIVERSITY?

What is a variety?

Botanists use the term 'variety' to distinguish between plant types of the same species that differ for some heritable observable traits. Plant breeders do the same for crop plants. Farmers often differentiate between varieties based on traits, the location or person who provided the original seed. The same word is used for 'seed' and 'variety' in many West African languages. So, what a 'variety' is depends on who is talking.

What is a local- or farmer-variety?

Individual farmers maintain seeds of specific varieties with certain characteristics, such as grain colors, particular maturities, adaptations or uses. Especially in cross-pollinated crops like pearl millet, farmers also associate certain varieties with certain places where they are maintained. The genetic composition of farmer varieties is based on the combined effects of both the people, with their seed management activities, and the place, with its prevalent environmental conditions. All farmer varieties possess intra-varietal diversity, with the level depending on the crop (high in pearl millet) and the diversity of plants farmers harvest for seed.

Farmers' roles in managing crop diversity

Crop diversity at different scales: Farmers decide which crops to grow and which trees, bushes, grasses and herbs they maintain in their fields, gardens, public spaces, and forests. This influences the diversity at the landscape and household level. At the field level, farmers influence diversity by choosing to grow certain crops and specific varieties, and their field management impacts the diversity of weeds, insects, birds and micro-organisms. The way a farmer manages her or his seed contributes to the plant-to-plant diversity within a crop, both for observable and imperceptible genetic differences. Thus, farmers manage crop diversity at all levels.

Maintaining diversity of a crop in a specific area involves both varietal- and intra-varietal, plant-to-plant, diversity. Farmers, by keeping and using different varieties, and obtaining seed from differing plants, maintain the diversity of a crop.

Enhancing the diversity of a crop: Farmers increase diversity by adding new varieties obtained from travel, the market, or from research, while maintaining the prior varieties. Farmers may also enhance diversity by selecting in their own varieties over several years under specific growing conditions. A farmers' selection will differentiate their seed from those of others, especially if seed exchange between farmers is limited. Thus, farmers' seed management practices shape the patterns of diversity of a crop in various ways.

Farmers managing their seeds

Farmers in West Africa produce mostly their own sorghum, pearl millet and cowpea seed. Farmers' activities throughout the growing cycle impact the quality, diversity, and availability of seed they use, the crops they grow, and the diversity they maintain in their field and landscape. These seed management activities include:

Farmers' ways of sourcing seed, such as using their own seed or obtaining seed from family members, friends, or the market: Their seed preparation activities before sowing may include cleaning, sorting and possibly treating the seed to minimize disease, insect or other damage.

Farmers' choice of the field and the methods of field preparation, sowing and all the subsequent field management operations that impact the conditions for plant growth: These conditions influence the genetic composition of seed harvested by favoring the growth of certain plants relative to their less well-adapted neighbors. Intercropping, fertility management, methods of weeding or pest control will therefore all impact the genetic composition of seed that farmers obtain from a particular field.

Farmers' plant- and seed-selection activities: Some farmers select specific plants for seed by observing the whole plant before harvest. Many pearl millet and sorghum farmers select panicles to keep for seed, either shortly after harvest or after storage during the dry season. Other farmers may sort the threshed grain to obtain seed. Thus, farmers use different selection practices at different points in time depending on the crop, their work schedules and responsibilities within the family. Certain family members, such as older women, may have specific responsibilities for selecting seed. Many villages recognize individual farmers for their expertise in producing high quality seed.

Understanding farmers' strategies and expertise for managing seed is a first step towards recognition.

▼ Farmers selecting panicles for seed at harvest

Farmers breeding new varieties

Farmer showing a sorghum panicle with preferred characteristics ▲

Hand sowing a sorghum field ▶

Selection can change the genetic composition of a variety or create a new variety only if there is genetic diversity for the traits selected and if the differences for those traits are heritable.

Selection by farmers: Farmers' choices of seed, of fields for seed production, of plants to harvest for seed and sorting grain to obtain seed are all selection decisions.

New genetic diversity can be generated in different ways. Naturally occurring mutations create new genetic diversity, but they are random and very infrequent. Farmers can increase genetic diversity in a variety by favoring crossing with other, genetically distinct, plants. Ways they can do this include sowing the variety adjacent to, or mixed with, seed from someone else or of another variety. Keeping wild or weedy crop relatives in their fields also contributes to genetic diversity. Since all of these ways depend on natural cross-pollination, they are most relevant for pearl millet and, to a lesser extent, sorghum. For all crops, farmers' retention of seed from different, interesting "off-type" plants in their seed lots contributes to maintaining genetic diversity in their varieties.

Many farmers in West Africa often *test new varieties*. The new variety may come from grain purchased in the market, obtained while traveling, or from other nearby farmers. Farmers prefer to test new varieties for one or more years before deciding to grow it on a larger area. Testing the same variety for two or more seasons is one way to make sure that the desirable traits observed originally are still expressed and are indeed heritable.

Farmers' seed management, involving generation of new diversity, selection and testing, is a continuous plant breeding effort.

Factors determining success from selection	Farmers' practices that contribute to each factor
Intensity of selection	• Choosing grains or plants to use as seed • Managing and choosing fields from which seed will be harvested
Level of diversity	• Harvesting seed from fields where different varieties were mixed or sown in proximity • Maintaining plants of wild or weedy relatives in the seed production field • Keep seed from interesting plants during harvest, during visits to other fields or to research stations, during travel
Heritability of field observations	• Sowing rows of a new variety next to the family variety to observe for one or more years • Mixing seed of a new variety with the family variety and observe adjacent plants of the two varieties

▲ Farmers' seed management practices contributing to successful selection

Selection intensity

West-African farmers sow sorghum and pearl millet in hills or planting holes with many seeds. Weaker seedlings die or are thinned out, leaving just a few plants per planting hole to reach maturity. Farmers' sowing practices thus create high selection intensity for seedling survival and seedling vigor. Additionally, farmers' selection of only a few plants out of many thousand for saving seed creates a high intensity of selection for traits that are observable at the time of selection.

Diversity of Farmers

In every agroecological region across West-Africa, rural families describe themselves by their dominant livelihood strategy: crop production and animal husbandry are predominant strategies, even though many crop producers also own animals, and many pastoralists grow crops. Each group may prefer different crops or varieties, pursue different strategies for resilience, and thus contribute to overall diversity in their area. Social differences in West-African villages are often based on settlement history, with the first settlers having more and different land use rights than more recent settlers. Rural households in West Africa tend to be large and multi-generational, usually headed by a male elder. Gender and age are important for delimiting the individuals' roles and opportunities for decision making in crop production and personal development.

What is mass selection ?

Mass selection is done by selecting individual plants from open-pollinated populations, such as pearl millet varieties. Seeds from selected plants are bulked. This selection method can effectively improve traits important for adaptation, such as plant maturity or height. It is not effective, however, for traits like yield that are strongly influenced by environmental differences within or between fields.

◀ Diverse users of indigenous crops
◀ Inspecting pearl millet panicle for selection

▶ Sorghum variety with off-type tall plants

"Degeneration" of varieties – why does it happen?

Breeders or farmers may observe that a variety changes or degenerates after cultivation for several seasons. One of the causes is natural crossing. Varieties of cross-pollinated crops like pearl millet cross with other varieties by wind carrying pollen from more than 1 km away! Varieties of predominantly self-pollinated crops like sorghum can also change by cross pollination since up to 30% of plants may produce some crossed seed. Cowpeas however have almost no outcrossing. Degeneration of cowpea varieties therefore is more likely due to viruses carried by the seed, the unintentional mixing of seeds from other varieties or mutations. Farmers' seed selection may minimize degeneration and even improve varieties for certain desired traits. Hybrid varieties naturally produce more variable plants when sowing saved seed. Farmers' selection can also be effective on plants of recycled hybrids.

NATIONAL BREEDING PROGRAMS AND THEIR APPROACHES TO VARIETY DEVELOPMENT

The institutional "landscape"

National agricultural research institutes in each country develop new varieties using conventional scientific methods. A new generation of West African breeders, trained in the region, now lead breeding programs for these indigenous crops. They collaborate with each other and with regional (CERAAS*) and international research institutes (ICRISAT, IITA, CIRAD, IRD*), and universities in their countries, the USA and elsewhere on a project basis. They receive funding from their governments to cover basic costs, but to do field work they rely primarily on collaborative projects with CERAAS and international research centers. The Collaborative Crops Research Program of the McKnight Foundation directly funds programs in Mali, Burkina Faso and Niger, mostly as part of Farmer Research Networks.

Academic and technical training institutes and universities also conduct research on plant breeding and crop genetic resources in each of these countries. These institutes usually rely on national breeding programs or collaboration with farmers to conduct field experiments. No private seed companies, national or international,

invest in breeding new varieties in any of these countries. One private company in Burkina Faso is trying to introduce a sorghum hybrid from Brazil, but has not initiated breeding activities. Farmer cooperatives are the only private organizations investing in variety development (see section on farmer-breeder collaboration).

National agricultural research organizations and the research stations where plant breeders are located for pearl millet, sorghum and cowpea breeding in four West African countries
▼

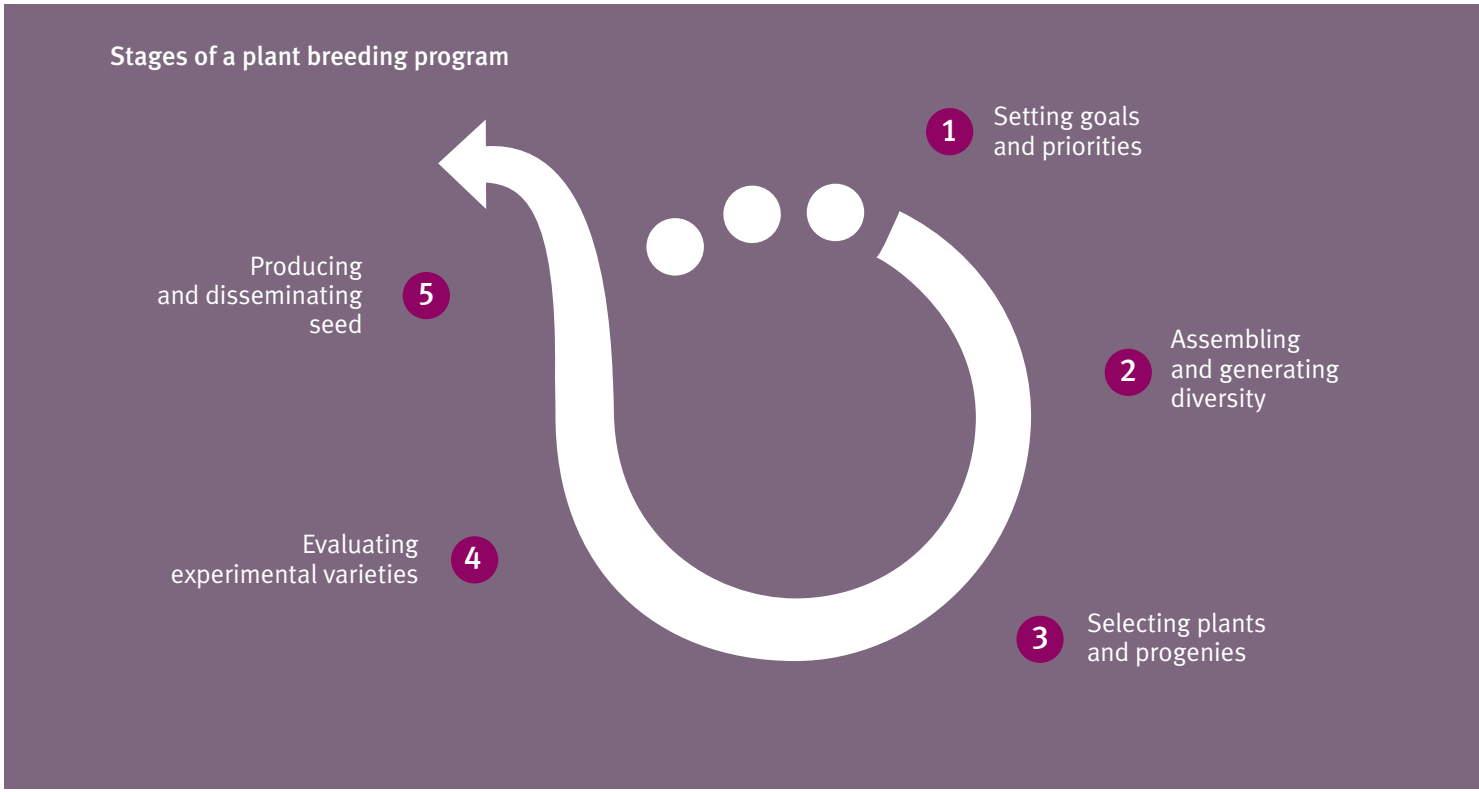
Country	Pearl Millet	Sorghum	Cowpea
Niger	INRAN (Kollo and Maradi)	INRAN (Kollo)	INRAN (Tahoua and Kollo)
Burkina Faso	INERA (Kamboinse)	INERA (Saria and Kamboinse)	INERA (Kamboinse)
Mali	IER (Cinzana) ICRISAT (Bamako/Samanko)	IER (Bamako/Sotuba) ICRISAT (Bamako/Samanko)	IER (Cinzana)
Senegal	ISRA (Bambey) CERAAS (Thies)	ISRA (Bambey) CERAAS (Thies) CIMMYT	ISRA (Bambey) CERAAS (Thies)

* Full names of all research institutes on page 30

◀ Sorghum breeding nursery

The breeding cycle:

Breeding new varieties is a long-term process. The actions and decisions made in each stage determine success in the next stages, and ultimately what types of varieties will be developed. National breeding programs conduct the following activities throughout the breeding cycle:



Priority setting: Each breeding program focusses on the agroecology in which their crop is most cultivated and in which their research station is located. The drier Sahelian- and the Sudanian-agroecologies receive most attention. Only the Malian sorghum program also addresses the more humid Guinea Savannah. Breeders identify priority traits by studying farmers' trait preferences. Continuous involvement of farmers throughout the breeding process increases farmers' acceptance of new varieties. The most common priority traits include improved adaptation to climate variability, quality for food or fodder, yield and yield stability.

Creating diversity: Breeding programs for all three crops primarily use farmer varieties as parents to retain their numerous adaptation and quality traits. Breeders cross different varieties to create offspring that combine desirable traits from each parent. Breeders also make crosses with researcher-bred varieties or farmer-varieties from elsewhere to improve desired traits for which the local farmers' varieties offer little or no diversity. For resistance to pod borers, the program in Burkina Faso is transferring Bt-genes from previously transformed cowpea varieties into locally preferred varieties by conventional crossing.

The story of SOSAT millet in Mali

The breeders crossed early maturing "**So**una" millets with late maturing "**Sa**nio" millets to create a new, highly diversified population, SOSAT. This population was used to develop new population varieties that combined high yield and earliness. One of them became the variety SOSAT-C88 that is widely grown by farmers in West Africa.

Selecting plants and progenies: Breeders select among the newly created progenies, and among plants within them, to develop experimental varieties. By selecting interesting progenies, breeders reduce the overall diversity to focus on the most promising materials. Sorghum and cowpea breeders use pedigree selection for easily observable traits like height, maturity or grain aspects. Pearl millet breeders use recurrent selection procedures (see next page). All breeding programs also select for resistance to major disease or insect pests if research funds and partners are available. Most breeders conduct selection at their experiment stations using fertilization and pest control practices; conditions that frequently differ considerably from those of farmers' fields.

Resistance to:	Pearl Millet	Sorghum	Cowpea
Diseases	Downy Mildew (4)	Anthracnose (3) Grain mold (3) Long smut (2)	Bacterial wilt (1) Mosaic virus (1)
Insects	Head miner (2)	Midge (3) Stem borers (1)	Thrips (3) Pod borers (3) Aphids (1)

Legend: in Brackets = Number of programs

▲ Diseases and insect pests for which West African breeding programs seek improved resistance

Evaluate experimental varieties: The breeding programs evaluate new experimental varieties to identify those that provide clear advantages to farmers. Although these trials need to be conducted at several locations, most programs have only one or two research stations located in the targeted agroecology. The programs therefore organize variety trials over multiple years and in farmers' fields. Breeders collaborate with and train farmer organizations, NGOs and extension agents in variety evaluation methods. Through this evaluation work, breeders and their farmer partners identify new varieties for dissemination and possible release. This is the costliest breeding stage for all programs.

Seed dissemination: Breeders produce early generation seed for large scale seed production of finished varieties. They also gather and share information about these new varieties to support farmers' decision-making about which varieties to cultivate. The breeders also train and support farmer groups in producing and marketing seed of new varieties.

Why is an "improved variety" not always better than a farmer variety?

No variety can be better than all others. This is true for so called "improved varieties" as well as farmer varieties. A varieties' relative superiority depends on the specific growing condition, the intended use and expected role in the farmers' production system. This is why West African farmers cultivate several different varieties to match their different production objectives (e.g. grain, fodder, food security or market-use) and conditions (e.g. soil type, sowing date, inter- or sole-crop).

Breeding methods and types of varieties being developed:

Pedigree Breeding is used by national breeding programs to develop line varieties of cowpea and sorghum out of the initial progenies produced by crossing. Breeders select individual, inbred (self-pollinated), plants and record the line's ancestry (pedigree). They repeat selection among and within these breeding lines up to five or more generations to produce experimental varieties that can be reproduced true to type. Line varieties are also referred to as open pollinated varieties.

Recurrent Selection or Population Improvement is used by pearl millet breeding programs to develop population varieties. This method uses repeated short cycles of crossing and inbreeding with selection. To complete a selection cycle, breeders identify superior progenies (often 30 or more) and cross them all together to create a new improved population bulk to start the next selection cycle. The simplest form of recurrent selection is 'mass selection'. Breeders also cross subsets of selected progenies to create new population varieties. A breeding program may need to conduct several cycles of recurrent selection before improved population bulks and new population varieties show clear superiorities over previous ones.

Hybrid Breeding: West African sorghum and pearl millet breeders develop hybrid varieties by first choosing or creating hybrid parents. Line varieties (bred by farmers and researchers) are used as hybrid parents for sorghum, whereas population varieties are used as at least one of the parents for pearl millet hybrids. Breeders cross these parents to make experimental hybrids using normal pollination techniques. Breeders and their partners evaluate experimental hybrids in the same way as line- and population-varieties.

Types of variety	Seed Production	Particularities
Line Variety	Self-reproducing via open pollination; short isolation distance required for purity	Little visible plant-to-plant differences, less population buffering, farmers' selection among plants will maintain the variety
Population Variety	Self-reproducing via open pollination; large isolation distance required for purity due to high cross-pollination	Considerable plant-to-plant differences, more population buffering, some hybrid vigor for yield and growth, farmers' selection among plants may adapt the variety to local conditions
Hybrid Variety	Hybrid seed produced by sowing the parents alternately in the same field to facilitate wind pollination;	High hybrid vigor, stronger growth, intra-varietal diversity depends on the diversity within the parents;
	Recycled hybrid seed produced by saving grain harvested from a hybrid variety	Recycled hybrids show greater plant-to-plant differences and somewhat reduced hybrid vigor compared to the original hybrid, farmers' selection among plants produces diversity for further breeding

PLANT BREEDING AND AGROECOLOGY — WHAT ARE THE CHALLENGES?

Breeding new varieties of indigenous crops in West Africa contributes to farming and food system innovations for resilience, nutrition and sustainability. However, plant breeding and improved varieties are often associated with industrialized agriculture, loss of biodiversity and dependency on external inputs. How can plant breeding support agroecological transition of farming and food systems? We look at this challenge for indigenous crops in West Africa using three principles of agroecology.

Biodiversity

The agroecological principle of biodiversity focusses on maintaining and enhancing overall agro-ecosystem diversity in time and space. This concerns the diversity among and within varieties of a crop as well as diversity of all plants, animals and micro-organisms, whether wild or cultivated, in a particular field, farm or landscape.

Plant breeding relies on accessing and using genetic diversity within a crop to develop new varieties. This is true no matter who the breeder is – a farmer or a scientist. Questions that all breeders face are: Can we adapt our sorghum, pearl millet or cowpea varieties to cope with climate change? Can we create varieties that open new options for producing or using the crop? Do we have the genetic diversity needed to achieve such breeding objectives?

Harmonized seed legislation across West-Africa harbors risks, that a few rather homogeneous varieties of

a crop become dominant in a production zone, reducing the diversity and resilience of production systems. However, farmers in West-Africa have the expertise for seed management of their indigenous crops and the final decision-making power about the seeds they grow. How can plant breeders support farmers' seed management, so that the crop biodiversity in the fields, farms and the landscape is maintained or enhanced, while creating varieties with clear advantages for production and use in the countries and the region?

Co-creation of knowledge:

The principle of co-creation of knowledge highlights the process of collaborative learning among farmers, and between farmers and researchers, for sharing local and scientific innovations.

Especially for indigenous crops, farmers and local users have extensive knowledge, cultural and practical experiences with varieties and seed management. Plant breeders' approaches to working with these crops, in contrast, use genetics and the accumulated scientific experiences for selection.

Can plant breeding programs be organized so that farmers benefit from scientific knowledge and methods for their own plant breeding and seed management efforts and goals? Can researchers not only learn from farmers, but work with them? How can farmers and breeders share roles and responsibilities to increase their capacities to create the diversity of varieties needed?

Participation:

Participation as a principle of agroecology refers to encouraging social organization and participation in decision-making by food producers and consumers for decentralized governance and local adaptive management of agricultural and food systems.

This principle raises questions about the governance of plant breeding programs. How are priorities determined for plant breeding research investments in a country or region? Who decides which crops to work on, which specific agroecological zones and production systems to target, which traits and which peoples' interests to focus on?

Similarly, this principle raises the questions, can, and how can, plant breeding programs encourage social organization and local decision making by farmers and consumers for decentralized governance of plant breeding and seed management efforts in a country?

▼ Exchange visit between women's groups for discussing seed and variety issues

HOW DO FARMERS AND NATIONAL BREEDING PROGRAMS COLLABORATE?

This section describes and analyzes the collaborative variety-development efforts of national breeding programs, farmers and their organizations. It highlights opportunities for farmer organizations and others to engage with these research programs to jointly contribute to agroecological transitions.

Farmer organizations and breeding programs collaborate in variety development of all crops in every country. Jointly evaluating new varieties is a common entry point for collaboration in all countries. Some farmer organizations in Burkina Faso, Mali and Niger collaborate with national breeding programs since several decades and engage in various stages of variety development.

Collaborative evaluation of experimental varieties:

Farmers are always curious about new varieties and breeders in West Africa are keen to respond to farmers' preferences and needs. These complementary interests motivate collaborative variety evaluation.

Farmer organizations conduct variety evaluations to assess a wide diversity of varieties in cooperation with the national breeding programs (see Table). Farmer organization members, neighbors and others look for advantages of specific varieties under different farmer's field conditions. Several programs also organize culinary evaluations of experimental varieties. Women from variety-testing households take responsibility for evaluating varieties for processing, cooking and food acceptability, often in partnership with national food and nutrition laboratories.

Farmers use these results from their fields and kitchens for choosing varieties to adopt and for seed dissemination. These farmers may thus increase varietal diversity on their fields by accessing new varieties that are not yet, or may never be, officially released.

Several collaborative breeding programs regularly conduct feedback and planning meetings where farmers and breeders share their experiences and results from the previous seasons' evaluations to plan the next season's activities. Farmers, through their inputs at these meetings, influence the objectives and design of activities towards their priorities and needs. This process provides an entry point for farmers' participation in the governance of long-term collaborative breeding programs. Long-term farmer engagement in collaborative variety evaluation, with both women and men contributing to planning and implementation, can thus strengthen local control of genetic resources.

▼ **Joint farmer-breeder variety trials (T), culinary tests (C) and feed-back/planning meetings (F)**

Country	Sorghum	Pearl Millet	Cowpea
Senegal	T, C	T, F	*
Mali	T, C, F	T	T
Burkina Faso	T, C, F	T	T ,C ,F
Niger	T	T	T

* Information not available

Farmers, by conducting variety tests at many sites, improve the effectiveness of variety evaluation by assessing performance under diverse conditions. Furthermore, breeders reported learning from farmers about their critical constraints, needs and opportunities for diversifying crop- and food-production systems when discussing variety comparisons.

Such co-learning among farmers and breeders through jointly evaluating new varieties can lead to new initiatives. Examples include: farmers organizing larger-scale production of seed of their preferred varieties in their country, farmers establishing their own seed-producer cooperatives, and farmers and breeders starting to collaborate earlier in the breeding process.

Collaboration for seed production and dissemination:

Farmers producing seed of new varieties is an immediate outcome of collaborative variety evaluations. Individual farmers add new varieties to their variety portfolios and may disseminate seed locally. Possibly of wider importance, farmer groups started to produce seed of new varieties and individual farmers joined to form seed-producer cooperatives.

Farmer-to-farmer collaboration in farmer seed-producer cooperatives is a major innovation in West Africa. By working together, farmers' expertise in seed production is expanding to produce seed of new, previously unknown varieties at scale. The breeding programs of all four countries contribute to strengthening these seed-cooperatives by providing training in seed production of open-pollinated and hybrid varieties. Breeding programs also facilitate linkages between seed-cooperatives and development organizations for strengthening seed business know-how, organizational capacities and infrastructure for conditioning-, storing- or packaging seed. Today, networks of West African farmer organizations produce most all certified seed of these crops and experiment with options for seed dissemination without formal certification.

Some seed-producer cooperatives also produce the early generation (foundation) seed required for seed multiplication of new varieties. The national programs support these efforts by providing the breeder's seed of open-pollinated varieties and hybrid parents.

Each organizations' choices of varieties to produce for their area help enhance local and regional diversity. This

Common steps for joint farmer-breeder variety evaluations

- Jointly plan the trials, choose the types of varieties to test, the growing conditions, the roles and responsibilities of individual farmers, farmer organizations and breeders
- Plan who to invite for participating in trial evaluations
- Discuss and agree on which traits to evaluate
- Decide how to indicate farmers' appreciations of individual traits or varieties
- Plan how to organize the evaluation process to support gender inclusiveness
- Conduct farmer evaluations with discussions regarding farmers' observations
- Analyze and synthesize results to understand who is interested in which varieties and traits
- Jointly present and discuss results and experiences by farmers and breeders to decide on next steps

Sharing varietal information:
Sharing information about new varieties is essential for farmers to make informed decisions when accessing seed. Farmer-to-farmer communication about new varieties is powerful. Farmer seed cooperatives in West Africa organize variety demonstrations with local radio coverage to share farmers' experiences, testimonials and seed-availability information.

seed work also provides an entry point for strengthening small-scale farmers' groups and organizations. Farmer cooperatives' engagement in producing seed of other crops or marketing their crops are two examples of farmers steering the innovation process by developing their organizational capacities.

Collaboration in creating diversity:

This stage determines what diversity will be available for selecting new trait combinations. Farmers and breeders can collaborate by jointly selecting parents or in making crosses to create the new diversity needed for selection.

All breeders study and use the diversity of farmer varieties from their countries as starting points for their programs. Farmers, however, are generally not involved in conducting these studies nor in drawing conclusions from them. Farmers' participation in such studies would enrich the results and clarify conclusions for further action.

Sometimes farmers offer specific varieties to breeders to use as parents and request improvement of a particular trait. Although breeders appreciate this input, joint decision-making by farmers and breeders on which parents to cross is rare. Breeders, however, increasingly plan new crosses based on their growing understandings of farmers' needs and priorities gained from collaborative variety evaluations.

Intentional crossing between varieties to create new genetic diversity requires techniques and special materials such as "selfing bags" to control pollination. Most all intentional crosses are therefore made by national breeding programs on their research stations. Pearl millet however, being highly open pollinated, is much easier to cross. Farmers therefore can easily make "uncontrolled" crosses.

Collaborative selection to develop experimental varieties:

Collaboration of farmers and breeders for selection in early generations can be highly beneficial since the greatest reduction in diversity occurs during this stage. A big question is how to organize the selection process so that collaboration is feasible, meaningful and effective for farmers.

"Uncontrolled" crossing in farmers' fields:
Pearl millet farmers can make "uncontrolled" crosses of their variety with one or more parents obtained from breeding programs, genebanks or other farmers. By sowing their variety and the introduced parent(s) near to each other, some of the seeds harvested from plants adjacent to another parent will be crossed seed. Similarly, seed harvested from pearl millet variety trials will undoubtably include crosses between neighboring plots.

Pearl millet programs invite farmers in Mali and Niger to evaluate or score progenies at their research stations to help identify experimental varieties. Similarly, the sorghum and cowpea breeders in Burkina Faso invite farmers to their research stations to observe and select individual plants or progeny rows to advance the selection process.

Pearl millet breeders in Niger and Mali also explored on-farm selection by providing variable populations for farmer-organization members to sow and select desirable plants. Sorghum breeders in Burkina Faso and Mali provided sets of progenies for farmers for sowing in their own fields. The participating farmers shared a portion of their selected seeds with the breeders.

Farmers' participation in early generation selection, especially under farmer managed field conditions, could simultaneously increase the effectiveness of breeding programs and help advance biodiversity and local governance of genetic resources. Such on-farm selection however is not routinely practiced due to logistical challenges and breeders' fears of losing breeding materials. Therefore, co-learning among farmers, farmer organizations and breeders during this stage of variety development is a wide-open area for future action and research.

Collaboration for setting national breeding program priorities and objectives

The overall goals of national breeding programs need to correspond to national agricultural policies and development plans. The agricultural sector is a high priority in all four countries. Farmers and their organizations influence agricultural policies and development priorities in their countries in different ways and to varying extents.

The national breeding programs contribute to the research priorities of their national agricultural research institutes. Some institutes in Burkina Faso and Mali conduct annual research review meetings with farmer representatives who may contribute to prioritizing research questions and targets.

▲ Farmer comparing varieties at harvest

Breeding programs need to translate research strategies into specific priorities for variety development. Decisions include which traits to improve for which types of farmers in which specific region. Jointly setting breeding priorities is an evolving area of collaboration between national breeding programs and farmer organizations. All programs conduct research to identify farmer-preferred traits for inclusion in new varieties for specific agroecologies or uses, often in a consultative manner. The discussions between farmers and breeders during collaborative variety evaluations or feedback and planning meetings may actually be more important for priority setting. Through these recurring discussions, key opportunities for developing new varieties are jointly identified.

Collaborative development of projects for donor funding is another opportunity for joint priority setting. Joint project development involves sharing a common vision and agreeing on the objectives as a basis for planning specific activities. Some breeding programs contribute as partners to seed- and breeding-projects led and managed by farmer organizations.

HOW TO MOVE FORWARD TOGETHER TOWARDS AGROECOLOGY AND TRANSFORMATION?

West African farmers and national breeders face many challenges and questions about how to organize breeding activities to contribute to agroecological transitions in their countries. Scaling-up, strengthening, and institutionalizing collaboration of farmers and breeders using agroecological principles is necessary. Breeding programs can improve practical methods for joint decision-making and equitably sharing responsibilities in long-term selection processes. Farmers can organize for engagement in innovative seed and variety development activities, representing their diverse interests and ambitions for food system development.

Analyzing current collaborative experiences of national breeding programs and their farmer partners highlights several opportunities for supporting agroecological transitions.

Planning collaborative activities ▼

Biodiversity: Options for advancing agro-biodiversity

Farmers and their organizations:

- Approach national breeding programs with requests or ideas to diversify varietal options.
- Share experiences on use and management of varietal diversity with other farmers and partners.
- Request new diversity from national breeding programs to respond to diverse and changing conditions and needs.

National breeders:

- Create and share breeding materials with traits not available in farmer-varieties, possibly in forms that facilitate farmer-breeders‘ own selection.
- Contribute to the competitiveness of indigenous crops by building on their robustness and resource use efficiency, thus favoring crop diversity in evolving production systems.

Farmers together with breeders and civil society:

- Explore ways to diversify variety development efforts by engaging more farmer organizations from different production systems in collaborative plant breeding.
- Initiate collaboration earlier in the breeding cycle to retain intra- and inter-varietal diversity useful under farmers’ production conditions.
- Strengthen and scale-up farmer-breeder networks that diversify varietal options for responding to farmers’ contexts.

- Support inclusion of agro-biodiversity as a goal for national agricultural research and biodiversity action plans with emphasis on farmers' indigenous crops.
- Contribute to seed legislation and regulations that favor biodiversity by allowing sale of seed of farmers' varieties, and generally facilitating intra-varietal diversity and enlarging the range of varieties available and accessible to farmers.

Co-Creation: Options for advancing co-learning and sharing local and scientific innovations

Farmers and their organizations:

- Strengthen farmer-to-farmer learning by conducting variety and seed activities as groups and enabling inclusion and sharing of experiences by diverse members.
- Facilitate farmer learning exchanges across agro-ecologies, production systems and types of organizations.

National breeders:

- Recognize farmers as breeders, their knowledge and expertise, as a basis for joint learning and innovation of seed systems.
- Offer training opportunities and diverse source materials to farmer groups and organizations interested in strengthening farmers' skills for enhancing local diversity and seed sovereignty.

Farmers together with breeders and civil society:

- Organize field trials and field days as learning events by planning activities jointly, sharing findings and experiences gained from the event or season, and drawing conclusions together.

▲ Farmer selecting in nursery received from breeders

- Learning by doing in collaborative variety and seed activities. All partners collaborating in the farmers' context can create new opportunities for adaptation of food systems.
- Dialogue among the main actors to reach shared understandings of crop production and food system constraints and opportunities. Understanding these issues for production and use of a crop and its role in the farming or food systems can clarify what plant breeding can offer.
- Document experiences with co-learning in relevant media targeting specific audiences to increase interest and engagement in collaborative breeding and seed activities.

A decade of collaboration to create a new sorghum variety in Mali

Farmers started the process by selecting plants from a diversified population provided by breeders, and then sharing selected seed. After a few years of inbreeding by breeders, farmers and breeders evaluated the resulting experimental varieties over two years in on-farm trials. One variety, "Lata", was chosen but was too variable for traits like plant height. A participating farmer, Bala Berthe, decided to clean it up. He selected the best plants out of large field on his farm the following season. Breeders multiplied his selections, and this variety was registered as "Lata – Bala Berthe". This variety maintains intra-varietal diversity while being visually uniform. "Lata – Bala Berthe" is widely grown in Mali and is used as a hybrid parent.

Participation: Options for encouraging social organization and local governance in the breeding process

Plant breeding and seed system development can function as an entry point to social organizing and learning about the power of farmers' participation in governance of food- and agricultural-systems.

- Strengthen farmer organizations' internal procedures for decision-making, resolving conflicts, managing finances, and sharing responsibilities. Well-functioning groups can more effectively set and pursue their own objectives and collaborate with partners.
- More farmers organize themselves for engaging in seed activities with their indigenous crops, building on their knowledge and expertise as a basis for interacting with researchers and policy makers.
- Strengthen the capacities of farmer groups to organize for local seed security.

National breeders:

- Develop mechanisms for effective and credible farmer representation during project planning, implementation and evaluation, as a basis for jointly setting long-term goals at the institutional level.
- Support farmer cooperatives and other group-based activities for long-term co-management of seed, variety and diversity issues.

Farmers, together with breeders and civil society:

- Create and support farmer-researcher networks that integrate plant breeding, variety testing and seed production activities for advancing farmers' development objectives.
- Recognize farmer seed-cooperatives as enterprises.
- Explore opportunities for improving seed security and access to varietal diversity based on culturally appropriate rules and practices in the West African context.
- Explore new options for sharing information, data and observations from collaborative breeding and seed production activities to strengthen local, decentralized decision making.
- Adapt seed legislation to recognize and enhance the capacities of local actors to manage their seed and varietal diversity, including sale of seed of farmer varieties.

CONCLUSIONS

The pearl millet, sorghum and cowpea farmers of West Africa, together with the researchers and development actors who support them, are in a unique situation for advancing agroecology. The rich diversity of these indigenous crops and the different farmers' knowledge systems for using that diversity are in place and active. Agreeing on principles for managing change and using modern social- and biological-science tools together can adapt the genetic base for West African food systems to respond to such daunting challenges as climate change. This approach can strengthen farmers' roles for innovation and enhance biodiversity, commonly threatened by high-input, industrial agriculture developments.

Realizing this opportunity will require:

- Understanding, recognizing and valuing farmers' seed management expertise by researchers, development- and regulatory-actors as a basis for planning and implementing variety- and seed-innovations.
- Political engagement to integrate agrobiodiversity maintenance and enhancement into national agricultural development and climate change adaptation plans by all food system actors.
- Emphasizing the process of joint variety development by building capacity for co-creation and sharing of knowledge by farmer-, national research- and development-organizations.
- Ensuring farmer's contributions to decision making throughout the entire breeding cycle, including the earliest stages, with joint planning by farmer-, research- and development-partners.
- Social-science support to sustain long-term farmer-researcher collaboration, enhancing mutual trust, joint learning, and sharing responsibilities for advancing local, decentralized management of indigenous crop diversity.

Jointly discussing variety performance in a farmers' field ▶

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Agricultural Research Institutes:

IER : Institut d'Economie Rurale, Mali
INERA : Institut National de l'Environnement et des Recherches Agricole, Burkina Faso
INRAN : Institut National de la Recherche Agricole du Niger
ISRA : Institut Sénégalais de la Recherche Agricole
ICRISAT : International Crops Research Institute for the Semi-Arid Tropics.
CERAAS : Centre d'Etudes Régional pour l'Amélioration de l'Adaptation à la Sécheresse is part of the CORAF/WECARD network of Centers of Excellence. It houses regional partnership initiatives from CIRAD (Centre International de la Recherche Agricole pour le Développement, France), from the USAID Innovation Lab on Crop Improvement, from the German Academic Exchange Service and others.
CIMMYT: International Maize and Wheat Improvement Center

Resources:

HLPE (2019) Agroecological and other innovative approaches for sustainable agriculture and food systems that enhance food security and nutrition. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, Rome *http://www.fao.org/cfs/cfs-hlpe/en/*

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GLOSSARY

Broad-based population: Group of individuals (plants) derived from a number of more or less genetically-distant (unrelated) varieties which are cross-pollinated/inter-mated to form a population.

Cross-pollinating crop: A crop that produces seed primarily by fertilization with pollen coming from different plants (as contrasting with self-pollinating crop).

Early generation seed: Seed of a specific variety produced by maintenance breeding and used for the purpose of certified seed production, usually in two classes "Breeders' Seed" and "Foundation Seed".

Experimental variety: A newly created variety that has not been tested in the target environment(s).

Farmer variety: Farmers may associate 'varieties' with certain types of plants, locations, uses or people who donated specific seed. Farmers may manage their seed lots without keeping different varieties separate, especially for cross-pollinated crops.

Heritable: The proportion of observed variability which is due to heredity and not to environmental factors; it is thus the fraction of the observed variability which can be used in breeding.

Hybrid variety: A variety for which seed is produced by open pollination between different parents that are usually sown alternately in the same field.

Improved variety: A variety that was bred using scientific plant breeding methods.

Open pollinated variety: A variety of either self-pollinating or cross-pollinating crops for which seed is produced via open pollination, often abbreviated "OPV".

Population buffering: When only a portion of plants are susceptible to stress at a given time or place, and all remaining plants able 'to escape' the adverse conditions due to diversity within a variety for key adaptation traits such as flowering time.

Population variety: An open pollinated variety developed from a broad-based population. Farmer varieties of pearl millet are all population varieties.

Replication: A complete set of varieties being evaluated in a particular trial. A trial with two replications therefore has each variety tested in two independent plots.

Seed: The reproductive organ of a plant. The term "seed" is used to describe what is sown to produce a crop, whereas the term "grain" refers to what is used for food or feed purposes.

Selection intensity: is the proportion of plants chosen for use as seed in the next generation from all the plants grown.

Self-pollinated crop: A crop that produces seed primarily by fertilization with pollen coming from the same plant (in contrast with a cross-pollinated crop).