FACILITATORS’ FIELD GUIDE
FOR FARMER FIELD SCHOOLS
ON PARTICIPATORY PLANT BREEDING
IN MAIZE, PEARL MILLET, SORGHUM AND GROUNDNUT

This field guide was produced under the leadership of the Community Technology Development Trust (CTDT), Harare, Zimbabwe, with technical support of the Oxfam team for the Sowing Diversity = Harvesting Security (SD=HS) Programme

Based on the training delivered by Rene Salazar, Marco Mare, Alexander Chikoshane, Davidson Masendeke and Patrick Kasasa

Compiled by Damaso Callo Jr. and edited by Bert Visser, with support from Rene Salazar and Gigi Manicad

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FOREWORD

The Facilitators’ Field Guide for Farmer Field Schools on Participatory Plant Breeding in Maize, Pearl Millet, Sorghum and Groundnut aims to assist facilitators in conducting farmer field school (FFS) sessions on participatory plant breeding (PPB) in their respective communities. In this context, participatory plant breeding should be understood in a broad sense: it includes participatory variety enhancement and participatory variety selection (both approaches working with stable lines), as well as participatory plant breeding involving selection and sometimes making crosses (hybridization).

Under the leadership of the Community Technology Development Trust (CTDT), and with the technical support of Oxfam’s team for the Sowing Diversity = Harvesting Security (SD=HS) Programme, this field guide was developed by the participants of the Training of Trainers (ToT) Workshop on Farmer Field Schools for Participatory Plant Breeding (FFS-PPB). The ToT was conducted at the International Crops Research Institute for Semi-Arid Tropics (ICRISAT) National Station, Matopos, Bulawayo, Zimbabwe during 16-31 July 2015. The field guide covers all topics and activities that need to be undertaken in a season-long FFS-PPB course. It is meant to function as the main reference for FFS facilitators, guiding the latter in FFS implementation. It also provides FFS facilitators with a framework for the preparation of regular and periodic reports.

As decided by the participants in the aforementioned workshop, the field guide focuses on four major crops important in Zimbabwe: maize, pearl millet, sorghum and groundnut. Maize, now a major cereal food crop that was introduced to Zimbabwe during colonial times, is a highly subsidized crop that is increasingly replacing traditional cereal crops due to strong government intervention and promotion. Pearl millet once formed a major staple crop in the semi-arid regions of Zimbabwe, together with sorghum (another cereal crop) and groundnut (a legume crop). These crops are still grown by local farmers over considerable acreages, particularly in the drier zones. The choice of these crops aims to capitalize on indigenous know-how on growing, harvesting and storing them. Each of these crops exhibits a distinct reproduction biology and is either cross- or self-pollinating; accordingly, each requires a distinctly different breeding methodology. For the first season, this field guide concentrates on participatory variety selection (PVS) and participatory variety enhancement (PVE) – the two approaches identified as the main strategies of improving the diversity of plant genetic resources (PGR) for maize, pearl millet, sorghum and groundnut in Zimbabwe.

The technical contents of the field guide have been based on the experiences shared by: Mr. Patrick Kasasa, Project Manager, Biodiversity; Mr. Hilton Mbozi, Project Coordinator of the CTDT; Mr. Renato Salazar, Technical Operations Adviser of the SD=HS Programme, Oxfam Novib; Mr. Marco Mare, Plant Breeder of the Crops Breeding Institute (CBI) and (ICRISAT); Mr. Alexander Chikoshane, Plant Breeder of the Centro Internacional de Mejoramiento en Maíz Y Trigo (CIMMYT); and Mr. Davidson
Masendeke of the Department of Agricultural Extension (Agritex). All acted as resource persons on topics including plant genetic resources, plant breeding and farmer field school methodologies addressed in this field guide.

We wish to acknowledge Mr. Andrew Mushita, CTDT Executive Director, for painstakingly overseeing the workshop, and Dr. Kizito Mazvimavi, ICRISAT Country Representative of Zimbabwe, Dr. Shadreck Ncube, Head of Matopos Research Station, and Ms. Sakile Kudita, ICRISAT Gene Bank Scientific Officer, for allowing us to use their research facilities and conference room for the workshop. Special thanks are given to Mr. Renato Salazar and Mr. Damaso Castillo Junior, who helped compile the technical and training process topics used in this field guide. Inputs on gender mainstreaming and experiential learning were in particular provided by the Southeast Asia Regional Initiatives for Community Empowerment (SEARICE) and Oxfam programme teams: Ms. Gigi Manicad, Mr. Bert Visser and Ms. Annick Osthoff. Mr. Bert Visser was responsible for editing the compiled texts.

We are grateful for the funding support from the International Fund for Agricultural Development (IFAD), the Swedish International Development Cooperation Agency (Sida) and the Dutch National Postcode Lottery (NPL).

This version of the field guide will be tested and circulated widely for further feedback, following which an improved version will be published in 2017-2018.
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<th>Definition</th>
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<tbody>
<tr>
<td>AESA</td>
<td>Agro-Ecological Systems Approach</td>
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<tr>
<td>Agritex</td>
<td>Agricultural Technical and Extension Services</td>
</tr>
<tr>
<td>CIMMYT</td>
<td>Centro Internacional de Mejoramiento en Maiz y Trigo (International Maize and Wheat Improvement Center)</td>
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<td>CTDT</td>
<td>Community Technology Development Trust</td>
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<tr>
<td>FFD</td>
<td>Farmers’ Field Day</td>
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<td>FFS</td>
<td>Farmer Field School</td>
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<td>GEAN</td>
<td>Gene x Environment Interaction</td>
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<tr>
<td>GS</td>
<td>Grow stages</td>
</tr>
<tr>
<td>HYVs</td>
<td>High Yielding Varieties</td>
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<tr>
<td>ICRISAT</td>
<td>International Crops Research Institute for the Semi-Arid Tropics</td>
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<td>IFAD</td>
<td>International Fund for Agricultural Development</td>
</tr>
<tr>
<td>IPM</td>
<td>Integrated Pest Management</td>
</tr>
<tr>
<td>NGO</td>
<td>Non-government organization</td>
</tr>
<tr>
<td>NPL</td>
<td>Dutch National Postcode Lottery</td>
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<tr>
<td>OPV</td>
<td>Open-Pollinated Variety</td>
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<tr>
<td>PAR</td>
<td>Participatory Action Research</td>
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<tr>
<td>PGR</td>
<td>Plant Genetic Resources</td>
</tr>
<tr>
<td>PGRFA</td>
<td>Plant Genetic Resources for Food and Agriculture</td>
</tr>
<tr>
<td>POP</td>
<td>Population</td>
</tr>
<tr>
<td>PPB</td>
<td>Participatory Plant Breeding</td>
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<tr>
<td>PVE</td>
<td>Participatory Varietal Enhancement</td>
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<tr>
<td>PVS</td>
<td>Participatory Varietal Selection</td>
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<td>SD=HS</td>
<td>Sowing Diversity = Harvesting Security</td>
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<tr>
<td>SEARICE</td>
<td>Southeast Asia Regional Initiatives for Community Empowerment</td>
</tr>
<tr>
<td>Sida</td>
<td>Swedish International Development Cooperation Agency</td>
</tr>
<tr>
<td>SYN</td>
<td>Synthetic</td>
</tr>
<tr>
<td>ToT</td>
<td>Training of Trainers</td>
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<tr>
<td>WUR</td>
<td>Wageningen University and Research Centre</td>
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1. INTRODUCTION TO PLANT GENETIC RESOURCES

1.1 Plant Genetic Resources Issues in Zimbabwe

What are Plant Genetic Resources for Food and Agriculture?

Plant genetic resources for food and agriculture (PGRFA) refer to plants that are used by farmers and breeders and maintained by collection holders. PGRFA may be cultivated, semi-cultivated or semi-wild, wild or gathered plants. PGRFA are valuable for supporting humankind with food, feed, medicines and other products. Generally, the value of these resources depends on the extent of diversity that they carry and the information available about their traits. A rich genetic diversity is invaluable for food production under conditions of climate change; it is a necessary basis for conventional plant improvement programmes in the public and private sectors, as well as for participatory approaches involving farmers.

What are important PGRFA in Zimbabwe?

PGRFA in Zimbabwe encompass many cultivated and semi-cultivated crops, e.g. cereals, legumes, root and tuber crops, as well as vegetables. The most important among these are cereal and legume staple crops such as maize, pearl millet, sorghum and groundnut, which provide calories, and in particular global and indigenous vegetables, which provide many additional nutrients.

Seed source analysis: where does the seed that farmers grow come from?

The seeds that farmers grow come from informal, intermediary and formal sources. Informal seed sources involve farmer-saved seeds exchanged and traded in local markets. Formal seed sources include national private companies and public institutions, as well as multi-national corporations and international agricultural research centres (see Table 1). Intermediary seed sources are those stemming from relief organizations and local seed businesses. Informal and intermediary sources may provide both farmers’ varieties (i.e. local varieties) and formally registered varieties developed by the public and private sectors.

How are plant genetic resources conserved on-farm?

Plant genetic resources (PGR) are not static. They evolve through the combined effects of natural processes and human selection. The role of farmers and their practices (including

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management and storage, as well as sharing mechanisms) influence the fate of their PGR. The farmers’ portfolio of PGR results from these practices, which include the informal flow of genetic materials through farmers’ own social networks. These practices make a major contribution towards the creation of on-farm diversity.

In addition to on-farm management of PGRFA, the latter are conserved in collections maintained by breeding institutes and genebanks (a practice known as *ex situ* conservation), whereas many wild relatives of our cultivated plants survive in nature ( *in situ* conservation).

**Table 1: Seed sources of farmers in Zimbabwe**

<table>
<thead>
<tr>
<th>Farm-saved/Community-based</th>
<th>Relief Aid</th>
<th>Local Seed Business</th>
<th>National Companies (private &amp; public)</th>
<th>Multi-national Companies</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ Mainly crops for household consumption</td>
<td>▪ Crops creating food security (subsistence) Beans, maize, cassava</td>
<td>▪ All crops Beans, rice, maize, sorghum, potato</td>
<td>▪ All crops Maize (hybrid &amp; open-pollinated variety [OPV]), sunflower, sorghum, wheat, rice</td>
<td>▪ All major crops, including export crops Maize (hybrids), exotic vegetables Formally released varieties Seed certified Marketing through national and local markets</td>
</tr>
<tr>
<td>▪ Maize, millets, sorghum, banana, cassava, beans, cowpea, pigeon pea, green grams, groundnut, Bambara nut, potato</td>
<td>▪ Mainly formally released varieties Free distribution, based on voucher schemes Seed may be certified</td>
<td>▪ Mainly formally released varieties Seed normally certified Distribution through local markets</td>
<td>▪ Formally released varieties Seed certified Marketing through national and local markets, or through input schemes</td>
<td></td>
</tr>
<tr>
<td>▪ Farmers’ varieties &amp; formal varieties (public and private sector)</td>
<td></td>
<td>▪ Distribution through local markets</td>
<td></td>
<td></td>
</tr>
<tr>
<td>▪ Locally produced seed</td>
<td>▪ Seed normally not certified</td>
<td>▪ Marketing through national and local markets</td>
<td></td>
<td></td>
</tr>
<tr>
<td>▪ For household use, exchange and local markets</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>▪ Seed normally not certified</td>
<td>▪ Crops creating food security (subsistence) Beans, maize, cassava</td>
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</tr>
</tbody>
</table>

*Source: Kasasa (2015)*

Small-scale farmers in developing countries, including women, are key in maintaining PGR diversity on-farm and managing the associated processes. Together, they maintain a high diversity of varieties of many crops, and exchange their varieties with other members in their community and beyond. They introduce and exchange new varieties from various sources (see Table 1), and maintain the knowledge on their own local varieties.

**What are the major threats to PGR conservation in Zimbabwe?**

The decline of a wide diversity of PGR in at least the last three decades is attributed to various factors, one being the diffusion of high yielding varieties (HYVs), including hybrids, developed by private companies and public sector research institutions. Globalization, migration and urbanization have also caused a shift in diets and changes in the underlying
diversity of PGR maintained in farmers’ fields. Finally, government policies have promoted the use of certified seeds of registered varieties, which overall show less diversity than the nationwide complex of farmers’ varieties.

Consumer preference for local crop varieties (e.g. in millets, sorghum, cowpea and groundnut) has decreased due to urbanization and prejudices in lower-income classes (which used to consume these grains, but now tend to favour the diet of higher-income classes). In both rural and urban areas, the most preferred staple is maize, ground to prepare sadza. However, maize by itself cannot provide sufficient nutritional value for a healthy body.

Cheap, subsidized maize distributed through non-government organizations (NGOs), public distribution systems and food-for-work programmes has further depressed the demand for local small grains and their many varieties.

Low prices and lack of procurement support for local varieties reduce incentives for farmers to grow them for local and national markets. The allocation of better lands for HYVs, which respond best to external inputs, leaves only marginal lands for local varieties. Consequently, farmers tend to grow local varieties in plots that cannot be used for alternatives which provide better yields and income.

### 1.2 PGR Diversity and the Role of Farmers in PGR Management

**Domestication and Diversity**

Crops have not evolved randomly across the globe: rather, their evolution has taken place within specific regions. These regions provided the right conditions for the emergence of agriculture because of the presence of wild cereals and legumes, as well as animals that could be adapted to support local agriculture.

The *centre of origin* is a geographical area where a group of organisms, first wild and then domesticated, developed their distinctive properties. Centres of origin are also referred to as centres of diversity, given that areas of domestication contain a wide genetic diversity of the concerned domesticated species. Some crops and farm animals developed new traits after migrating to certain new areas, which may therefore also be called (secondary) centres of diversity (Wikipedia, 2015).

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Many small-scale farmers across the world maintain their own locally adapted diversity of crops that may have once been introduced from other parts of the world. Thus, sub-Saharan Africa – which is home to cultivated sorghum, pearl and finger millet, cowpea and groundnut, as well as cattle – can also be considered a secondary centre of diversity for maize and cassava, which originated in the Americas. In particular, the diversity of maize in Southern and Eastern Africa’s small farming systems provides a good example of a second centre of diversity that is situated far away from the region where the crop was originally domesticated (i.e. southern Mexico).

Locating the origin of crop plants is important for plant breeding. This allows one to locate wild relatives and, therefore, new useful genes these relatives may contain that can be incorporated into the related domesticated species by means of crossing. Knowledge of the origins of crop plants is also important because it identifies areas that should be conserved in order to avoid genetic erosion and the loss of genetic diversity due to the loss of ecotypes and landraces, the loss of habitat (such as rainforests), as well as pollution and increased urbanization.

**Drivers of Diversity**

The evolution of PGR diversity is driven by natural selection, the movement of seeds between different regions of the world, and conscious selection by farmers and professional breeders. This process, which began in ancient times, still continues today.

**Role of PGR Diversity**

PGR diversity is essential for resilience in agriculture. It allows adaptation to biotic stresses (e.g. pests and diseases) and abiotic stresses (e.g. drought and iron toxicity), other diverse agro-ecological conditions and climate change.

**Genetic Erosion**

Genetic erosion is the decrease in the diversity of species and, more distinctly, the decrease in the numbers of varieties within our crops. Over the course of history, humanity consumed products from more than 2,000 plant species, whereas today 86 percent of our food is derived from only 32 species.

Genetic erosion is caused by socio-economic and political changes, including globalization, market pressure, the development of monoculture, government policies, centralized plant breeding, and the loss of farmers’ role in breeding and seed production.
Role of farmers in PGRFA management

The role that farmers have traditionally played in PGRFA management includes on-site (in situ) selection and improvement and maintenance of existing crop varieties (traditionally entailing mass selection complemented by pedigree selection of special and favoured plant types). As mentioned earlier, diversity is necessary for breeding, adaptation to climate change and global food security. The conservation and development of this diversity requires the contributions of small-scale farming systems, and these need to be strengthened through participatory plant breeding (PPB). The in situ management of crop diversity performed by farmers is also known as on-farm management.

In Zimbabwe, the majority of farmers are women. Aside from their role in agricultural production, women’s knowledge and skills are important in seed management (see Special Topic 10.7). Therefore, special attention is needed to ensure women’s participation in the Farmer Field Schools (FFS).

1.3 Strengthening Farmers’ Seed Systems in Changing Realities

Given the changing realities, farmers’ seed systems need to be strengthened in order to secure their role in maintaining crop diversity in the field. Many farmers have adopted components of intensive production systems and major segments of agricultural production have become market-driven. As a result, the management of diversity has dwindled. To promote the ongoing maintenance of PGR in functioning small-scale systems, support for diversity conservation has to go hand in hand with strategies promoting sustainable agriculture and improved livelihoods for farmers. Such support should come from facilitating government policies, including seed policies. Relevant seed laws affecting PGR management by farmers in Zimbabwe are discussed in Annex 11.1.

This Farmer Field Schools for Participatory Plant Breeding (FFS-PPB) field guide – which will be used by the Community Technology and Development Trust (CTDT) to address the problem of decreasing PGR and strengthen farmers’ seed systems in Zimbabwe – will focus on two main activities: participatory variety selection (PVS) and participatory varietal enhancement (PVE). In PVS, on the one hand, farmers will test under local growing conditions the performance of stable and advanced lines obtained from the breeding stations of the Crops Breeding Institute (CBI), the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and Centro Internacional de Mejoramiento en Maiz y Trigo (CIMMYT), with the aim of increasing the diversity of local genetic resources. In PVE, on the other hand, farmers will select desirable traits and enhance the genetic homogeneity of the most popular but ‘deteriorated’ varieties (i.e. not homogeneous, exhibiting suboptimal traits) used in their community.
2. THE FARMER FIELD SCHOOL (FFS) APPROACH

The FFS empowers farmers through field-based experiential learning; it enables farmers to make their own observations, analyse these observations and use the results as a basis for conclusions and decision making. It implies defining and analyzing problems and challenges, and acting on consequential solutions. Practice-oriented field observations and experimentation allow for continuous learning and enable farmers to continuously adapt their PGRFA to ever-changing environments and markets. The principles of adult learning guide the FFS learning processes, as explained in Annex 11.2. The main components of the FFS curriculum are agro-ecosystem analysis (AESA), group dynamics exercises and special topics. The learning process is focused on skills development. The details of FFS curriculum are discussed in Annex 11.3. Below is a description of typical FFS features.

2.1 Non-formal Education Methods Used in FFS

The following methods of informal education are used in FFS:

- Discovery-based learning techniques (including AESA, participatory action research (PAR), collection of genetic resources, identification and functional classification of pathogenic insects, diseases and other abnormalities);
- Experiential learning methods (including setting up of experiments, analysis of findings and sharing of experiences among participants, facilitators and technical resource persons);
- Participatory approaches (including group discussions and team-building exercises).

These methods are applied together and coherently.

2.2 FFS as a ‘School Without Walls’

The FFS involves education and training of adults within their own community. It does not necessarily make use of school buildings. In fact, much of the training takes place in the field. Thus, it is also described as a ‘school without walls.’ The FFS includes the following activities:

- Observation and analysis of crop growth and other crop physiological properties, such as vigour, morphology and useful traits (these constitute the core of the FFS curriculum);

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This summary presented by: Callo, Jr., D.P. 2015. Introduction to Farmer Field School. Training of Trainers Workshop on Farmer Field School for Participatory Plant Breeding at the International Crop Research Institute for Semi-Arid Tropics National Station, Matopos, Bulawayo, Zimbabwe on 16-31 July 2015
• Focus on developments in farmers’ own fields;
• Season-long, hands-on experimentation and field studies in a ‘learning field,’ usually conducted in a group of 25 – 30 farmers.

2.3 Components of FFS

The following elements characterize the curriculum:

• *AESA*: A prolonged analysis of plant health and plant disease surveillance; water, weed, soil and nutrient management; and a survey and collection of insect pests, predators and parasites (see Special Topic 10.1);
• *Group Dynamics*: Team building and leadership training form a major part of the FFS. Some group dynamics exercises are detailed in Special Topic 10.3;
• *Special Topics*: In addition to the special topics indicated above, other specific issues and interests, such as seed selection, biodiversity conservation, composting, post-harvest techniques, produce processing, marketing of seed and food products, may be addressed in the FFS (see Annex 11.6).

2.4 Focus on farmers’ knowledge and skills development

The FFS aims to increase farmers’ knowledge and skills by addressing the following capacities:

• Management and decision-making skills in response to agronomic and ecological challenges;
• Leadership skills that may facilitate group learning activities and problem-solving processes;
• Critical skills enabling farmers to identify and analyze problems and take effective actions.

2.5 Facilitation

The success of an FFS depends largely on good facilitation. This requires the facilitators to guide the learning process rather than to provide answers. The facilitators should ideally guide the participants to analyze and arrive at their own conclusions and solutions for the situation at hand. Some pointers in facilitation are provided in Annex 11.7.
2.6 Field Studies

In Zimbabwe, the FFS-PPB studies focus on PVS and PVE in order to address sub-optimal production, poor food and nutrition security, and decreasing PGR diversity. For the purpose of PVS, and in order to enlarge the availability of plant genetic diversity for farmers participating in the FFS, CTDT has established strong partnerships with the breeding institutions CBI and ICRISAT (for pearl millet, sorghum and groundnut), and CIMMYT (for maize). These institutions have committed to provide stable improved lines to farmers for testing under local growing conditions. As a complementary strategy, PVE is employed to restore and enhance the properties of popular but ‘deteriorated’ varieties grown in the community. This is achieved through (re-)selection for desirable traits that characterize these local varieties and, subsequently, seed production of such preferred varieties.

3. PREPARATIONS FOR FFS-PPB IMPLEMENTATION

During the preparatory phase of the FFS-PPB project, a series of activities should be undertaken:

3.1 Identification of Potential FFS-PPB sites and participants

The implementing organization and its partners should identify potential FFS sites, taking into consideration the cropping conditions (e.g. humid, semi-arid or arid) and the ownership status (e.g. communal or individual holdings) of the sites being considered.

Participant selection should be guided by clear and transparent criteria that are defined and agreed with the communities beforehand. Participants should be selected for their willingness to consistently participate in the season-long FFS and share the acquired knowledge. Appreciation for gender equity and social inclusion is a value that also should be built into the FFS (see Special Topic 10.7).

3.2 Initial Assessment of Potential FFS-PPB Sites

Local community partners should be able to facilitate the organization of the FFS. The selected sites should include representative agro-ecological conditions. The participation of women in the FFS should be guaranteed. Initial discussions should be conducted to acquire insights concerning the crop portfolio available to the community, their food and nutritional status, as well as the biotic and abiotic stresses affecting the farming activities of the
community. This is usually achieved by means of informal meetings with key leaders and small focus group discussions with farmers in the community.

3.3 Selection of crops and varieties for FFS-PPB

The initial identification of the most important crops and varieties and their preferred traits occurs during the discussions with key local leaders and in small focus groups that ensure the active participation of women. The selected crops and desired crop varieties should fit the agro-ecological conditions of the community and should also include women’s crops and varietal preferences.

3.4 Estimating the Need for FFS-PPB

Initial discussions with local farmers on their need for better varieties and better quality seeds should guide the planning of FFS activities. To this end, a planning meeting and a start-up session may be organized (see Special Topics 10.4 and 10.5) in order to provide a sense of farmers’ expectations, address women’s participation and build collective ownership of the FFS.

4. ESTABLISHMENT OF THE VILLAGE BASELINE

The establishment of the village baseline is a crucial step towards ensuring that the FFS addresses the primary needs and objectives of the farmers in the community. Their commitment to the FFS project can only be assured if it focuses on and satisfies their needs. The baseline should be disaggregated by gender in order to distinguish and specifically address women’s positions and needs.

The proper organization of the FFS, the identification of well-suited participants, their explicit commitment to the project, and the elaboration of farmers’ and facilitators’ respective roles and responsibilities are essential elements in ensuring that the FFS project becomes the villagers’ project.

In Zimbabwe, the assumption has been that more PGR diversity is needed in the marginal, semi-arid cropping areas in order to improve farmers’ livelihoods and food and nutrition status. In this regard, the challenge is to analyse and understand the crop diversity that is available in the community and the associated shortcomings, as this forms the basis for the

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4Adapted from Smolders, H. and R. Salazar. (2003). Facilitator’s Guide for On-Farm Conservation and Development of Plant Genetic Resources in Pearl Millet and Cowpea, With Special Reference to Conditions in Sub-Saharan Africa (Mali). U.N. Food and Agriculture Organization and Centre for Genetic Resources, the Netherlands, Wageningen University and Research Centre
FFS (see Annex 11.4). These baseline data establish the starting point for a collective diagnosis and the joint development of the FFS agenda, as well as the benchmark against which the later outputs of the project will be measured. Establishing the baseline also ensures that the FFS intervention is realistic and well grounded, and that it is specifically responsive to the needs of women.

4.1 Selecting appropriate crops

In this first activity, a meeting with 25 to 30 farmers is organized in the community. At the meeting, the ‘biodiversity wheel analysis’ is applied at the crop level (see Annex 11.5). This exercise helps farmers to identify their most important field crops. The following steps are taken:

a. The farmers are divided into five subgroups and each subgroup independently conducts an exercise using the biodiversity wheel;
b. The facilitator assigns a chairperson for each subgroup to lead the discussions (with support from the facilitator);
c. Farmers discuss and list their 8-10 most important crops;
d. Farmers discuss and assign each crop to a ‘block’ in the wheel that represents it best;
e. Farmers discuss and agree to select two crops that are most important to them out of the larger group of 8–10;
f. Each subgroup presents the result of their biodiversity wheel exercise to the plenary;
g. The plenary discusses the results of each subgroup and jointly agrees on the most important crops (usually one to three).

In the process, the community comes to a common understanding of the role that these key crops have in their livelihoods and the reasons behind the ranking of their crops.

4.2 Analysing strengths and weaknesses of current varieties

In the following activity, the strengths and weaknesses of currently grown varieties of the selected key crops are analyzed. To this end, the biodiversity wheel exercise is carried out on the varieties of the crops selected in the previous activity (see Annex 11.5). This exercise helps farmers to identify the most important varieties of their selected crops. The steps followed are similar to those of the first activity:

a. Each of the five subgroups of farmers conducts again a biodiversity wheel exercise, this time on the varieties of the most important crop(s);
b. The assigned chairperson leads the discussions in his/her small group (with support from the facilitator);
c. Farmers choose one of the selected crops that is most important to them, e.g. either maize, pearl millet, sorghum or groundnut;
d. Farmers discuss and list all varieties for that particular crop that are grown in or are available to the community;
e. Farmers discuss and agree where each variety belongs in the biodiversity wheel;
f. Farmers subsequently list the positive and negative traits of the varieties in the different segments of the biodiversity wheel;
g. Each subgroup presents the results of their biodiversity wheel exercise to the plenary;
h. The plenary group discusses the results of the biodiversity wheel exercises and agrees on the most important crop varieties.

4.3 Formulating selection and breeding objectives

In order to ensure that the breeding objectives address the concrete needs of the community and are realistic, simple scoring techniques are used to arrive at an agreement on the most preferred traits. For this purpose, each farmer is allocated a limited and equal number of seeds with which to score his/her most valued traits. The results help to identify new varieties, or breeding lines and populations, to be introduced to the community through PVS. They also help to identify those varieties that are already grown in the community but which have deteriorated and should therefore be subjected to PVE. The results are also used as input information by the partner breeding institutions, enabling the latter to determine which stable and advanced lines may best be provided to a particular FFS site. The following steps are taken:

a. In each subgroup, farmers focus on the crop(s) that was/were selected in the biodiversity wheel exercise and on the varieties of these crop(s) grown in the community;
b. Farmers discuss and agree on 8-10 most important traits that they would like the ideal new variety/varieties to have;
c. Each farmer is given a limited number of seeds (e.g. 20) and asked to use them to ‘score’ each of the identified traits;
d. The number of seeds allotted to each box (i.e. trait) determines the ranking of that trait and guides the setting of PVS/PVE objectives: the higher the number of allotted seeds, the more important the trait. Farmers discuss if the traits are really needed and whether it is realistic to work on these traits;
e. The results of each subgroup are reported to the plenary for discussion and agreement;
f. Farmers identify which local varieties best score for PVE and provide guidance on the most desirable traits for newly introduced varieties.
CTDT ensures that the partner breeding institutions (CBI, ICRISAT and CIMMYT) are informed about the results of the ranking exercise, so that they can select the varieties and lines that best fit farmers’ expectations, prepare enough seeds of the cultivars (i.e. advanced stable lines) for on-farm evaluation and deliver these on time to the corresponding FFS sites. An agreement should be made with the breeding institutions early enough regarding the number of stable and advanced lines and the required amounts of seeds in order to ensure that these are made available at the FFS site at sowing time. Such availability is strongly influenced by the extent and type of breeding programmes managed by these institutions. Different communities may select different crops and rank preferred traits differently, meaning that the breeding institutions might have to prepare different lines for different communities.

4.4 Organizing the FFS-PPB Project

Once all of the required PGR baseline data have been gathered for planning, the selection of FFS-PPB participants commences. Community leaders and village farmers are consulted and around 25-30 farmer participants from the same village are identified. The composition of the FFS-PPB group should overlap with the composition of the community group that performed the biodiversity wheel exercises, but does not need to be identical. This allows less interested farmers to leave and newly interested farmers to join. Commitments from farmers and partners are formulated and agreed upon, the levelling of expectations is carried out, and rules and responsibilities are defined. A guide to FFS curriculum development detailing further issues is presented in Annex 11.6.

4.5 Selection of FFS-PPB site

The selected community FFS site should be easily accessible, near a road or a pathway, and within walking distance for all participants, especially women. The site and the individual plots allotted to individual farmers participating in the FFS must be representative of the conditions in the community and should preferably be located in an area that is relatively homogeneous in terms of soil quality and water availability. The plots should also be familiar to women and be representative of their own plots; otherwise, results may only cater to men’s interests and demotivate women’s participation. Since there will be no replicated test of a particular single variety or line within a single plot, sloping sites should be avoided as they may result in different water availability and may therefore complicate the analysis and interpretation of results.
5. ESTABLISHMENT OF FFS-PPB PLOTS

This stage includes all activities from land preparation to sowing of the test plots.

5.1 Plot Designs

The plot design and allocation of each line should minimize the risk of distortions by factors such as slope and fertility gradients, or other irregularities. The participants should preferably be organized again in five subgroups, each subgroup with a leader and a reporter, and allocated its own plot in the larger FFS-PPB site. At this stage, it should be decided whether or not to form women-only groups. This may be particularly relevant in cases where women’s crop and trait preferences clearly deviate from those of men. The role of reporter may rotate among the group members, so that each member can gain experience in the process of documentation. All FFS members should participate in land preparation (an area of 1,000 sq. m at most), whether for PVS or PVE. The AESA will later form a key activity that will be carried out every week or every session, as the case may be. More details on how to design FFS studies are presented in Annex 11.6.

Participatory Variety Selection (PVS)

Varieties or lines

In the PVS, stable and advanced lines provided by CBI, ICRISAT and CIMMYT are tested. Popular varieties from within the community as well as from other districts or provinces can be included for comparison.

It is recommended to sow a maximum of 10-12 lines (including two popular varieties) during the first season. This number is both manageable and sufficient for farmers to gain the required knowledge and skills to successfully complete the FFS. One of the selected popular varieties should serve as the ‘standard’ or control variety for the purpose of comparison. This control variety should normally be the most popular, i.e. the variety most commonly planted by farmers in the village.

Field Size

Each single variety requires a field size of about 50-60 sq. m. If a maximum of 12 varieties is used, the total area needed is about 500-600 sq. m per crop. Two separate plots have to be allocated to farmers’ popular varieties (see Figures 1 and 2). To increase the reliability of results and avoid complications in the farmers’ interpretation and analysis of data, replicate tests using the same lines may be conducted in other nearby villages involved in the FFS-
The study field should preferably be surrounded by a fence in order to guard it against grazing cattle.

**Planting Density**

Plant spacing for maize, pearl millet, sorghum and groundnut should be either as per farmers’ practice or as recommended below:

- *For maize*, the planting density is one seed per hill, at a distance of 0.2m between hills x 0.9m between rows x 10m long rows, resulting in 278 plants per 50 sq. m without thinning.
- *For pearl millet*, given that seeds are small, the planting density is three seeds per hill at a distance of 0.2m between hills x 0.9m between rows x 10m long rows, amounting to 834 plants per 50 sq. m. However, two seedlings per hill are thinned out one week after emergence of the crop, thereby reducing plant population to 278 plants per 50 sq. m.
- *For sorghum*, given that seeds are relatively small, the planting density is 2 seeds per hill at a distance of 0.2m between hills x 0.9m between rows x 10m long rows, totaling 556 plants per 50 sq. m. However, one seedling per hill is thinned out one week after emergence of the crop, thereby reducing plant population to 278 plants per 50 sq. m.
- *For groundnut*, given that seeds are relatively bigger, the planting density is one seedling per hill at a distance of 0.25m between hills x 0.5m between rows x 10m long rows, amounting to 400 plants per 50 sq. m; no thinning is required for this crop.

**Plot identification**

It is very important to properly label the plots with durable sticks and tags in order to easily identify the location of the planted varieties. In addition, it is useful to make a map or layout of the field and indicate on it where each variety is planted. The field layout may also indicate the slope and the variation in homogeneity of the field plots. If the site and its individual plots are sloping, then the varieties should be arranged in parallel to the direction of the slope (see Figure 1). If the site is relatively homogeneous, then the varieties can be evenly distributed over the site (see Figure 2).
Participatory Variety Enhancement (PVE)

Varieties

The basis for the PVE and the selection of the varieties to be tested lies in the established community baseline. The selection concerns local ‘deteriorated’ varieties that are popular with the farming community, but of which good quality seeds cannot be obtained. Seeds that are available may result in heterogeneous field stands, or may have been consistently infected by pathogens, or may have (partially) lost one or more of their valued traits. Farmers should choose one or more of their most popular varieties, the traits of which they want to enhance due to observed ‘deterioration.’ They should then identify which specific traits they wish to improve. Given that men’s and women’s preferences in this regard are likely to differ, it is important to ensure that farmers of both genders participate in the exercise. Women’s preferences should be actively taken into account in the selection process. The analysis of desired characteristics should lead to the establishment of breeding objectives jointly agreed upon by men and women farmers.
Field size

The size of the field plot needed for the study depends on the number of farmer subgroups participating in an FFS session. An individual variety should be allotted 300-500 sq. m in total, depending on the crop. The number of rows of the field study plot should be divisible by the number of farmer subgroups, ensuring that each subgroup has an equal area and time for field observations. No replications are needed.

Planting distance

Plant spacing for maize, pearl millet, sorghum and groundnut should be as per farmers’ practice. Alternatively, plants can be seeded at 0.90m between rows (lines) and 0.20m between hills (plants), with the exception of groundnut for which a spacing of 0.5m between lines and 0.25m between is recommended.

Isolation distance

- For maize and pearl millet, which are open-pollinating species, ensure a distance of at least 300m from the next stand of the crop. Alternatively, realize isolation by staggering the planting time, with an interval of at least 18-20 days between plots. Make sure that no other maize or pearl millet is grown in the immediate vicinity of the PVE site. If there is only one local variety to be enhanced, then isolation needs to be practiced in relation to nearby farms. If there are two local varieties to be enhanced, then the varieties can be planted in the same FFS site but isolated by time. Alternatively, they can be planted in two different sites that are well isolated from each other.
- For sorghum and groundnut, which are mainly self-pollinating, ensure an isolation distance of at least 2m between plots of two varieties if more than one variety is being enhanced. Be aware that hybridization might occur even in the case of these self-pollinating crops. Depending on local conditions and the traits of the varieties, out-crossing levels may still be as high as 15 percent.

Identification

Label the fields in order to easily identify the location of the varieties planted. In addition, make a map of the field or a field layout, and indicate on it where each variety is planted (see Figure 3a and Figure 3b).
5.2 Proper handling of seeds and plants

For PVS, proper handling of the lines to be tested should be ensured throughout the process, from the receipt of the seeds in the community until sowing time. The study field is divided into 12 plots; two plots are assigned to each farmer subgroup. All subgroups share
responsibility for the plot(s) planted with the standard variety/varieties, which function(s) as a control for all newly introduced lines.

For PVE, only one plot is established for each variety identified for enhancement. This study plot is then divided into five sections and each section is assigned to a separate farmer subgroup. Each subgroup will gather data on a weekly basis from its own assigned section. For both the PVS and PVE, the sowing period should be similar to that which is normally observed in the village.

5.3 Plot Management and Responsibilities

Each subgroup is responsible for the study plots assigned to it. Although regular care should be practiced at all times, the host farmer who owns the FFS site and its study plots should ensure that they are protected from poachers and stray animals. The entire FFS group can assist in this task and work together to erect a fence around the study plots.

The facilitator should regularly discuss the selection objectives with the participants in order to establish and reconfirm the type of data to be gathered, how often they will be gathered, and how they will be gathered at every stage of plant growth and development. It should be emphasized to the participants that data gathering, consolidation and interpretation are collective and collaborative activities of each subgroup and the FFS group as a whole, and that these activities are essential for the success of the FFS.

5.4 Critical Selection Stages in PVE

To optimize the quality of the observations during variety enhancement, farmers should conduct several rounds of positive and/or negative selection in the field. Recommended plant stages for the purpose of selection are as follows:

For Maize

a. From planting to tasseling: most suitable for observations of germination rate, plant vigour, leaf colour, stem base colour, degree of tillering, early tasseling, and responses to pests and diseases;
b. At silking: most suitable for observations of early silking, silk colour, plant height, and responses to pests and diseases;
c. At maturity, just before harvest: suitable for observations regarding early maturity, plant height, ear size, cob cover and grain yield.
For Pearl Millet and Sorghum

a. From planting to flowering: suitable for observations of germination rate, plant vigour, leaf colour, stem base colour, degree of tillering, and responses to pests and diseases;
b. At flowering: most suitable for observations of date of flowering, plant height, and responses to pests and diseases; and
c. At maturity, just before harvest: suitable for observations regarding early maturity, number of productive tillers, panicle size, panicle exertion and grain yield.

For Groundnut

a. From planting to flowering: suitable for observations of germination rate, plant vigour, leaf colour, early flowering, flower colour, and responses to pests and diseases;
b. At pod development: most suitable for observations of seed setting, growth habit, and responses to pests and diseases; and
c. At maturity, just before harvest: suitable for observations regarding early maturity, number of pods, number of seeds per pod and total seed yield.

6. ACTIVITIES IN FFS-PPB PLOTS AT VEGETATIVE GROWTH STAGE

Each subgroup is expected to select at random five sample plants within each tested variety or line. These randomly selected plants should be marked with sticks or pegs and be used for collecting agronomic and morphological data on a weekly basis throughout the season. In addition, infestation by insect pests and other natural enemies can be measured from five additional plants selected every week during the vegetative stage. During the vegetative growth stage, the incidence of pests and diseases, as well as the occurrence of drought and other abiotic stresses, should be observed and qualitatively measured (i.e. the percentage of infected plants, or the relative abundance of pests and pathogens). Special topics on ‘morphology and growth stages’ of pearl millet (see Annex 11.8), maize (see Annex 11.9), sorghum (see Annex 11.10) and groundnut (see Annex 11.11) can be integrated into the curriculum at this stage.

Field Management

Soil tillage. Local soil tillage practices for maize, pearl millet, sorghum and groundnut should be used. These practices can be identified and agreed upon with the farmer groups during the pre-season discussion, i.e. at the start of the FFS.
Fertilizer use. Fertilizer application levels should be as per normal farmers’ practices, taking into account recommendations for maize, pearl millet, sorghum and groundnut under prevalent local conditions. These levels should be determined for each site separately through consultation with the farmers’ group. It is important to apply fertilizer (organic or inorganic) in strictly uniform quantities, as the volume of fertilizer used may considerably influence the performance of the planted varieties and thus the comparison between varieties or lines.

Use of agro-chemicals. In order to properly measure resistance to or tolerance for insect pests and diseases, no pesticides should be used in the field study, unless the infection threatens to destroy all plants and, therefore, disrupt the field study.

Weeding. No herbicides should be used. Usual weeding practices should be applied.

Extension support

CTDT coordinates with the Agricultural Technical and Extension Services (Agritex), whose staff regularly visit ongoing FFS-PPB sessions to monitor the quality of the training being undertaken. Extension staff can also serve as resource persons, including on group dynamics - a relevant theme for the participants at the time of field visits – given that most of the staff are well acquainted with the farmers in the community.

Agro-Ecosystem Analysis (AESA)

Each FFS is expected to perform an AESA, as discussed in Special Topic 10.1. The AESA should be conducted on a weekly basis and observations recorded in the AESA Sheet for Vegetative Stage (see Table 2) in order to track the growth and development of the crop during its growth stage. Any additional characteristics should also be recorded in the AESA sheet if found to be important during discussions with farmers.

Rouging at the Vegetative Growth Stage

The FFS should include a participatory discussion with the entire farmers’ group, aiming to develop a set of selection criteria by means of which to identify preferred plants (in PVE) and varieties (in PVS). For the PVS plots, the selection criteria is used as the basis for selection of the most desired varieties, whereas for the PVE plots, the selection criteria is used to guide rouging, which should be undertaken twice during the vegetative growth stage. The first rouging is performed two weeks after plantlet emergence and the second is done two weeks after the first rouging.
**Rouging in PVS Plots**

No rouging activity should be undertaken in the PVS plots for maize, pearl millet, sorghum and groundnut. Instead, the selection criteria developed by the participants should be used to select the most desired varieties from among the available PVS varieties and lines.

**Rouging in PVE Study Plot**

Rouging is a highly effective practice in PVE. Rouging should target plants showing inferior characteristics compared to the majority of plants within a plot (e.g. less vigorous plants, tall plants, plants with fewer tillers [pearl millet and sorghum], droopy leaf-type plants, suspected off-types or volunteer crops, as well as diseased plants).

**Organizing FFS discussions**

On a weekly basis, each subgroup should be asked to present the results of their observations from the past week in a plenary session. This encourages farmers to discuss various issues and compare their observations with those of other groups. In this context, farmers should be asked to undertake the following:

a. Describe the general plant development for each variety. Do the different varieties develop in the same way? How do the weather conditions influence plant development? What fertilizer and other management practices were applied during the week? How did this affect crop development for each variety?

b. Compare the pest and disease situation with that of the previous week. Are there more insect pests and has disease pressure increased? Is it clear why? Is the development of insect pests and disease the same on all varieties? Are there some varieties that have fewer insects or less disease infestation?

c. Compare growth development and performance of varieties (in the case of PVS) or of individual plants (in the case of PVE). Identify the best performing variety in PVS based on observations and the weekly data gathered, and explain why this variety was selected. In PVE, rouge the weak plants, and select and clearly mark the best performing plants in order to monitor these throughout the entire cropping season.

d. Rank the varieties according to their overall levels of performance.

e. Reflect on the observations of other subgroups: what varieties do they prefer? Are these the same varieties as selected by the reporting subgroup? Why? Are there any other important characteristics that were not included in the observations? Why are these characteristics important to one or more of the other subgroups?
7. ACTIVITIES IN FFS-PPB PLOTS AT REPRODUCTIVE GROWTH STAGE

Most of the selection activity is undertaken during this stage. In the PVE study plot, the final rouging is conducted. In PVS, final observations regarding the relative performance of the stable varieties and lines are undertaken. The AESA is a very important ongoing activity at this stage, as most of the observations are related to selection. Activities related to the special topics included in this field guide are also carried out at this stage (see Annex 11.8 for pearl millet, Annex 11.9 for maize, Annex 11.10 for sorghum and Annex 11.11 for groundnut).

In addition to PVS and PVE, farmers can also undertake PPB (in a narrow sense) by making crosses between two preferred varieties to obtain progeny that better fits the needs of the community. Such crosses may, for example, involve a preferred local variety and a modern variety accessed from the market. PPB in this sense requires large investments in terms of land, time and expertise in the creation of crosses. Some background is provided below regarding this type of PPB.

In plant breeding, hybridization accounts for only 10 percent of the activity, while 90 percent involves selection. Hybridization is a special FFS topic that may be carried out during the reproductive stage of varieties in order to create entirely new genetic variability in crops.

Important Task

In consultation with the breeding institutions, CTDT provides the materials needed for hybridization (i.e. hybridization kits, glycine bags, paper bags, threads, tags), ensuring that they are made available in a timely manner when they are needed. Likewise, CTDT ensures that the technical experts of these institutions schedule regular field visits to the FFS-PPB sites and provide the necessary technical backstopping, particularly in the hybridization and subsequent selection phases.

Special Topics

When the plants enter the reproductive growth stage, a special topic on the Reproductive Systems of Crops should be conducted during the first weekly session (see Annex 10.8 for pearl millet, Annex 10.9 for maize, Annex 10.10 for sorghum and Annex 10.11 for groundnut). A special topic on Hybridization (see Special Topic 10.2 and Annex 10.8 for pearl millet, Annex 10.9 for maize, Annex 10.10 for sorghum and Annex 10.11 for groundnut) and Inheritance of Traits (see Special Topic 10.10) should be carried out during the second weekly session held during this growth stage. Selection of segregating lines (see Selection Techniques in Pearl Millet in Annex 10.8) should be undertaken as the last special
topic in the case of PPB (taken in a narrow sense as performing crosses and selecting the progeny).

**Agro-Ecosystem Analysis (AESA)**

At this growth stage, continue conducting AESA and record on a weekly basis the progress of growth and development of the crop using the *AESA Sheet for Reproductive Stage* (see Table 3). Note in the AESA sheet other characteristics that are found to be important in discussions with farmers. In particular, the following characteristics should be documented:

- *For maize*: plant height, number of leaves, leaf angle, days to tasseling, days to silking, occurrence of pests and diseases.
- *For sorghum and pearl millet*: plant height, number of tillers, days to full bloom, occurrence of pest and diseases.
- *For groundnut*: number of branches, plant height, days to flowering, occurrence of pest and diseases.

**Rouging at the Reproductive Stage**

At this stage, farmers should perform the last rouging operation in the PVE study plot using the set of selection criteria developed for this purpose. In the PVS study plot, the selection criteria developed by the participants for major traits pertaining to this growth stage should be applied as the final basis for selection of the desired variety or varieties. Off-type plants must be removed before flowering.

**Rouging in PVS Study Plots**

As in the vegetative growth stage, no rouging activity should be undertaken in the PVS plots during the reproductive growth stage. Instead, the selection criteria developed by the participants should be used to select the most desired varieties among the PVS entries.

**Rouging in PVE Study Plot**

Rouging should target plants showing inferior characteristics compared to the majority of plants within a plot (e.g. less vigorous plants, tall plants, plants with fewer tillers [pearl millet and sorghum], droopy leaf-type plants, suspected off-types or volunteer crops, and diseased plants).

**FFS Discussions**

Same as during the vegetative growth stage, each subgroup should be asked to present at a weekly plenary session the results of their observations from the past week. This should
encourage farmers to discuss various issues and compare the results of other subgroups with their own observations. The following questions and issues should be addressed:

a. Describe the general condition of the plants. Do the different varieties develop in the same way? Which variety flowered first? Which variety has more tillers? How did the weather conditions influence plant development?

b. Aside from rouging (in PVE only!), what other management practices were applied during the week? How did this affect crop development for each variety?

c. Compare the pest and disease situation to that of the previous week. Are there more infested and diseased plants? How could this happen? Is the insect pest damage or disease infection more severe in its effects on plant health? Why? Is the development of insect pests and disease the same on all varieties? Are there varieties that have fewer insect pests or lesser disease damage?

d. For PVS, compare growth development and performance of varieties. Rank the varieties according to their overall levels of performance. Select the best performing variety based on observations and the weekly data gathered, and explain why this variety was selected.

e. Reflect on the observations of other subgroups: what varieties do they prefer? Are these varieties the same as those selected by the reporting subgroup or different? Why or why not? Does the selection of varieties differ between men and women? Which characteristics are important to men and/or women and why? Are there any other important characteristics that were not included in the observations?

8. ACTIVITIES IN FFS-PPB PLOTS AT MATURITY STAGE

The final evaluation of the tested varieties and lines against the breeding objectives should be undertaken during the maturity stage. Evaluation data for statistical analysis should be gathered at this stage. Plans should be made for the Farmers’ Field Day (see Special Topic 10.11) and regarding the management of seeds from the PVS and PVE study plots. Related special topics should be addressed.

Individual plants with preferred traits (positive selection) should be marked with a coloured tag for later recognition. Plants with undesirable characteristics (negative selection) must be rouged or removed during observations. After harvest, the selected plants can still be further screened on desired characteristics and off-types removed. This is particularly relevant for the PVE studies.
Special Topics

A special topic on Conducting a Farmers’ Field Day (refer to Special Topic 10.11) should be scheduled for discussion in the first weekly session during harvest time. A special topic on Evaluation of Varieties by Farmers (refer to Special Topic 10.12) should be discussed during the second weekly session. During the third and fourth sessions, special topics on Harvesting and Seed Production of High Quality OPV Seed for Pearl Millet and Maize should be addressed.

Important Task

The final gathering of data for statistical analysis should be undertaken at this stage. To this end, CTDT coordinates with the partner breeding institutions in order to schedule visits of their technical staff to the FFS sessions. These visits provide the necessary technical backstopping for the gathering of data for statistical analysis. Such visits also enable the staff of the partner breeding institutions to identify possible breeding materials that could be useful in the next FFS season.

Agro-Ecosystem Analysis (AESA)

Continue conducting AESA during the maturity stage until two weeks before harvest. Record on the AESA Sheet for Maturity Stage (see Table 4) the progress of growth and development of the crop at the time of observation. Note on the AESA sheet other characteristics that have been identified as important during discussions with farmers in the course of the FFS. Some important characteristics to consider are:

- For maize: days to maturity, degree of lodging, number of ears, plant height, length and circumference of ears, occurrence of pests and diseases.

- For sorghum and pearl millet: days to maturity, degree of lodging, number of productive and non-productive tillers, plant height, length and circumference of panicle, panicle exertion, occurrence of pests and diseases.

- For groundnut: days to maturity, number of branches, plant height, number of pods, number of mature and immature seeds per pod, size and colour of seeds, occurrence of pests and diseases.

At the end of the season, ensure that the following final data has been entered into the AESA Sheet for Maturity Stage:

- Grain yield
- Gross margin
- Ranking
These data will ultimately become the most important yardsticks for selecting the best varieties that farmers could add to their current popular variety or use to replace it.

Use the three sets of AESA evaluation sheets (for vegetative stage [Table 2], reproductive stage [Table 3] and maturity stage [Table 4]) to encourage FFS participants to think about the relevance of each of their observations. Prepare an overview of the agreed observations on a flip chart for reference.

Data for Statistical Analysis of PVS Study Plots

Before harvesting, select 30 plants from each plot (i.e. for each variety or line in the PVS studies) for measuring agronomic data as explained above. The breeding institutions (e.g. CBI, ICRISAT and CIMMYT) use these data for statistical analysis.

Harvesting of PVS Study Plots

Each plot containing a different variety or line should be harvested separately, and the seeds should also be dried and weighed separately to determine the yield. At this stage, farmers may wish to test the seeds further using other criteria such as storage behavior, cooking qualities and taste. The harvested seeds should not be used for re-planting because of the high risk of contamination with other grains and deterioration of quality. Instead, seeds of the preferred varieties should be requested from the collaborating breeding institutions.

For Maize, Pearl Millet and Sorghum

Harvest each variety only when 80 percent of the all ears or panicles in a specific plot are physiologically mature. Physiological maturity of the ears or panicles can be determined by the presence of black layers at the base of the kernels or grains. Harvest only the three inner rows of a five-row plot, leaving behind one hill or plant at both ends of each row. Thus, approximately 144 plants per plot should be harvested (48 hills per 9.6m row x 3 rows per plot).

For Groundnut

Harvest each variety separately only when 80 percent of all pods in a specific plot are physiologically mature. Physiological maturity of the pods can be determined by the presence of black layers at the base of the seeds inside the pods. Harvest only the 8 inner rows of a 10-row plot, leaving one hill or plant at both ends of each row. Thus, approximately 304 plants per plot should be harvested (38 hills per 9.5-metre row x 8 rows per plot).
Harvesting of PVE Study Plots

Depending on the type of variety enhancement, different harvesting methods may be applied:

- When using **positive mass selection**, harvest all marked ‘superior’ plants, which may then be dried, labeled, and stored together until the next season. Harvest a total of 10 percent of the seeds of ‘superior’ plants (hills). Mix the ‘superior’ seeds.

  - *For maize*: Prepare around 1,000 ‘superior’ seeds for next-season planting in 1,000 hills (e.g. one seed per hill without thinning) in a plot size of 10m x 50m = 500 sq. m (i.e. 0.9m between rows x 0.2m between hills x 10m rows).

  - *For pearl millet*: Prepare 3,000 ‘superior’ seeds for next-season planting in 1,000 hills (e.g. three seeds per hill to be thinned to one seedling per hill one week after germination) in a plot size of 10m x 50m = 500 sq. m (i.e. 0.9m between rows x 0.2m between hills x 10m rows).

  - *For sorghum*: Prepare 2,000 ‘superior’ seeds for next-season planting in 1,000 hills (e.g. two seeds per hill to be thinned to one seedling per hill one week after seed germination) in a plot size of 10m x 50m = 500 sq. m (i.e. 0.9m between rows x 0.2m between hills x 10m rows).

  - *For groundnut*: Prepare 4,000 ‘superior’ seeds for next-season planting in 4,000 hills (e.g. one seed per hill without thinning) in a plot size of 10m x 50m = 500 sq. m (i.e. 0.5m between rows x 0.25m between hills x 10m rows).

- When applying **modified pedigree selection**, harvest each single marked ‘superior’ plant separately. Seeds of each ‘superior’ plant should then be dried, labeled and stored separately until the next season. Harvest a total of around 1,000 ears or heads for maize, pearl millet and sorghum, or plants for groundnut. Prepare around 56 seed stocks (ears, panicles) from the marked ‘superior’ maize, pearl millet and sorghum plants for ear- or head-to-row planting in the next season. Prepare 300 seed stocks from marked ‘superior’ groundnut plants for plant-to-row planting in the next season. After the completion of seed preparation, unused or remnant seeds should be stored as a reserve and/or for succeeding planting seasons.

  - *For maize*: Prepare around 56 ‘superior’ seed stocks (ears) for next-season planting in 56 rows (i.e. one seed per hill without thinning) in a plot size of 10m x 50m or 500 sq. m (i.e. 0.9 m between rows x 0.2 m between hills x 10m rows) plot.
For pearl millet: Prepare 56 ‘superior’ seed stock (head) pockets for next-season planting in 56 separate rows (i.e. one seed stock pocket per row of three seeds per hill, to be thinned to one seedling per hill one week after germination) in a plot size of 10m x 50m = 500 sq. m (i.e. 0.9m between rows x 0.2m between hills x 10m rows).

For sorghum: Prepare 56 ‘superior’ seed stock (head) pockets for next-season planting in 56 separate rows (i.e. one seed stock pocket per row of two seeds per hill, to be thinned to one seedling per hill one week after germination) in a plot size of 10m x 50m = 500 sq. m (i.e. 0.9m between rows x 0.2m between hills x 10m rows).

For groundnut: Prepare 300 ‘superior’ seed stock (plant) pockets for next-season planting in 300 separate rows (i.e. one seed stock pocket per row of one seed per hill without thinning) in a plot size of 10m x 50m or 500 sq. m (i.e. 0.5m between rows x 0.25m between hills x 10m rows).

Evaluation of Varieties by Farmers

In the final activity, the facilitator should guide the farmers on how to perform an overall evaluation of the varieties and lines included in the FFS-PPB field studies. Three methodologies can be used to evaluate the varieties, namely: (a) visual observations, (b) pair-wise ranking, and (c) score card evaluation. These methods are discussed in Special Topic 10.13. It is important to allow for gender-disaggregated data evaluation.

9. REFLECTIONS, LESSONS LEARNED, AND PLANNING FOR THE NEXT SEASON

This stage involves final reflections on what has been accomplished during the first FFS-PPB season. A review of the lessons learned should be undertaken with project leaders and facilitators to reveal ‘what went well’ in the first season and ‘what needs improvement’ for the next season’s activities. A simple course evaluation may also be undertaken to determine which areas to improve and how to improve them (see Special Topic 10.13). The lessons learned will be the basis for improvement of the following FFS elements:

- Draft field guide;
- Technical and participatory processes;
- Partnership with breeding institutions (i.e. CBI, CIMMYT and ICRISAT) and other partners (i.e. Agritex, local NGOs and government organizations);
- Gender and social inclusion aspects.
The review will also provide a basis for the identification of advanced farmers in different FFS-PPB sites for the purpose of training them as future FFS-PPB facilitators. Special attention may be needed to identify and support women FFS-PPB facilitators in order to enable the FFS to reach out to and address the training needs of both men and women farmers.

A special topic on the evaluation of cooking and eating qualities of tested varieties may also be undertaken if the farmers so desire. The approach for this activity is elaborated under Special Topic 10.9.

Once they have grasped and reviewed all of the above information, the farmers should be ready to develop plans for the next season with guidance from the facilitator. The methodology for this activity is detailed in Special Topic 10.14.
10. SPECIAL TOPICS

10.1 Agro-ecosystem Analysis (AESA) or Genotype x Environment Interaction Analysis (GEAN)

Introduction

AESA stands for a thorough analysis of the agricultural environment, and equally considers aspects of ecology and politics. For the FFS participants, AESA provides a way of considering complex, interlinked factors for proper decision making. Every week during the season, the participants will study the various components of the crop agro-ecosystem. They will study climate developments and weather conditions, plant morphology and agronomy, the incidence of herbivores and natural enemies of herbivores. They will also investigate pests and diseases, and their natural enemies, as well as their interactions in the cropping ecosystem, and they will use this information for their agro-ecosystem analysis and decision making (Callo Jr. et al, 1999).

Many local and modern crop varieties may not survive if left alone in the field. It is only by human interference, through specific farm management practices like fertilization, pest control and continuous selection, that these varieties are maintained and improved. The so-called agro-ecosystem in which this takes place – the result of abiotic, biotic and human interferences – is very important in bringing out the characteristics of the local varieties. Local varieties thrive best in the agro-ecosystems in which they have developed, and are used and reproduced. Droughts, floods, pests, diseases and other hazards all interact with crops and hence with farmers’ crop production.

Varieties respond differently to the environment. For example, modern varieties are usually more responsive to fertilization than local varieties. However, local varieties normally demonstrate better growth under stress conditions such as drought. These responses are known as genotype x environment interactions (G x E interaction). In the FFS-PPB, it is important to determine whether the differences between varieties and advanced breeding lines are only the result of genetic differences or also caused by the interactions between the genotype and the environment.

These observed differences are discussed and elaborated in weekly exercises, all related to agro-ecosystem observations including G x E interactions. These sessions will lead participants through weekly sets of observations, questions, analysis and illustrations, which are designed to improve the observation and decision-making skills of the participants (Smolders and Salazar, 2003).
AESA allows farmers to observe the various interactions between the genotype and the environment. Sometimes, these will be simple observations on such aspects as the rainfall pattern, soil type, agronomic characteristics of the crop, and pest and disease occurrences, among others. Farmers may be less familiar with methods of objective and quantitative observation (for example, on plant morphology, yield, and pest and disease incidences); hence, there is a need to discuss on how these observations can best be made and used. Small exercises on topics critical to the particular plant stage serve to assist farmers in learning the skills of observation, comparison and interpretation.

It is important to tie these weekly exercises to questions that farmers come up with, or link them with points in time coinciding with decisions concerning field management. Group dynamics demand that the exercises are kept flexible. Each week a new topic should be addressed. Facilitators may find some guidelines in reading through the special topic on ‘Agro-ecosystem analysis and G x E interaction’.

**Recording**

Each subgroup in the FFS-PPB should keep a notebook for recording all data from the observations. Variety observations should be taken from a random sample of 10 plants per individual variety plot. Results of the genotype x environment (G x E) observations should be summarized on the agro-ecosystem observation sheets. Examples of ecosystem observation sheets are provided in Tables 2, 3 and 4.

**Objectives**

- To allow farmers better understand the local agro-ecosystem;
- To let farmers identify and analyze relationships in their agro-ecosystem and determine genotype x environment interactions through analysis in the field;
- To allow participants to improve their decision-making skills.

**Materials**

- Always keep a stock of notebooks, papers, tape, marker pens, magnifying glass, scissors, plastic bags and meter sticks.

**Procedure**

The AESA activities should normally start with group field observations for about 30 minutes, followed by a classroom reflection. These activities fit very well with the weekly FFS sessions and can be used as group dynamics exercises. The topics provide major links with further activities in the course of the FFS-PPB, including in-depth learning activities, if and when required. Field observations are recorded on a weekly basis in the AESA sheets.
(see Tables 2, 3 and 4), and thus at various crop stages (e.g. vegetative, reproductive, and maturity).

Ideally, the weekly AESA exercises should facilitate a variety selection process or a crop management decision, e.g. fertilization, pest or disease management. Alternatively, the exercises should reflect on practical questions from the participants.

**Learning Exercises**

*Abiotic factors*

a. If feasible, collect weekly rainfall figures and compile the data graphically. Discuss the crop’s water requirement and the implications of flooding and drought.

b. Observe the plants’ responses if a sudden heat wave occurs, or if rains are delayed and a drought sets in. Explain the importance of water for the crop’s nutrient management and indicate stages in the crop development that are most sensitive to water stress.

c. In case of drought, study the field layout and observe carefully whether there are differences in drought stress between various parts of the field. Carefully check whether these variations influence the comparison between the varieties and breeding lines that are studied in the FFS-PPB.

d. Study the influence of sunlight on photosynthesis and plant growth. Explain the basics of photosynthesis in relation to the plant’s physiology and growth.

e. Study crop morphology by observing varieties with different plant types. Discuss plant types in relation to their effectiveness of light interception.

f. Observe plant competition for nutrients as affected by plant density. On a weekly basis, record plant development as affected by plant density.

**Some Questions for Conceptualization**

a. What influence will the rainfall have on the growth of plants?

b. What effects will unequal distribution of rain and/or irrigation have on plant growth?

c. Why are some varieties more drought resistant? What is so specific about these varieties?

d. What relationship exists between root development and drought susceptibility?

e. How does the condition of the field compare with the previous week? Can you explain what happened since the last meeting?

f. What do you expect will happen next week, considering the weather forecast and the plant growth stage?
g. How important is water in the plant’s nutrient management? In what growth stage is the plant most sensitive to water stress?

h. Are damages on the plants caused by abiotic stress or biotic factors (pests and diseases)?

i. What types of plants are most effective in intercepting light for photosynthesis? Which ones are most effective in environments experiencing water stress? Can you identify varieties with such characteristics? Does this information influence your plant breeding objectives?

**Biotic Factors**

Ask the participants to go into the field, observe and collect as many different types of living organisms in the crop ecosystem as possible, including some for each variety or line being evaluated. Include healthy plants, plants with disease, insects, spiders, rats, snakes, birds and others. Classify the collected organisms by their function in the ecosystem. Explain and discuss the functions and relationships between each organism.

*Insect-plant interaction*

a. Groups should observe and, if possible, collect various insects in the field using an insect net, then bring them to the classroom. Explain to farmers which insects are harmful and which ones are not.

b. Monitor harmful insects by recording their prevalence in the field on a weekly basis, particularly during the most critical period in the plants’ growth. Compile the results graphically and discuss.

c. If necessary, create an insect ‘zoo’ by collecting some of the most harmful insects and placing them in a cage made from a glass bottle or a plastic bag and containing some potted plants or plant parts. Observe if and how the insects damage the plants or plant parts. Make a drawing of each stage in the insects’ development at the time of observation. Explain whether the insects are pests or natural enemies, and discuss the potential crop damage they can cause.

d. Record the damage caused by insects to different varieties by drawing the damaged leaves, pods, inflorescences and seeds. Score each variety and discuss the plant’s reactions. Explain the plant’s physiology, i.e. why some genotypes are resistant or tolerant to pests and others are not.

*Disease-plant interactions*

a. For each variety being evaluated, ask the participants to find and collect a number of plants with symptoms of possible diseases. Explain the differences between damages caused by abiotic factors and biotic factors (i.e. diseases). Monitor harmful crop diseases
on a weekly or bi-weekly basis. Observe and record the progress of the most harmful diseases, and discuss the disease cycle.

b. Record disease resistance levels of different varieties by drawing the damaged leaves, pods, stalks and seeds, wherever applicable. Score and discuss plant reactions. Explain each plant’s physiology of resistance and tolerance, and discuss why some genotypes are more resistant or tolerant to disease than others.

**Natural enemies and predators**

a. Ask a farmer to tell a story about how his crop was damaged and what he did to prevent damage in the next season. Alternatively, facilitators may recount stories about farmers who successfully prevented damage by using natural predators. Discuss how FFS participants could to apply this method in their fields.

b. Observe varieties and identify morphological characteristics that potentially prevent bird damage (e.g. awn length, seed colour, etc.) and rat damage, among others. Prepare drawings of the plant parts with these characteristics.

c. During or after an attack by natural predators, study the field layout and observe carefully the damage done to various parts of the field. Determine whether these disparities might influence the results of variety comparison.

**Some Questions for Conceptualization**

a. Which organisms are at the bottom and which ones at the top of the ecosystem? Which are the main pests and where do they come from?

b. Are there specific pests that farmers should monitor more closely? What sort of damage do these pests do and mainly at what stage of growth?

c. List the various types of pests present in the field. Are they present in all plant groups or do they occur in some varieties only?

d. If a decision is taken to spray against pests, would it affect observations concerning pest resistance? When should spraying take place?

e. How does the population of natural insect enemies compare with that of the previous week? What is the importance of natural enemies? Are birds considered natural enemies or pests? How can farmers make use of this?

f. Are pests and diseases present in all plants, or are they concentrated on certain plants or varieties? Which varieties are preferred by pests?

g. What sort of damage do pests do at this stage? Is there any way that harmful insects present in the field could be prevented from increasing in numbers?

h. Do the surrounding fields influence your field? How? What is the condition of the other fields?

i. How do diseases spread? What is the main disease in your field?
j. Discuss how the different varieties or advanced lines should be examined for diseases based on the symptoms. How should this be recorded?
k. Are some leaves dying? Why? Is this natural? In which variety is this more pronounced or observed? Make drawings of the symptoms.
l. If a decision is taken to spray against diseases, would spraying affect observations concerning disease resistance? When should farmers spray?
m. Is there any disease in the field now? How can spreading of the disease be prevented? Do diseases influence yield qualitatively or quantitatively?

n. Where do birds come from? Are they always present in the locality? Is there any way to prevent birds from doing damage to the field?
o. How can farmers control rodents?
Table 2: Agro-ecosystem analysis (AESA) sheet at vegetative stage

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<tr>
<th>AESA NO.</th>
<th>VARIETY</th>
<th>GROUP</th>
<th>CROP</th>
<th>DATE</th>
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<td>WEATHER CONDITION (Sunny, Cloudy)</td>
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<td>CROP AGE</td>
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<td>SOIL CONDITION (Dry, Moist)</td>
<td>Comments On Crop Condition (If not good)</td>
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<td>Sample No.</td>
<td>Date Planted</td>
<td>Date of Emergence</td>
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<td>Weed Spectrum (Grasses, Sedges, Broadleaves, Annual, Perennial)</td>
<td>Weed Density (Low, Medium, High)</td>
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Source: adapted from FAO (2013)
Table 3: Agro-ecosystem analysis (AESA) sheet at reproductive stage

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<thead>
<tr>
<th>AESA NO.</th>
<th>GROUP</th>
<th>DATE</th>
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<td>VARIETY</td>
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<td>Comments On Crop Condition (If not good)</td>
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<tr>
<th>Sample No.</th>
<th>Plant Height (cm)</th>
<th>No. of Tillers</th>
<th>Disease Name &amp; Intensity (Low, Medium, High)</th>
<th>Pest Name/Number/Intensity</th>
<th>Natural Enemies Name/Number/Intensity</th>
<th>Days to 50% Flowering</th>
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<td>Average</td>
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Weed Spectrum (Grasses, Sedges, Broadleaves, Annual, Perennial) | Weed Density (Low, Medium, High)

Source: adapted from FAO (2013)
Table 4: Agro-ecosystem analysis (AESA) sheet at maturity stage

<table>
<thead>
<tr>
<th>AESA NO.</th>
<th>GROUP</th>
<th>DATE</th>
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<tbody>
<tr>
<td></td>
<td>CROP</td>
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<td></td>
<td>CROP STAGE</td>
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<tr>
<td>WEATHER</td>
<td>CONDITION</td>
<td>(Sunny, Cloudy)</td>
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<tr>
<td></td>
<td>CROP CONDITION</td>
<td>(Poor, Fair, Good)</td>
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<tr>
<td>SOIL CONDITION</td>
<td>(Dry, Moist)</td>
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<tr>
<td>Sample No.</td>
<td>Plant Height (cm)</td>
<td>Days to Physiol. Maturity</td>
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<tr>
<td>Average</td>
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</table>

Source: adapted from FAO (2013)
The results of the variety observations should be summarized in matrices and graphs. There are several methods for comparison of varieties, e.g. the scoring card, pair-wise ranking and index ranking. In this field guide, only pair-wise ranking and the scoring card will be discussed and used. Conduct an exercise on evaluation methods in order to acquaint farmers with these methodologies.

**Discussions**

On a weekly basis, ask each subgroup to present the results of their observations from the past week in the plenary session. This will encourage farmers to discuss various related topics and compare observations of other groups with their own.

**Weekly**

a. Describe the general condition of plant development for each variety. Do the different varieties develop in the same way? How did the weather conditions influence plant development? What fertilizer and other management practices were applied during the week? How did this affect crop development for each variety?

b. Compare the pest and disease situation to that observed the previous week. Are there more insect pests and diseased plants? Why? Is the insect pest damage or disease infection more severe? Why? Is the development of insect pests and disease the same on all varieties? Are there some varieties that have fewer insect pests or little disease infection?

c. Compare growth development and performance of varieties. Select the best performing variety, based on observations and the weekly data gathered, and explain why this variety was selected and at which stage:

- Vegetative stage
- Early flowering stage
- Plant maturity stage

d. Arrange the varieties according to their overall levels of performance.

e. What varieties do other subgroups prefer? Are these the same varieties as selected by the reporting subgroup? Why? Are there any other important characteristics that were not included in the observations? Why are these characteristics important?
At flowering, ripening and harvesting stage of cereals and pulses

a. Is there any difference in the time of flowering between varieties?
b. Is there any difference in the time of maturation between varieties?
c. Do some varieties shatter easily compared to others?
d. What are the characteristics of the pods and panicles?
e. Do you see any difference in grain characteristics?

At the end of the season

a. After comparing the yields, do you see many differences?
b. Are the varieties with the least disease damage best yielding?
c. Do you observe any difference in the cooking qualities and taste of the varieties?
d. Note and discuss specific problems and advantages observed for each tested variety or breeding line. Are there important observations that were missed out during the season’s activities?
e. How can we improve the study for the next season?
f. Prepare a summary table of all the characteristics observed.

10.2 Hybridization (Cross Breeding) in Pearl Millet

Introduction

This exercise should be treated as a special study (i.e. optional activity) in the FFS-PPB sessions. It does not require separate plots; instead, the border rows of the PVS and PVE plots should be used for the exercise. If this is not carried out in the first season, it is strongly suggested to plan and undertake this exercise as a regular activity in the second FFS-PPB season. The exercise will familiarize farmers with the different steps involved in controlled cross breeding of pearl millet.

As a natural cross-pollinating crop, pearl millet varieties readily cross without human intervention. Self-pollination also occurs naturally in pearl millet up to a maximum of 20 percent. Controlled pollination is used to manage both processes and enable parent varieties with preferred qualities to cross.

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In this exercise, farmers will learn to control crosses by making use of the differences in emergence of pistils and anthers within the inflorescence of a pearl millet panicle. Using techniques of cutting and bagging, farmers will be able to introduce preferred characteristics in their populations for further selection.

**Objectives**

- To demonstrate to farmers the procedures and techniques used in cross breeding of pearl millet;
- To let farmers practice the cross pollination technique and manage the pollination processes in pearl millet.

**Materials**

- Pearl millet plants in flowering stage
- Knife, magnifying glass, forceps, tape, glycine bags, marker pens, drawing paper, labels

**Time guide:** 4 hours.

The cross pollination practices may take longer to complete, depending on whether farmers can find suitable male and female flowers of the preferred varieties.

**Procedure**

a. Start the session by asking participants to review the reproductive process of the pearl millet plant and to name the stages and flower parts involved. Ensure that farmers understand the reproduction process. A drawing should assist in the visualization.

b. Go to the field and select a number of pearl millet varieties in the borders of PVS and PVE plots at the early flowering stage. Undertake the activity with subgroups of 5-6 participants.

c. Present the participants with the following scenario: If farmers want to develop new varieties, what qualities would they prefer? Ask the groups what varieties possess these qualities and what varieties would be good to combine to incorporate the preferred characteristics. Request them to identify in the field the two most preferred varieties for making a cross. Present the results to the plenary.

d. Alternatively, if farmers have already developed a crossing scheme, which is highly preferred, recall and discuss this scheme. Note the number of female flowers of each variety that are needed to conduct the crosses.

e. Assign variety plots to each subgroup for the exercise.
f. Ask the subgroups to select in the border rows of PVS and PVE plots a number of suitable flowering panicles that they want to use as females in the cross. Note that the anthers in the top of the flowering spike should be just emerging, but anthers in the middle and bottom part should not yet have emerged. Suitable tillers should be marked with a label.

g. Demonstrate the spike cutting and bagging process. Ask farmers to repeat the exercise using their marked panicles as follows:

- Examine the spike again and ensure that anthers have emerged only in the top part. If emerged anthers are found below the top, there is a risk of contamination and the spike should be rejected.
- Remove about four-fifth of the upper portion of the spike with scissors.
- Cover the remaining lower portion of the spike with a glassine bag and close tightly.

h. Pollination should take place immediately after preparation of the female spikes. The emergence of the stigmas before emergence of the anthers is used to the advantage of cross-pollination. The interval is greatest in the lower-most regions of the spike.

i. Demonstrate the pollination process and ask participants to conduct the same as follows:

- Select suitable spikes in the border rows of PVS or PVE plots of the variety that they want to use as male. Note that anthers in the spike should have emerged fully.
- Remove the spike(s) and collect them in a plastic bag. Attach a label to the bag with the name of the variety.
- Go to the variety plot with the previously prepared female spikes and carefully remove the bag.
- Make sure that the stigmas have appeared.
- Firmly shake the male spike over the exposed stigmas on the female spike.
- Cover the pollinated female spike again with the glassine bag and close it tightly.
- Note the date and parents used in the cross on the glassine bag (the name of the female parent should be on the left side) and the name of the person who made the cross.
- One male spike may be used to pollinate maximum 4-5 female flowers.

j. Check if each subgroup has completed its exercises satisfactorily and summarize the learning topics.

k. After this demonstration and completion of the cross pollination exercises, the farmers may be led to conduct their own crosses. Prepare a cross planning table and further details on the management of the cross breeding field.
1. After seven days, check for the percentage of successfully pollinated spikes. This can be distinguished by the appearance of the white endosperm from the floret. Compute the success rate as follows:

\[
\% \text{ set seed} = \frac{\text{Number of florets with seeds}}{\text{Total number of pollinated florets}} \times 100
\]

Questions

a. Why is it necessary to understand the reproduction process of pearl millet for successful cross breeding? Why do you need to monitor the flowering stages of the parent varieties?

b. Why is it good to prepare a cross table indicating the preferred parent varieties?

c. Can you make controlled crosses without glassine bags? Why is emasculation in pearl millet so difficult?

d. Consider this scenario: two varieties are planted in adjacent rows, while no other varieties are planted nearby. You decide not to apply the demonstrated bagging method, because the plants will cross anyhow. Would you be successful in making the particular cross? What will happen? Why do we still prefer the bagging method?

e. What is the success rate of your crosses?

f. What parts of this exercise did you find difficult? Do you have suggestions for improvements?

10.3 Group Dynamics Exercises

Introduction

Group dynamics represent the interactions between members of a group at any given time, which actively influence the individual, the group and the situation (Ortigas, 1994). Group dynamics reflect interactions that influence the attitude and behaviour of people when they are in a group together. These interactions may be perceived as either threatening or acceptable. In either case, tension can grow within the group and its individual members. The more rigid a person’s position is towards what he or she perceives as threatening, the more tense he or she becomes. Tensions can reach an explosive level. It is at this point that the release of tension is achieved by means of aggressive behavior. A person who responds less rigidly to pressures from his or her environment is less tense and, therefore, more apt to manifest accepting behavior.
The concepts of emotional value and tension play a significant role in the study of group dynamics. To a participant, for instance, group acceptance can be a positive emotional value and group disapproval a negative one. If a group shows characteristics attractive to a participant, the group will elicit an approaching behavior from him or her. If the group behaves threateningly, avoidance behavior may well result on the part of the participant.

Group dynamics exercises are meant to help counter negative attitudes and perceptions resulting from group interactions between participants and facilitators during the learning process. Group dynamics activities are either games, trust exercises or initiatives that are more often used as group exercises by facilitators in the conduct of FFS-PPB sessions. Such group dynamics exercises are included in order to (Philippine National IPM Program, 1993):

- Develop the participants into a closer knit FFS-PPB team;
- Establish a learning climate that is enjoyable as well as fruitful;
- Help participants experience and be able to identify such aspects of teamwork as mutual support, the importance of individual roles to a team’s success, and behaviors that can build or hinder teamwork; and
- Help participants to experience what can be accomplished by working together.

Facilitators for the FFS-PPB project should be trained in these group dynamics activities and make use of those activities that they feel are most appropriate in a given situation. Some examples of group dynamics exercises (Callo Jr. et al., 1999) are provided below.

**Group Dynamics Exercise No. 1: Drawing without Lifting of Pen**

**Purpose**

- To develop cohesion and cooperation among group members.

**Materials**

- Chalkboard and chalks, or newsprint and marker pens

**Procedure**

Divide the group of 25-30 participants into five smaller groups. Give each group five minutes to make a group drawing of a farmer without lifting a pen. Give
each participant one minute to do his/her share in the drawing activity. Then, give the next set of directions. This time, give each group five minutes to plan together on how to come up with an illustration of a farmer where each group member has a part in completing the drawing. Give each group five minutes more to work on their drawings as planned. Evaluate each group’s drawings after five minutes. Ask the following questions:

- How did the first drawing look? How does your drawing look this time? Why was this so?
- How did you come up with your second drawing? What attitudes or behaviors did each member exhibit? Are you happy with the result of your first drawing? Your second drawing?

The purpose of this exercise is to demonstrate that a higher quality of results can be achieved when a group thinks and works together. While each group can work without a clear plan and direction, the result of their work may not be ideal. However, when each group plans cooperatively how the activity should be undertaken and each member is given a specific assignment to perform and guidelines to follow, the result is likely to be much better if not perfect.

When the method is most appropriate

This game is appropriate for a group of 25-30 participants. Use this as a group dynamics exercise, an icebreaker, or a starter for sessions on planning, problem solving, leadership, community organizing or group work.

Group Dynamics Exercise No. 2: Block of Ice

Purpose

- To illustrate how people change when participating in a development process.

Materials

- Chalkboard and chalk, or newsprint and marking pens

Procedure

Draw on the board a block of ice measuring 8 cubic feet or 2' x 2' x 2' (approximately 50cm x 50cm x 50cm). Divide a group of 25-30 participants into five smaller groups and give each group the following instructions:
Imagine that you are given a block of ice with the above-mentioned dimensions.
Alter the shape of the block of ice to one measuring 2' x 1' x 4'.
Plan together how the group should go about it.
List down the steps that the group should follow in altering the shape of the ice block.

When method is most appropriate

This activity is most appropriate when linked with discussions on how people react to various situations in a development process. People participating in any development activity or programme are like a block of ice: to change, they need to be ‘liquefied,’ moved to a new situation and made to stay in that situation of change.

Group Dynamics Exercise No. 3: Nine-Dot Game

Purpose

- To be aware of the concepts, objectives and approaches of the FFS-PPB programme in reference to the problems and issues of farmers in the local community. Compare with past training experiences.

Materials

- Manila paper, tape and pens

Procedure

Draw nine dots on a flip chart, as shown below:

● ● ●
● ● ●
● ● ●

Ask the participants to join all of the nine dots with only four straight lines and without lifting the pen from the paper. Then ask them to share their results. The solution should look something like this:
In this game, farmers have to look outside the square to find the solution. Ask the farmers: Why was it difficult to find a way to do this at first? How did you overcome the problem? Discuss how this experience relates to solving other problems (e.g. very often, before we are able solve a problem, we need to look beyond the things that we think are the problem in order to identify the real causes).

Tell the farmers that the nine dots can represent the nine most important problems of farmers in this community. All of the problems may begin with ‘P.’ Ask them to help you list them. Adapt the identified problems so that they fit into the nine categories beginning with ‘P,’ as shown below:

- Plant genetic resources (loss of diversity)
- Pests (including diseases)
- Poverty (profits are low)
- Pesticides (poisoning)
- Programmes (that are no good)
- Politicians (do not help us)
- Public health
- Pollution
- Provision of water
- Protection of environment

Link each of the nine problems to an explanation of some of the central concepts and approaches of participatory plant breeding. Below are some of the ideas that could be discussed:

- In the FFS-PPB project, we explore ways to solve the problems of loss of diversity of our PGR, pests and diseases, low profits, pesticide resistance and pesticide poisoning. The project is based on what farmers need and want to learn; farmers decide what they will do in the FFS.
- The FFS is based in the farmers’ fields and so looks at the real problems that are happening now. We learn by exploring these problems together as a group. By working together, we can discover how to solve problems that are too big for one person: a group can do much more than one. By becoming a
strong group, we will be able to get more support and attention from the local governments or other organizations that we may want to influence.

- The fields are a part of the local environment and the community, so we also look at the effects our actions have on things that are outside our fields.

The facilitator guides a participatory discussion on how the FFS-PPB project differs from the farmers’ current experiences and ideas of PGR diversity.

When the method is most appropriate

Use the activity as a starter for a session on ‘Concepts, Principles, Objectives and Approaches of the FFS-PPB Project.’ It should assist farmers to compare their past experiences with the FFS-PPB concepts, objectives and approaches in addressing problems and issues in their own fields.

Group Dynamics Exercise No. 4: The Longest Line

Purpose

- To develop sharing and cooperation among participants.

Materials

- Items carried by the participants on their person (e.g. the contents of their pockets, etc.).

Procedure

Divide a group of 25-30 participants into five subgroups. Give the following instructions:

- Within five minutes, make a line out of the items found on the person of each group member.
- After completing the line, stand in a straight line and clap hands three times to announce that the subgroup has completed the task. The group with the longest line of items wins.

When the game ends, analyze the activity. Ask the following questions:

- What happened during the activity?
- How did each group come up with their line?
- What behaviors or attitudes did the group members show?
Explain to the team members that they can achieve successful programme or activity results when they work cooperatively, voluntarily share their efforts, resources, ideas and talents, and actively participate in all stages of the undertaking.

**When the method is most appropriate**

This game is appropriate for a group of 25-30 participants. Use it as a starter for a session on ‘FFS-PPB Planning’ in order to demonstrate to the farmers how to go about group activities and carry out objectives successfully.

**Group Dynamics Exercise No. 5: Battle of Sports**

**Purpose**

- To demonstrate the value of planning and coordination as part of successful teamwork.

**Procedure**

Divide the group of 25-30 participants into five subgroups. Assign a different sport activity or action to each subgroup, for example:

- BASKETBALL, SHOOT
- BASEBALL, BAT
- VOLLEYBALL, TOSS
- FOOTBALL, KICK

Point to any group to start the game. The group should say its assigned sport and its corresponding action thrice, before calling out the sport and the corresponding action of the group it has chosen to respond. The selected group should say its sport and its corresponding action thrice, before calling out the sport and the corresponding action of another group.

For example, the basketball group may say, ‘BASKETBALL SHOOT, BASKETBALL SHOOT, BASKETBALL SHOOT TO FOOTBALL KICK.’ The football group should answer, ‘FOOTBALL KICK, FOOTBALL KICK, FOOTBALL KICK TO VOLLEYBALL TOSS,’ and so on.

Eliminate any group that makes a mistake in calling out or doing the actions of the sport assigned to it. The group that is not eliminated automatically wins. Ask
the winning group why they think they won over the rest (expect different answers). Ask the following questions:

- Why did your group not make any mistakes?
- How did you choose which group you were going to call out next?
- Did you have a leader?
- Did you make a plan?

Accepting all answers will encourage participants to share in the discussion as well as give them the feeling of respect. Emphasize the value of planning and coordination for successful teamwork.

**When the method is most appropriate**

Use this as an initiating exercise in the morning or before the start of the afternoon sessions. However, use it at any time of the day when the group experiences a dip in its energy level and needs a perk-up exercise.

### 10.4 Planning Meeting for the First Season

**Introduction**

Prior to the planting season, facilitators should organize a session with farmers and community leaders to launch the FFS-PPB activities. This pre-season session will allow farmers to anticipate the learning topics and develop mutual expectations. It will also allow the facilitators to make some critical decisions regarding field studies, prospective participants, required training materials and responsibilities. The pre-season activities should build enthusiasm and commitment from prospective participants and the community.

**Objectives**

The pre-season session aims to achieve the following objectives:

- To help farmers understand what FFS-PPB is all about and establish mutual expectations with the community regarding the FFS-PPB training programme;

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• To identify prospective participants among the farmers and field study plots for season-long FFS-PPB activities;
• To conduct an assessment of available PGR;
• To organize small groups, ensure gender and social inclusion, prepare training materials and draft a work plan for the planting season.

**Timing of the pre-season session**

In the course of pre-season planning and commencement of groundwork activities, facilitators should establish protocols with village officials and community leaders. It may be useful to allow for a short time gap between the PGR assessment and the identification of prospective participants. This allows farmers to share findings of the PGR assessment with others in their community and thus generate enthusiasm among a larger group of farmers, especially those who were not present during the assessment. This also gives the facilitators enough time to compile the PGR assessment data, prepare training materials and decide whether the data provide sufficient basis for successful FFS-PPB implementation.

### 10.5 Start-Up Session

**Introduction**

A multi-season FFS-PPB training requires a fair degree of commitment. Frequent fluctuation of participants’ attendance in the weekly small-group activities jeopardizes the continuation and success of the programme. However, it may be difficult to expect farmers to commit themselves to a prolonged multiple-season undertaking. Thus, a commitment for one season is the minimum that farmers should probably pledge and the least that one should expect from them at this early stage. Women may face hindrances to their participation due to inter-related reasons, such as prejudices that do not recognize women as farmers, household responsibilities conflicting with the FFS timing, constrained mobility to participate in training at more distant locations, and the lack of self-confidence to participate in the FFS. It is therefore important to jointly understand hindrances to women’s participation and collectively seek solutions to address these.

**Objectives**

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7 Smolders, H. and R. Salazar. (2003). Facilitator’s Guide for On-Farm Conservation and Development of Plant Genetic Resources in Pearl Millet and Cowpea, With Special Reference to Conditions in Sub-Saharan Africa (Mali). U.N. Food and Agriculture Organization and Centre for Genetic Resources, the Netherlands, Wageningen University and Research Centre
To ensure enthusiasm and commitment from the participants
To inform farmers about the training programme and the timeline of activities
To discuss with the farmers their investment in terms of time and effort, and implications and expectations of their participation in the FFS
To understand and address hindrances to women’s participation

Procedure

Pre-selection

Village leaders should be asked to organize a community meeting. During this meeting, the findings of the baseline survey should be discussed and the community should be informed of the criteria for the selection of participants. It should be clarified that selection does not mean that other interested farmers are not welcome to join the activities. There will be a Farmers’ Field Day at the end of the season, where the selected participants will report to the whole community on the progress of their study. In addition, all farmers should be welcomed to visit the field studies at any time and discuss with the participants the nature and objectives of the FFS. Farmer participants should be selected using the following criteria:

- Farmers with a keen interest in the activity, preferably those with known experience in plant selection and on-farm crop experimentation;
- Full-time farmers, rather than seasonal farm workers, or government workers or employees;
- Farmers who have farmland in the immediate village neighborhood and who are or have been recently engaged in the cultivation of maize, pearl millet, sorghum and groundnut;
- Farmers in good health, between 18 and 60 years old, preferably with some basic schooling;
- Farmers who are committed to attend the full duration of the season-long training and follow up activities.
- Farmers who attended an FFS training on another topic (e.g. integrated pest management [IPM]);
- More or less equal participation of women and men farmers.

Setting Expectations

As some farmers are new to the concept, introduce the participants to the objectives and basic operations of the FFS-PPB curriculum. Discuss the
timeframe for the season’s activities and raise expectations regarding the curriculum, objectives and outputs. It should be explained that expectations are mutual: a facilitator offers his/her skills in PPB to the participants, but in return expects the latter to know why they attend the training and must be committed to it. Discuss mutual expectations.

A facilitator is expected to:

- Facilitate mutual expectations;
- Motivate participants to ensure commitment and re-establish it whenever they start losing interest in an activity or not take an activity seriously;
- Provide participants with a goal (daily, weekly, season-wise) which can help them to think ahead during the learning activities and inspire them to meet the demands of the programme;
- Address hindrances to women’s participation;
- Provide participants with a basis for evaluation of their activities and the results of the FFS.

A participant is expected to:

- Know why she/he is participating in the activity;
- Know what is expected from him/her;
- Understand the nature of participation required to achieve the goals of the training;
- Jointly commit to promote effective women’s participation;
- Provide the facilitator with a basis for evaluation of the results of the FFS.

Document the objectives of the training and the mutual expectations. Give each participant a copy of this document and also reproduce it on a flip chart for display in the room. Explain that this is the ‘Learning Agreement.’ If participants have questions about the methods or goals at any time during the training, the expectations can be recalled. At the same time, the facilitator may remind the participants about the expectation regarding their commitment to the training. Reconfirm the expectations on a weekly basis to strengthen the group’s involvement in the topics.

**Final preparations**

Qualified participants should be asked to record their name, age and gender, and details concerning their farming experience, family household and educational
background. Subsequently, decide with the farmers which site is most suitable for the field studies. Discuss the criteria for site selection.

10.6 Designing Farmer Field School Studies

Introduction

This exercise will allow participants to learn about and get familiar with the various components of the breeding and selection cycle. It will enable them to understand the underlying importance of variability for plant breeding and selection.

Farmers are always seeking to improve the qualities of their field crops. While they may appear to hold on to their traditional varieties, they keep on improving these varieties using indigenous knowledge and traditional selection techniques. Given the opportunity, farmers are very likely to regularly introduce and test new varieties from neighbouring communities, national breeding programmes or markets. In the process, genes may be passed on to traditional varieties through natural out-crossing, so that these become part of the existing farmers’ cultivars. Even in self-pollinating crops, a certain level of outcrossing and variability always occurs.

Farmers may learn from their trained facilitators to better monitor and control the existing variability, and to introduce new variability through variety selection, variety enhancement, cross breeding and line selection. Initially, better selection methods may be established and applied to enhance existing varieties and for the purpose of variety selection. These breeding methodologies are part of the ‘breeding processes,’ which are repeated every season with the aim to improve crop varieties according to the breeding objectives.

PPB is a collaboration between farmers and scientists to co-define and execute a joint breeding and selection agenda. The PPB strategy aims to improve local cultivars and varieties by enhancing local variability, relying on traditional and improved farmers’ selection techniques, and allowing farmers to compare and select between local and newly introduced varieties and breeding lines. At the same time, techniques and practices of modern breeding are shared with farmers, thus strengthening the latter’s ability to control and direct the development of the local plant genetic resources system.

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8Smolders, H. and R. Salazar. (2003). Facilitator’s Guide for On-Farm Conservation and Development of Plant Genetic Resources in Pearl Millet and Cowpea, With Special Reference to Conditions in Sub-Saharan Africa (Mali). U.N. Food and Agriculture Organization and Centre for Genetic Resources, the Netherlands, Wageningen University and Research Centre
Objectives

- To enable men and women farmers to identify their own sources of existing and new varieties and variability.
- To make farmers familiar with various methods that can be applied in the farmer-led breeding process.

Materials

- Tape, marker pens, paper, flip-over chart

Time Guide: 1 ½ hour

Procedure

a. Organize farmers into small groups and ask whether they have acquired seed of new varieties during the last three years. List the names of the new varieties in Table 5 (see below). Discuss new varieties of maize, pearl millet, sorghum and cowpea in sequence or in separate groups.

b. Request farmers to indicate where they obtained the seed and whether they have retained the variety for production or rejected it. Is access different for men and women? How? Specify as much as possible.

c. Each group should present their findings in the plenary. Discuss findings.

d. Ask the participants what measures can be taken to further increase variability in their crops and, if appropriate, discuss differences in access for men and women.

e. Explain the various components of the breeding process: variety evaluation and selection, variety enhancement, cross breeding, and line selection. Explain the role of each component in the breeding process, what it does and the way it contributes to variability and creates opportunities for selection. Refer to Figure 4 for a diagram of the farmer-led breeding processes.

Table 5: Farmers’ sources of new variability

<table>
<thead>
<tr>
<th>NO.</th>
<th>VARIETY</th>
<th>YEAR TESTED</th>
<th>WHERE OBTAINED</th>
<th>SELECTED OR REJECTED?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
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</tbody>
</table>

Source: Adapted from Smolders and Caballeda (2006)
f. Remind participants about the previous exercises aimed to identify the positive and negative traits of their local varieties and the breeding targets. Focus on the fact that to start up a breeding and selection process, the selection of a portfolio of starting materials should be part of the planning process.

g. Explain that the components in the breeding process will be further studied in the course of the FFF-PPB through field studies and exercises. However, for the first season, it is suggested to set up PVS (Study 1) and PVE (Study 2) for weekly observations, and to set up Cross Breeding (Study 3) and Line Selection (Study 4) only in the second season or depending upon participants’ priorities and the availability of segregating materials from breeding institutions.

h. Verify whether the participants understand the breeding process by asking in which components they have already been engaged and which components are totally new to them.

i. Based on the above discussions, design with farmers the field studies that they wish to carry out in the coming season.

Notes

a. Recall the option of selecting off-types from variety populations and multiplying these to obtain a new variety. Farmers practice this a lot, but often fail to mention it during discussions. Remind them that it is an important exercise in plant breeding, which they regularly undertake spontaneously. The same goes for selecting mutants from plant populations: some are positive mutations which the farmers wish to maintain to establish a new variety.
b. This exercise is meant as an introduction to the field studies. It is essential to conduct this exercise during the planning session, as it allows farmers to understand the implications of the various field studies and decide which field studies are most relevant for them and should be included in the FFF-PPB sessions.

Questions for discussion

a. What is variability? How will the use of variability contribute to crop and variety improvement?
b. What measures can be taken to increase variability?
c. What is the difference between natural (spontaneous) crossing and artificial (deliberate) crossing?
d. What are the basic differences in the breeding processes for maize, pearl millet, sorghum and groundnut?
e. What methods described in the breeding process are already familiar to the participants? What methods are entirely new to the participants?
f. What method described in the breeding process would participants like to know more about? Disaggregate by gender.
g. Considering the crops and varieties grown in the community, what field studies would participants prefer to conduct in the coming season? Disaggregate by gender.

10.7 Gender Equality in Seed Diversity Conservation, Development and Management

Session Guide

This session examines the respective roles and contributions of women and men in agriculture, particularly in the conservation, development and management of on-farm seed diversity. It analyses some prevailing practices and their underlying assumptions bearing on equity and sustainable seed management. It offers a perspective through which values and attitudes may be affirmed or modified, and practices changed. The session could best be performed during seed maturation and crop harvesting growth stages. Whereas gender forms a major basis for unequal positions and different roles in the community, other variables might result in similar inequalities, including age, marital status and income. A gender analysis might also extend to such functions.
Objectives

At the end of the session, participants should be able to:
- Raise awareness of perceived and prescribed roles of women and men and analyse the values underlying those roles;
- Discuss gender equity as an imperative to sustainable seed management;
- Examine one’s personal perspective on gender equity;
- Discuss lessons and action plans to support women’s agenda and their participation in the FFS.

Learning aids and materials

- Papers
- Marking pens
- Cards
- Visual aids for presentation (PowerPoint or flip charts or other appropriate materials)

Duration: 4 hours

Procedure

Activity 1: Sharing personal experience as a man/woman (30 minutes); exchange of short stories

- Divide the participants into 2 or 3 groups (around 10 participants per group).
- Ask the individual participants to reflect on their own individual experiences, in particular on any incident that made each participant realize that she/he is a man or a woman.
- Facilitate the sharing of experiences within the group. Be respectful of the fact that not everyone may be open to sharing personal reflections.
- Ask volunteers to share one experience per subgroup in the plenary, ensuring that men and women are represented.
- In the plenary, let the selected participants share their experiences and lead a discussion by asking the following questions:
  - What made him/her feel that she/he is a woman/man?
  - Why did she/he feel that way?
- Moderate discussions to highlight the economic, social and cultural attributes and opportunities associated with being a woman or a man.
- Lead the discussion on basic gender concepts (see 10.7.1).
**Note:** The experiences will reveal some of the **socially constructed ways** of being women and men.

**Activity 2: Old and new stereotypes (30 minutes)**

- Distribute cards with gender-related proverbs (see 10.7.2) to the participants.
- Ask the participants to read their cards; then ask if they know of other similar proverbs.
- Discuss with the participants the implications of such proverbs on men and women, their roles and behaviour.
- Ask the participants to relate the proverbs to the experiences shared earlier among them.

**Note:** Lead the discussion on common stereotypes of men and women farmers, and on what the experiences and proverbs say about how norms, rules, practices and social expectations are different for men and women. Explain how these form an unconscious part of our perceptions, which in turn influence our behaviour (see 10.7.2 for some important points to highlight in the discussion).

**Activity 3: Gender-specific activity clock and calendar (1 hour)**

- Divide the participants into two groups: one group of all men and one group of all women. If time is limited, each group can further divide into two so that they can do the activity clock and the activity calendar simultaneously.
- Ask the subgroups to prepare the activity clock (see 10.7.3) and activity calendar (see 10.7.4).
- Ask each group to present their individual outputs in the plenary.
- Lead the discussion by asking the following questions:
  - What major differences do you notice in the way men and women farmers spend their day and year?
  - How are tasks and responsibilities (both in the household and in the farm) divided between male and female household members?
  - What are the implications of these differences for the farm and the family?
  - What are some of the consequences of these differences to men/women?
  - What are some of the consequences of these differences to society?
Activity 4: Access and control (1 hour)

- Divide the participants into two groups (one group of men and one group of women).
- Ask each group to fill in the Access and Control Profile (see Table 5).
- Ask each group to present their outputs in the plenary.
- Discuss the information generated from this activity in relation to:

Access and control over resources

- Who owns the agricultural resources, i.e. land, farm equipment, etc.?
- Who has better access to cash?
- Who has better access to land, seeds and other inputs?

Note: Where women cannot own land, their chances of getting credit are nil. Without credit, whatever capital there is may not be augmented. Similarly, the hiring of labour and acquisition of tools and equipment are severely limited.

- Does the national or local culture support girls and boys going to school? If there are schools, are they situated close enough to settlements so as not to endanger girls on their way to and from school?
- Are extension services available? If they are, do they include women officers? Are extension workers approaching women too? How does the community respond to this? Are training programmes designed with women farmers in mind? Are they offered in venues and at times accessible to women?

Note: Training programmes fail when the above concerns are overlooked. Note in particular that the capability to harness material resources, assuming they are available, is greatly enhanced through education and training.

Decision-making in the farmers’ family

- How are decisions in the farmers’ family made?
- Who has a say on what crops/varieties to plant, where to source the seeds and what to do with other assets (e.g. fertilizers)?
- Who decides on the use of proceeds from the sale of farm produce?

Note: Participation in all aspects and levels of activity (more importantly, decision making) in the household and in the community by all members ensures equity. It guarantees that labour is shared according to each one’s
capability, and that resources are allocated according to each one’s needs. Likewise, it ensures that education and training are availed of equitably and that decision making is a co-responsibility.

- When the who, the what, and the how questions have been answered, lead the discussion on to the critique level by asking why for every major practice. Give particular attention to stereotypical comments, such as: "The women do not know which varieties are good and where to source the seeds," or "It’s insulting to men when women speak up in mixed company."

- Summarize the comments and present to the group for validation.

**Activity 5: Synthesis**

- Distribute three colours of cards. **Yellow** represents conditions that can be changed but would take time: consultation and consensus with community needed. **Green** represents conditions that can be changed by the individual himself/herself. It can be implemented in the individual’s own household. **Red** represents conditions that cannot or should not change according to the farmers’ views.

- Ask each participant to write down an item on a card of the appropriate colour and post it on the designated board or wall. Place the green, yellow and red cards in separate columns.

- Determine whether there are common items under the green and yellow cards. Elicit opinions and insights on the why of each item. Reaffirm the green entries and give a strong signal that the yellow entries depend on the position of each individual.

- Document and present inputs on potential positive changes using a PowerPoint presentation or other visual medium (see 6. Social Inclusion for some important points to highlight).

**Activity 6: Lessons and actions to support women’s participation in FFS**

- Divide the groups into men and women.
- Ask each group what they have learned about gender roles in the sessions:
  - Why is it important to be aware of gender and social inclusion?
  - What is the role of women in farming and seed management?
  - What are the obstacles to women’s participation in the FFS?
  - What would women do differently in the FFS?
**Plenary Discussions and Synthesis**

- Ask each group to report and facilitate common reflections.
- Search for a consensus on how to support women’s participation in the FFS.
- Ask the plenary do develop an action plan.
- Ask how and when they plan to monitor and assess action plans.

**10.7.1 Basic Concepts on Gender**

**Key definitions**

*Gender* - refers to the economic, social and cultural attributes and opportunities associated with being women or men. It describes the *socially constructed ways* of being women and men, rather than the biological differences. It changes according to culture, class, time and place.

*Gender Relations* - refers to *relations of power* between women and men which are revealed in ideas and behaviour, differences in roles, the division of labour, access to and control over resources, and in ascribing different expectations, abilities, desires and aspirations to women and men.

*Gender and Social Inclusion Analysis* - Identifies the differences between women and men of different ethnicities regarding their:

- Specific roles and activities;
- Access to and control over resources;
- Access to benefits and role in decision making;
- Social practices which cause discrimination and violence against women.

**Why focus on women?**

- Men’s roles, responsibilities and contributions are often recognized by the community and the authorities.
- Policies, institutions and societal structures are supportive towards the roles of men.
- At the same time, women often remain systematically excluded.
- For women’s empowerment, existing power relations caused by gender differences need to be transformed.
- For inclusion, existing multiple exclusions need to be identified, addressed and corrected.

**Gender and Ethnic Equality**
To strive for gender and ethnic equality does not mean to ignore the biological differences between the two sexes, nor to ignore the differences between what it means to be a man and what it means to be a woman, or what it means to belong to an ethnic minority.

The process of achieving gender and ethnic equality - while respecting these differences -- refers to changing norms, values, attitudes and perceptions in order to attain equal status between men and women, as well as between advantaged and excluded social groups.

Gender and Ethnic Equity

This refers to fairness in women's and men's roles and positions, or in those of advantaged and disadvantaged social/ethnic groups. In particular, it refers to fairness in access to socio-economic resources. Discrimination results from inequitable access to socio-economic resources due to being a man or being a woman, or being a member of an advantaged group or ethnic minority.

Empowerment

Empowerment is the enhancement of assets and capabilities of diverse individuals and groups to function and to engage, influence and hold accountable the institutions that affect them (World Bank definition).

Two Dimensions of Empowerment:

Livelihood Empowerment (access to assets and services) leads to:

- An increase in access by women, or the poor and excluded, to assets and services that are needed to sustain at least a minimum level of livelihood security;
- The creation of systems and mechanisms for upward mobility of women, the poor and excluded.

Note: Assets may be natural, physical, financial, social and human. Livelihood empowerment can be initiated by outsiders (government, donors, NGOs, etc.).

Mobilization empowerment (voice, influence and advocacy) results in an enhanced:

- Ability of women, the poor and excluded to engage in a debate with, influence and hold accountable the institution that affects them;
• Understanding of the systemic causes of poverty and social exclusion involving women, the poor and excluded;
• Capacity of women, the poor and excluded to aspire and act on their aspirations, and overcome the sense of powerlessness.

What is social exclusion?

Social exclusion occurs when formal laws and government policies and/or informal social practices, values and beliefs:

• Result in the conscious or unconscious ignorance and disregard of the interests of groups of people, in particular women or ethnic minorities, or groups belonging to a certain class or age;
• Prevent members of certain social groups from getting equal access to:
  o Economic assets and opportunities;
  o Public goods, services and rights;
  o Political voice and influence.

10.7.2 Gender-related proverbs and stereotypes

“Sons are sticks for old age”

“Bringing up a daughter is like manuring and watering a plant for someone else’s courtyard”

“One unmarried girl must obey her father, a married woman her husband, and a widow her children”

Old and new stereotypes of men and women farmers

• Men cultivate cash crops, while women cultivate food crops in small plots only for family subsistence.
• Women can best be reached by agricultural services and resources (e.g. extension, training, credit) indirectly through their husbands.
• Women are overburdened with work and therefore cannot participate effectively in development activities.
• Women farmers are generally poor and can only manage subsistence farming.

What do the proverbs and our experiences say?
• Rules, practices, the division of labour, social expectations, and vulnerability and mobility conditions are different for women and men as a result of religious and cultural traditions, societal values and beliefs.
• These ideas have been in existence for many years in communities and societies. As a result, they form an unconscious part of our perceptions, which in turn influence our behavior.
• These ideas become part of our lives so much that even if we are doing gender work, we unconsciously remain influenced by these perceptions and beliefs.

Table 6: Basic gender analysis questions

|------------------------|------|--------|-------|---------------------|

10.7.3 Guide on preparing the Activity Clock

Draw two large circles on two separate papers and slice both circles (one representing morning and the other representing afternoon) into portions to show the amount of time spent doing a particular activity in a typical 24-hour period by a typical woman/man farmer.

**Figure 5: Sample activity clocks**

<table>
<thead>
<tr>
<th>Morning Activities</th>
<th>Afternoon Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cook</td>
<td>Feed family &amp; wash</td>
</tr>
<tr>
<td>Collect fuel</td>
<td>Rest</td>
</tr>
<tr>
<td>Wake up; cook</td>
<td>Weeding</td>
</tr>
<tr>
<td>Feed family &amp; animals</td>
<td>Feed animals</td>
</tr>
</tbody>
</table>

10.7.4 Guide on preparing the Activity Calendar

- Prepare a matrix (see sample in Table 7a below).
- Ask the participants to identify all the activities/tasks that they do on-farm, off-farm and within the household.
- Give some examples if needed.
### Table 7a: Sample Gender-Specific Activity Calendar

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<th>M</th>
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<th>N</th>
<th>D</th>
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<tbody>
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<td><strong>CROPS</strong></td>
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<td>Ploughing</td>
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<tr>
<td>Planting</td>
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<tr>
<td>Seed Selection</td>
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<tr>
<td><strong>ANIMALS</strong></td>
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<td>Herding</td>
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<td>Watering</td>
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<td>Milking</td>
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<td><strong>HOUSEWORK</strong></td>
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<td>Cooking</td>
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<tr>
<td>Collecting Firewood</td>
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<td>Feeding the Baby</td>
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<tr>
<td><strong>OFF-FARM</strong></td>
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<tr>
<td>Selling Crops</td>
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<td>Other Activities</td>
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10.7.5 Access and Control Profile

Table 7b: Access and Control Profile

<table>
<thead>
<tr>
<th>Resources</th>
<th>Access</th>
<th>Control</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Women</td>
<td>Men</td>
</tr>
<tr>
<td>Land</td>
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<td></td>
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<tr>
<td>Seeds</td>
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<tr>
<td>Labour</td>
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<tr>
<td>Cash</td>
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<tr>
<td>Other</td>
<td></td>
<td></td>
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<tr>
<td>Benefits</td>
<td></td>
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<tr>
<td>Outside income</td>
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<tr>
<td>Asset ownership (e.g. land)</td>
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<tr>
<td>Basic needs (e.g. nutritional diet)</td>
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<td></td>
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<tr>
<td>Education</td>
<td></td>
<td></td>
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<tr>
<td>Political power (community decision-making)</td>
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<tr>
<td>Other</td>
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</tbody>
</table>

Source: IIRR, ETC (2002)

10.7.6 Social Inclusion (Rules of the Game)

Development of action plans contributes to:

- Removal of institutional barriers in order to increase the access of women, the poor and the excluded to development opportunities.
- Changes in informal practices and behavior, as well as in formal law and policy, in favour of women and the poor and excluded.
- Structural changes in opportunities within which women and the poor and excluded effectively seek to exercise their advocacy capacities.

What are the domains of change that we can support?

- Improving access to assets and services for women, the poor and excluded farmers
- Increasing their voice and influence
- Supporting changes in the “rules of the game” that have traditionally favored the elite/advantaged
10.8 Developing the Work Plan

Introduction

In the first FFS-PPB season, farmers should decide on the key study activities and responsibilities for the coming planting season. PPB activities usually span several seasons. It is suggested that the farmers make plans only for the next immediate season. Farmers must be reminded, however, not to lose sight of their long-term objectives.

Objectives

- To decide on the crops, varieties and type of field studies for the first season;

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9Smolders, H.and R. Salazar. (2003). Facilitator’s Guide for On-Farm Conservation and Development of Plant Genetic Resources in Pearl Millet and Cowpea, With Special Reference to Conditions in Sub-Saharan Africa (Mali). U.N. Food and Agriculture Organization and Centre for Genetic Resources, the Netherlands, Wageningen University and Research Centre
• To consider the number, source, and type of varieties, and advanced lines and populations to be planted and used for PVS, PVE and, possibly, cross pollination and line selection;
• To draft a work plan for the coming season, ensuring that the plan includes women’s interests and objectives.

Materials

• Tape, small pieces of paper, marker pens, paper

Time Guide: 2 hours

Procedure

Farmers’ Field Studies

a. Briefly review the components of the breeding process and the proposed field studies with the participants. For the first season, farmers may opt to work only on PVS and PVE, and to work on hybridization only to a limited extent, if at all. However, for the second season, they may try to work on all components of the plant breeding cycle.
b. Explain to participants the implications and time requirements of the field studies involved and the need to limit the number of studies for the first FFS-PPB season in order to set realistic goals.
c. Discuss crops and varieties involved: maize, pearl millet, sorghum and groundnut. Elaborate on the options for PVS, PVE and, possibly, hybridization and progeny selection. Note that for the first season, the selection of varieties will depend on the availability of varieties, cultivars and advanced lines from sympathetic breeders and farmers.
d. Make a final decision on the type of field studies to be included in the coming cropping season.

Varieties for Field Studies

a. Ask the farmers to split up into small groups. Review the breeding objectives established during the PGR baseline assessment.
b. Discuss the number of new varieties, local cultivars and breeding lines that are needed for each field study. Ask the farmer groups to determine what varieties they would like to include in the field studies.
c. Small groups will present their findings. Note the possibility to obtain additional varieties from breeding institutions. Discuss the findings in the plenary and seek consensus.
Organization and Responsibilities

a. Divide the farmers again into small groups and ask them to plan the activities that they intend to carry out during the next two seasons (e.g. PVS, PVE, hybridization, progeny selection) and decide on the priorities for the first immediate season.
b. Ask them to write down the activities on a flip chart using the format shown in Table 8.

c. Ask each group to present their work plan.
d. Ask participants what preparations are needed for the implementation of the activities.
e. Finally discuss how the group members will be tasked to undertake weekly observations and data gathering for each activity.

Questions (please be consciously sensitive to women’s participation and needs)

a. What field study will demand most of your time and work?
b. Do participants have sufficient land to conduct the selected field studies?
c. What is better: to do a lot of activities superficially or to do a few activities well?
d. Do you think you have all the necessary materials to conduct the field studies?
e. Considering the plant breeding objectives, what kind of varieties, cultivars and advanced lines would be best to include in the FFS? Are women’s needs and preferences addressed?
f. If participants will perform hybridization, what varieties have favorable characteristics that they wish to cross with their own varieties?
g. What kinds of activities should be undertaken between this planning session and planting time?
h. Are there activities that may not be amenable to women’s participation? How can these hindrances be overcome?
i. Who is responsible to supervise the activities?

Table 8: Format for planning FFS-PPB activities for the coming two seasons

<table>
<thead>
<tr>
<th>NO.</th>
<th>MAIN ACTIVITY</th>
<th>TIMING &amp; DURATION</th>
<th>RESPONSIBLE PEOPLE</th>
<th>EQUIPMENT NEEDED</th>
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<tbody>
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</table>
10.9 **Cooking and Eating Quality Evaluation**

**Introduction**

To farmers, the characteristics of grain, like shape, colour, processing qualities, texture and taste, are as important as the absolute yield. A grain is almost worthless if it does not have the right properties for the type of foods the family eats. This is particularly so in semi-arid regions of Africa, where most villagers are subsistence farmers. After harvesting their maize, pearl millet, sorghum or groundnut crop, farmers deliver it to their home-yard, where women grind the grain or boil it for use in one of their favourite dishes.

It is therefore very important to evaluate the processing, cooking and eating qualities of the varieties and selected lines. Only stable varieties and advanced segregating lines available in surplus quantities should be evaluated. The early generations of segregating lines are not stable enough, as they continue to change in character.

**Objectives**

- To let farmers (and invited guests) evaluate grain characteristics and processing, cooking and eating qualities of varieties and advanced selection lines
- To evaluate and understand the farmers’ gastronomical preferences

**Materials**

- Kitchen, several grinding and cooking tools, plates
- Tags, paper, markers
- A panel of evaluators (including other villagers who are not participants of the FFS)

**Time guide:** 5 hours per crop

This exercise can be part of a workshop celebrating the end of the season’s training sessions. The evaluation of dishes may be followed by a presentation of

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10 Adapted from Smolders, H. and R. Salazar. (2003). Facilitator’s Guide for On-Farm Conservation and Development of Plant Genetic Resources in Pearl Millet and Cowpea, With Special Reference to Conditions in Sub-Saharan Africa (Mali). U.N. Food and Agriculture Organization and Centre for Genetic Resources, the Netherlands, Wageningen University and Research Centre
the overall results and the final evaluation. Conduct the evaluation of dishes made of maize, pearl millet, sorghum and groundnut separately.

**Procedure**

a. Split up the participants into one group of men and one group of women.
b. The first activity is to design the evaluation form. Ask the participants how they prepare their maize, pearl millet, sorghum and groundnut dishes, and what characteristics they prefer in the preparation and taste of their food. What is a good grain to them?
c. Ask the groups to list the criteria by which each of the food dishes mentioned is evaluated. Rank the criteria in order of importance.
d. Groups should present their list of criteria in the plenary session. Discuss the differences between the preferences of women and men.
e. Agree on the dishes that should be prepared, the criteria that should be measured, and the measuring scale. On a scale of 1 to 5, use ‘5’ to indicate the most preferred and ‘1’ to indicate the least preferred. For computational reasons, do not use ‘0.’
f. Prepare the evaluation form for each dish (**Table 9** offers an example).

**Table 9: Evaluation form for cooking and eating qualities of crop varieties**

<p>| CROP: ________________________________________ | DISH: ________________________________________ | DATE OF EVALUATION: ________________________ |</p>
<table>
<thead>
<tr>
<th>VARIETY</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Aroma</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Cooking ability</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Starch content*</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>4. Taste</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Colour, others</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Starch content may be important to farmers because it determines how long the food stays in the stomach. Farmers may prefer food that stays longer in the stomach so that they do not experience hunger too often.

a. For each variety, prepare the dish that the farmers want to evaluate. Note that all dishes should be prepared under the same conditions in terms of heat, water content, etc. Do not use salt or sauce for this test. It is strongly advised that the dishes be prepared by or under the supervision of the facilitators.
b. Take care to keep the lines and varieties separate. Give each entry a number code. Note down the names and the origins of the grains used for the dishes in a notebook. Do not reveal this information to the farmers, as they may be influenced by their preferences.
c. Place each dish on a plate and line up all dishes on a table along with their identification numbers. Place a glass of water after every dish so that the food tester could rinse his/her mouth before tasting the next dish.

d. Give the farmers the evaluation form and ask them to stand in a line. Instruct the first farmer to taste the first entry and to fill his form without others observing it. He should then proceed to the second plate and so on. After the first farmer has tasted three dishes, the second farmer can start tasting. Once finished, ask the farmers to re-check their entries for each criterion and write their names on their evaluation sheets.

e. Prepare a big sheet paper with the evaluation form and ask each farmer to enter his/her scores per variety or line. The score for each criterion should be totalled and the varieties ranked.

f. Finally reveal the variety names. Note the reactions and discuss the results.

g. Repeat the exercise with the other crops and dishes that farmers wish to test.

h. Document the evaluation results.

Notes:

- Farmers usually find this exercise very exciting. Since the names of the varieties are hidden, there may be surprises for both farmers and facilitators. Cover the testers’ eyes and ask for silence if they try to guess the origin before or during the test.

- Uncover potential differences in taste by grouping farmers by gender (men/women), age (young/old), or by any other nature (ethnic origin, education, etc.).

- Participants should taste a maximum of 3-4 dishes only per day. The taste receptors of the participants may falter if they taste too many varieties and dishes at once, which would affect the test results.

Questions

a. Did you find major differences in taste or appearance of the entries tested? Did you find entries that performed better than the control variety?

b. If you compare the gastronomical characteristics with the agronomic characteristics, do you see large similarities or differences?

c. Do you think you will be successful in selecting a variety with better cooking and tasting characteristics?

d. Do any characteristics that have come up in this exercise need to be more emphasized in the breeding programme? Which are these?
10.10 Difference Between Genotype and Phenotype

Introduction¹¹

Observation is an essential tool in achieving the desired breeding and selection goals. For successful selection, it is important to take a close look at the plant performance and to observe the various characteristics during plant growth, harvest and storage.

Some characteristics are ‘heritable,’ which means that they are transferred with the seed and re-appear in the next season, regardless of the season or the environment. Other characteristics only appear when the plant is grown in a particular environment and may still be heritable to a large degree or, alternatively, largely be determined by the environment with only a small genetic contribution/component. The level of heritability is an important factor in plant breeding as it determines the success of selection. The question is, how do we know whether and to which extent a characteristic is heritable or not?

Breeders therefore distinguish between genotype and phenotype. Plants, just as other organisms, are made up of thousands of genes, which in isolation or together determine the plant’s growth and development. A genotype is the genetic skeleton of a plant; it is a fundamental part of a plant’s life form but not exclusively responsible for the plant’s appearance. A phenotype is the plant’s physical characteristic that farmers see in the field. Each plant’s appearance is determined by a genotype, the expression of which may be modelled, ‘disturbed’ or modified by the environment in varying proportions to form the phenotype. Phenotype literally means ‘the form that is shown’; it is the outward physical appearance of the combination of traits that make up the plant.

In this first topic on basic genetics, the participants will focus on variations in the field and differences between genotype and phenotype. In the course of the training programme, they will learn how to apply these principles in their selection practices.

¹¹Smolders, H. and R. Salazar. (2003). Facilitator’s Guide for On-Farm Conservation and Development of Plant Genetic Resources in Pearl Millet and Cowpea, With Special Reference to Conditions in Sub-Saharan Africa (Mali). U.N. Food and Agriculture Organization and Centre for Genetic Resources, the Netherlands, Wageningen University and Research Centre
Illustration

The difference between genotype and phenotype can be best illustrated by Mendel’s Laws of Inheritance (see Figure 7). These include the Law of Dominance and the Law of Segregation.

The Law of Dominance requires an understanding of the following genetic terms:

- DNA is the primary carrier of heritable information (composed of thousands of genes).
- A gene is a piece of DNA that contains the actual heritable information.
- Alleles are different versions of the same genes (which may be one or two dominant [AA for homozygous dominance and Aa for heterozygous dominance] or two recessive [aa for homozygous recessive]), where ‘A’ determines the outcome and ‘a’ does not in a heterozygous (Aa) allele.
- Qualitative trait is expressed qualitatively, which means that the phenotype falls into different categories. The pattern of inheritance for a qualitative trait is typically monogenetic, which means that the trait is influenced by a single gene.
- Quantitative trait shows continued variation along a gliding scale. If several gene effects are present, the phenotypes within a population will typically have a normal distribution.
- The gene alleles affect the phenotype and genotype of plants. Thus, phenotype is the visual appearance of the plant (P = Gene + Environment) and genotype is the genetic make-up of the plant.

The Law of Inheritance, subsequently, can be demonstrated as in Figure 7 below, highly relevant for the understanding of a hybrid variety:

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Figure 7: An illustration of Mendel’s Law of Inheritance

**Red Flower (PP) x White Flower (pp)**

<table>
<thead>
<tr>
<th>Genes</th>
<th>P</th>
<th>P</th>
<th>P</th>
<th>P</th>
<th>P</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pp</td>
<td>Pp</td>
<td>Pp</td>
<td>P</td>
<td>P</td>
<td>P</td>
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<td></td>
<td>Pp</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>P</td>
</tr>
</tbody>
</table>
| All plants look similar phenotypically but are genetically different

<table>
<thead>
<tr>
<th>Genes</th>
<th>P</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PP</td>
<td>Pp</td>
</tr>
<tr>
<td></td>
<td>Pp</td>
<td>P</td>
</tr>
</tbody>
</table>
| 3:1 (Segregation)

10.11 Farmers’ Field Day

Introduction\(^{13}\)

When all crops are about to be harvested (i.e. when the standing crop is at its best to see) and after field evaluations of varieties or cultivars have been completed, it is time to conclude the season’s FFS-PPB activities. The Farmers’ Field Day (FFD) is the culminating activity of the FFS-PPB season-long sessions, organized in order to report back to the whole community on the lessons learned and the progress made. The best time to have an FFD is when the crops in the ‘learning field’ are still standing and nearing maturity - unless there is an emergency situation and no choice but to harvest the crops before the FFD.

The FFD is an activity that brings the farmer participants and other members of the community together. It is an occasion for the farmers and the facilitators to show the community and other stakeholders (e.g. local officials) what they have learned and what have been the results of their participatory action research (PAR) activities. It also highlights what a group of farmers can do when working together as a team to solve their problems. Thus, the FFD also serves as a

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\(^{13}\)Callo Jr., P.D., W.R. Cuaterno, and H.A. Tauli. (1999). *Handbook of Non-Formal Education and Team Building Exercises for Integrated Pest Management*. ASEAN IPM Knowledge Network, SEARCA, College, Laguna, Philippines, KASAKALIKASAN, Department of Agriculture, Diliman, Quezon City, Philippines and SEAMEO SEARCA, College, Laguna, Philippines
platform for farmers to generate support for their follow-up activities among dignitaries, authorities and officials, and other prospective stakeholders.

The FFD may include such activities as a field tour, an exhibition and/or a programme in which local officials deliver speeches. The participants and the community also jointly prepare foods as part of the event. The FFD is a genuinely festive occasion, with a festival-like atmosphere. Folk media ¹⁴ prepared by farmers complete the celebrations.

It is important to prepare well for the FFD. The preceding days are usually full of activities: field evaluations are finalized, graphs and tables prepared, performances rehearsed and exhibition rooms arranged. The FFD is the training participants’ affair, meaning that they must plan and implement it. The farmer participants may choose to invite fellow farmers from the same or neighboring villages. The facilitators may choose to invite their local chief executives or direct supervisors with the end view of informing them about the programme.

Apart from the preparations for the FFD, ample time will be needed to evaluate the lessons learned and to plan for the next season. This can be done either before or after the FFD.

Implementing an FFD ¹⁵

**Objectives**

- To help farmers decide on activities for the FFD
- To organize the FFD

**Materials**

- A ‘learning field’ in maturity stage
- Exhibition area and materials
- Tape, paper and markers

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¹⁴ Folk media are cultural resources that accumulate indigenous knowledge passed down from generation to generation; they are woven into proverbs and poems, songs and dances, and are embedded with a strong sense of cultural identity. In many cases, these media can be a subtle and effective way of introducing development ideas and messages (Crowder et al, 1998).

¹⁵ Smolders, H. and R. Salazar. (2003). Facilitator’s Guide for On-Farm Conservation and Development of Plant Genetic Resources in Pearl Millet and Cowpea, With Special Reference to Conditions in Sub-Saharan Africa (Mali). U.N. Food and Agriculture Organization and Centre for Genetic Resources, the Netherlands, Wageningen University and Research Centre
Time guide

Participants should devote considerable time to the preparation and organization of the FFD. Planning activities should start about three weeks ahead of the day. The last few days before the FFD, when farmers send out invitations, prepare exhibition materials and conduct rehearsals, are usually very busy.

Procedure

a. Discuss with the farmer participants what makes an FFD. What are the reasons for holding an FFD? What might happen during an FFD?
b. Write down the answers and use them as a basis for planning the group’s FFD.
c. Plan the FFD activities.
d. Conduct the FFD.
e. Evaluate and document the FFD activities.

Notes

- The FFD can be perfectly combined with the cooking and eating quality evaluations of varieties and advanced lines. The invited farmers and guests can participate in the testing and ranking of the different lines and varieties according to their preferences. The whole activity can thus take on a cheerful character.
- The FFD is also an excellent time to hold a graduation ceremony for the farmers who have participated in the field studies and training sessions throughout the season.

Guide Questions

1. Who should be invited for the FFD? Why?
2. How should participants approach local leaders to ensure the latter’s involvement in and commitment to the FFD?
3. How should the knowledge and skills learned in the FFS be shared with other farmers and local officials?
10.12 Evaluation of Varieties by Farmers

Introduction

In PVS, it is not necessary to go through a complex process of variety evaluation in order to compare the performance of a set of varieties and stable advanced lines. Considering that only a small number of criteria are perceived as important (such as drought resistance, early maturity, resistance to pests and diseases, or grain yield), selection of the best performing variety is not a complicated activity.

Most farmers are not familiar with statistical analysis. Hence, burdening them with academic statistical methods may be counterproductive, as they will quickly lose interest. It is essential to leave the initiative with the farmers. It will keep them involved, put them in charge of the selection process and enhance the probability that they will make further use of their selected options.

Some of the most basic methodologies for variety and stable line selection are discussed below. They will enable farmers to understand the effectiveness of their own comparison methods and add new skills for use in their PPB programme.

Procedure for variety evaluation

a. Ask the farmer subgroups to go to the field for the last time to inspect the different variety plots and select the best performing variety. Each subgroup should note down which variety performs best in their opinion and why.

b. Ask each group to make pair-wise variety comparisons with the control variety (normally the farmers’ most popular variety). Indicate which varieties perform better than the control and which do not perform well enough (use the format of Table 10).

Table 10: Pair-wise variety comparison with the farmers’ popular variety

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control Variety</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

16Adapted from Smolders, H. and Salazar, R. (2003). Facilitator’s Guide for On-Farm Conservation and Development of Plant Genetic Resources in Pearl Millet and Cowpea, With Special Reference to Conditions in Sub-Saharan Africa (Mali). U.N. Food and Agriculture Organization and Centre for Genetic Resources, the Netherlands, Wageningen University and Research Centre
c. Ask subsequently to make variety comparison in all kinds of combinations. Ask them to take variety numbers 1-11 (including the control or the farmers’ most popularly grown variety). Using Table 11 below, each group should indicate which one of the two varieties being compared is the best performing and explain why.

Table 11: Pair-wise variety comparison in all kinds of combinations

Visual comparison

d. Return to the classroom and ask subgroup participants to summarize the observation results of the first exercise, comparing the tested varieties with the control and ranking the varieties in the order of highest frequency. Indicate the reasons for choosing the variety.

Pair-wise comparison

e. Ask the assigned subgroups to present the result of their pair-wise comparisons. With assistance from the facilitator, prepare a table that includes all varieties and count how many times a variety is selected as the best performing.
f. Next, ask the subgroups to present the comparison with the control or the farmers’ popular variety. With assistance from the facilitator, make again a ranking of the best performing variety.
g. Compare the results of the pair-wise ranking with the ranking results from the visual comparison exercise.
h. Select the first five varieties that rank highest for the scoring card comparison.

**Scoring card comparison**

i. For the scoring card comparison, ask each subgroup to present the collected observation data and indicate which of the criteria are the most important.
j. With assistance from the facilitator, select the top 10 criteria developed in the course of the exercise on breeding objectives.
k. Ask the entire group to complete sample Tables 12a, 12b and 12c (see below) by recording the information for the selected top 10 criteria.
l. Then ask the group to prepare a ranking with the best performing variety on top and the worst performing variety at the bottom.
m. Present and compare the results of the scoring cards with the results of the pair-wise comparisons.
n. Examine the final scores for varieties in the bottom column and compare these. Indicate the best performing variety. Observe the relative scores in the table for each individual criterion and compare these with the scores in the scoring card. Note the differences.
o. Ensure that all farmers are involved in the comparisons and understand the methods.

**Questions**

a. Individual farmers may have different opinions on whether a variety performs better than the other does. Why is it important to find out which variety performs best? How do breeding objectives relate with this performance exercise? Are there differences in men and women’s preferences?
b. What are the strengths of the visual and pair-wise comparisons? What are the weaknesses of these methods?
c. What type of information do the farmers need in order to complete a score-card? Who should collect these data?
d. When do we use the score-card method? What are the limitations?
Table 12a: Sample Scoring Card Comparison for Maize

<table>
<thead>
<tr>
<th>CRITERIA</th>
<th>Variety Rank No. 1</th>
<th>Variety Rank No. 2</th>
<th>Variety Rank No. 3</th>
<th>Variety Rank No. 4</th>
<th>Variety Rank No. 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Early maturity</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>2. Plant height</td>
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<tr>
<td>3. Lodging</td>
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<tr>
<td>4. Drought tolerance</td>
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<td></td>
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<tr>
<td>5. Length of ears</td>
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<tr>
<td>6. Circumference of ears</td>
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<td>7. Leaf angle (erect)</td>
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<tr>
<td>8. Resistance to pests &amp; diseases</td>
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<tr>
<td>9. Grain yield</td>
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<tr>
<td>10. Gross margin</td>
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</tbody>
</table>

Table 12b: Sample Scoring Card Comparison for Pearl Millet and Sorghum

<table>
<thead>
<tr>
<th>CRITERIA</th>
<th>Variety Rank No. 1</th>
<th>Variety Rank No. 2</th>
<th>Variety Rank No. 3</th>
<th>Variety Rank No. 4</th>
<th>Variety Rank No. 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Early maturity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Plant height</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>3. Lodging</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>4. Drought tolerance</td>
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<tr>
<td>5. Number of productive tillers</td>
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<tr>
<td>6. Length of panicle or head</td>
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<tr>
<td>7. Panicle exertion (fully exerted)</td>
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<tr>
<td>8. Resistance to pests &amp; diseases</td>
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<td></td>
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<tr>
<td>9. Grain yield</td>
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<td></td>
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<tr>
<td>10. Gross margin</td>
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</table>

Table 12c: Sample Scoring Card Comparison for Groundnut

<table>
<thead>
<tr>
<th>CRITERIA</th>
<th>Variety Rank No. 1</th>
<th>Variety Rank No. 2</th>
<th>Variety Rank No. 3</th>
<th>Variety Rank No. 4</th>
<th>Variety Rank No. 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Early maturity</td>
<td></td>
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<tr>
<td>2. Growing habit (spreading)</td>
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<tr>
<td>3. Number of pods</td>
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<td>4. Number of seed per pod</td>
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<tr>
<td>5. Size of seeds</td>
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<tr>
<td>6. Colour of seeds</td>
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<td>7. Resistance to pests</td>
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<tr>
<td>8. Resistance to diseases</td>
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<td></td>
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<tr>
<td>9. Grain yield</td>
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<tr>
<td>10. Gross margin</td>
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</table>
10.13 Course Evaluation\textsuperscript{17}

At the end of the season, it is time to evaluate the season-long FFS-PPB activities. It is important to note that evaluation of the season’s training is not a one-time activity, but rather an ongoing process. Evaluation has at least three stages:

a. Each field day should start with a review of the farmers’ expectations concerning the day’s learning targets and finish with an evaluation using a checklist or the Ballot Box method (see below). This allows the participants to get the most out of the activities and the facilitators to learn and modify their approaches.

b. Towards the end of the training season, the changes assumed to have been caused by the training activities should be evaluated. This includes the changes in know-how, field skills and confidence of the participants that have occurred between the beginning and the end of the training. Evaluation may use several methods, including T-Cross, Piling Up and Ballot Box (see below).

c. Finally, it is important to evaluate the impact of the training. Farmers may improve their knowledge, skills and attitudes (e.g. cooperation, confidence, and gender and social inclusion), but this may not resolve their major problems. Impact is perhaps the most difficult factor to measure, since FFS-PPB training is not likely to produce tangible results in one or two training seasons. Thus it may not be feasible to conduct such an evaluation at the end of the first training course. However, it is important to keep impact in mind as the overall goal of the training activities. To warrant a continued interest of the farmers’ community in the FFS-PPB, the season’s training activities should have an impact on one or more of the following three aspects: the farmer’s benefit and income, the environment, and community organization and self-funding activities.

Some Group Evaluation Methods

- The **Ballot Box** is a method that uses multiple choice questions and field situations to test the farmer’s know-how and skills at the beginning and at the end of the season. The Ballot Box can also be used to test farmers’ know-how and skills at the beginning and the end of a single day. Questions should be developed before the start of the season.

- The **T-Chart** is an evaluation method whereby a T-shape drawn on a large piece of paper forms two columns, one for activities deemed to be ‘good’ and one for activities that ‘need to be improved.’ Farmers write the names of

\textsuperscript{17}Smolders, H. and R. Salazar. (2003). Facilitator’s Guide for On-Farm Conservation and Development of Plant Genetic Resources in Pearl Millet and Cowpea, With Special Reference to Conditions in Sub-Saharan Africa (Mali). U.N. Food and Agriculture Organization and Centre for Genetic Resources, the Netherlands, Wageningen University and Research Centre
activities on cards, which are then stuck to either one of the columns as appropriate. The activities that ‘need to be improved’ should be discussed with the aim of finding solutions to the identified weaknesses.

- In the *Piling-Up* evaluation method, the farmers are asked to make drawings on a large piece of paper to represent various aspects of the programme (e.g. field study, group activities, FFD, etc.). Subsequently, each participant is given some seeds or coins and asked to score each activity by piling the seeds/coins on top of the drawing that represents it. Discuss the activities with the lowest scores with the aim of finding solutions for improvement of such activities, or alternatively, for their replacement.

### 10.14 Developing Plans for the Next Season

On completion of the training course evaluations, participants and facilitators should discuss the following issues:

- What kind of field studies should be conducted in the next season?
- Who will be responsible for seed storage during the off-season?
- When is the best time to conduct a more detailed pre-season planning meeting?
- What new activities should be introduced in the next season?
- Who is going to participate in the next season’s activities?
- What changes have you experienced during the FFS and what impact this has had on your farm and yourself?

Based on the answers, design a study plan together with the farmers and decide what activities should be carried out in the next season. Also, discuss the group’s plans to help other farmers in the village understand more about PPB. Upon completion, consolidate the study plan and discuss what kind of support will be needed to carry it out and how this support can be obtained.

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18Smolders, H. and R. Salazar. (2003). Facilitator’s Guide for On-Farm Conservation and Development of Plant Genetic Resources in Pearl Millet and Cowpea, With Special Reference to Conditions in Sub-Saharan Africa (Mali). U.N. Food and Agriculture Organization and Centre for Genetic Resources, the Netherlands, Wageningen University and Research Centre
11. ANNEXES

11.1 Plant Genetic Resources (PGR) Issues and Seed Laws in Zimbabwe

Background

Seed diversity in farming systems is fundamental for agricultural production and food security. It creates a basis for productivity and resilience in farming systems, nutritional values, and food and livelihood security. Furthermore, local crop genetic material may be important for modern breeding through the development of improved seed varieties. Crop genetic resources are the result of interactions over many generations of crops and farming people: shared knowledge, seed exchange, and the accumulation of valuable traits in crop populations.

Important Seed Laws

The most important seed laws in Zimbabwe are: (a) The Seed Act [Chapter 19:13]; (b) The Plant Breeders Rights Act [Chapter 18:26]; and (c) The Plant Pests and Diseases Act [Chapter 19:08]. There are also subsidiary regulations in place dealing with seed variety release, certification, quarantine and phyto-sanitary aspects. These include: (a) The Seed (Amendment) Regulations 2003 (No.12) SI 100/2003; and (b) The Plant Pest and Diseases (Pests and Alternate Hosts) (Amendment) Order, 1988. However, for this field guide, it will be of major interest to highlight some practical provisions under The Seed Act and The Plant Breeders’ Act.

The Seed Act

The Seed Act aims to promote varietal and seed quality. It sets the market rules for the suppliers, and establishes the institutional framework of the national certification agency. It regulates the procedures and standards for:

- Varietal release (aiming to make only those varieties of proven value available through the formal system);
- Seed certification (aiming to control the varietal identity and purity throughout the seed chain); and

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• Seed quality control (regulating seed characteristics such as viability, purity and seed health).

In this context, the current Seed Act creates major challenges. It is important to highlight that the legislation was crafted before the enactment of the land reform law and that at the time it mainly served the interests of ‘white’ commercial farmers who dominated in the area of seed production. Very little has been done to foster an enabling environment that strengthens the seed system of smallholder farmers and allows them to operate in their specific niche to address food security, biodiversity management, economic development and the promotion of agricultural entrepreneurship. The country needs to come up with farmers’ rights policy and legislation that will support fully the informal seed system, according to which farmers will be allowed to produce, save, exchange and sell on a commercial basis farm-saved seeds or propagating materials.

**The Plant Breeders’ Right Act**

The Plant Breeders’ Rights Act deals with the registration of plant breeders’ rights in respect to certain varieties of plants. It provides protection to the rights of persons who are registered as the holders of such rights. The Plant Breeders’ Rights Act recognizes a breeder’s exemption, i.e. an exemption to the rights conferred allowing any breeder to use released varieties for further breeding. Furthermore, the farmers’ exemption allows the safe use, exchange and sale of seeds of protected varieties by small farmers within a radius of 40 km from their farm. Patenting offers no exemption to research; one cannot use a patent variety for research – it is against the law (Salazar, 2015).

Thus, the Plant Breeders’ Rights Act vests a monopoly into the developers of new varieties of plants, in line with the International Convention for the Protection of New Varieties of Plants (UPOV, 1991). It provides intellectual property protection to plant varieties that are distinct, novel, uniform and stable; accordingly, the breeder has exclusive rights to sell, including the right to licence other persons to sell and export seeds and reproductive materials of plants of that variety. The law has created major challenges as it provides protection only to breeders but not to farmers. Its enactment involved very little participation of smallholder farmers in decision making at the national level.

Finally, access and benefit sharing (ABS) provisions as articulated in international instruments, such as the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA), the Convention on Biological Diversity (CBD) and the Nagoya Protocol, have not been domesticated fully into national law.
Domestication of these international instruments will provide an enabling environment for the development of smallholder farmers in terms of seed production. Farmers need to own their plant varieties, and collectively benefit from the utilization of their knowledge and technologies, innovation and practices. This requires the granting of access and procedures that are not granted under the present Plant Breeders’ Right Act.

**Recommendations**

There is a need for the establishment of a differentiated seed quality assurance system in Zimbabwe. The policy and legislation to be put in place should also outline strategies for the differentiated provisions of plant variety protection and farmers’ rights. Behind this is the notion that there is a need to provide an enabling environment to support the professionalization of farmers and enhance their capacity in varietal choice, quality seed production, processing and storage. In this view, there is a need to develop a national seed policy, which provides a strategy to strengthen smallholder farmer seed systems in complementation of commercial seed systems. Similarly, there is a need to develop a national seed plan that can provide a landscape overview of the seed sector and its current status, and define roles and responsibilities. This would enable the nation’s seed sector to be more vibrant, as foreseen by the Integrated Seed Sector Development Programme, and this could be undertaken in the process of developing a seed policy.

**11.2 Principles of Adult Learning in the Farmer Field Schools**

This section starts by explaining the experiential learning theory and how it is translated within the FFS activities. It further highlights the suitability of this approach for the FFS: as with all adults, farmers’ knowledge is by nature experiential and therefore the experiential learning methodology is relevant to support farmers’ experiments, observations, decisions and practice on their management of plant genetic resources for food and agriculture (PGRFA). The section concludes with the scale-up pathways in which the FFS is one of the six components.

The FFS is an experiential approach consistent with formal and non-formal adult education. It begins and builds on farmers’ local and/or traditional knowledge, and further supports the farmers’ learning processes. The FFS is used as a participatory and interactive learning and field-based approach. Consistent with

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20 Prepared by Gigi Manicad and Annick Osthoff
the experiential learning cycle, experience has the central role in the learning process (Malinen, 2000; Yardley et al, 2012): facts (concrete experience) are the basis for observation and reflection, and findings (abstract concepts) are transformed into experimentation and further actions (Kolb and Kolb, 2009; Kolb, 1984). The FFS allows farmers to experiment, observe and analyze the outcomes, which are the basis of farmer’s decisions and actions (Hagiwara, 2012). New and/or additional knowledge is produced through transformation of experience.

Figure 8: Kolb’s learning styles

Through (experiential learning) FFS group discussions, experimentations of ideas and practices (which are closely related to participants’ farming activities) allow farmers to collectively identify solutions to their local challenges. Aside from enabling farmers to adapt their PGRFA management to – for example – climate change, the farmers’ participation also has the potential to increase their awareness of their rights, improve their negotiating power and, ideally, lead to the establishment of farmers’ networks (Iqbal, 2014). Critical analysis (i.e. reflection, which is part of Kolb’s learning cycle and of the FFS, and which turns experience into learning), the activities (which include analytical steps through group presentations) and the role played by the facilitator are components that also enhance farmers’ analytical skills.

The FFS enables activities that: link decisions with consequences; create knowledge; bring different stakeholders together; encourage improved communication and understanding (of problems and solutions); offer tools to handle local issues (such as climate change adaptation, empowerment of farmers and, in particular, women); and allow collaboration with scientists (through farm
experimentation, participatory breeding methods and the use of local knowledge for seed development and distribution).

Kolb’s learning cycle is seen as imbedded in the FFS: experimentation carried out seems to allow sufficient time for farmer-to-farmer, peer-reviewed decisions and activities, and thus seems to apply and reflect the experiential learning cycle. Participants identify an area of interest and build a project around it. The content is delivered in a way that helps participants to transfer learning outcomes to other farmers. The participatory surveys done through the FFS allow gathering information which is relevant to the local context and, at the same time, make it possible for scientists, researchers and farmers to work as partners. The FFS enhances group building (van den Berg, 2004) and increases farmers’ knowledge, enabling them to improve farming and PGRFA management in changing context (Gwary et al, 2015). Communication is an integral component of the FFS: trained farmers are expected to become local agents who share knowledge and train other farmers. This also proves to be beneficial to the farming community as a whole due to its capacity-building functions (Butt et al, 2015). Farmers’ access to information is seen as key to their ability to make sound decision (Tadesse and Bahiigwa, 2015). For farmers, more interactive forms of curriculum result in better learning results (Francis et al, 2011) and knowledge has to be explored in a so-named ‘safe environment.’ Some methods to build relationships and trust include hands-on workshops, farm visits, on-farm focus groups and networking (Franz et al, 2010). In terms of farmer-to-farmer learning, the advice and experiences of other farmers are highly valued sources of information (O’Halloran and Murray-Prior, 2014). The FFS is seen as a ‘stepping stone’ towards the formation of farmers’ networks (Gwary et al, 2015; Blackie, 2014).

The protected or safe space provided by the FFS further enables participants to question traditional norms and practices that restrict their behaviours and actions; this safe environment/space is key for the learner to practise critical reflection and explore new knowledge (Duveskog, 2013; Burch et al, 2014). The facilitator ensures that the FFS participants share, learn and test in a safe space (Burch et al, 2014). Learning occurs in a collective space among group members simultaneously. This gives room to changes at the individual level as well as to wider social change, because it combines impact on an individual with impact on social structures, in addition to inducing technological innovations (Duveskog, 2013).

Learning in FFS is about providing a platform for personal development and changes in relationships with others. These findings are in line with what Habermas refers to as the three domains of human interests and knowledge (Duveskog, 2013): FFS participants demonstrate an increased capacity to control their environment through improved farming practices and PGRFA
management (instrumental domain), while also enhancing social relationships, interactions and communication (practical domain), and developing their self-knowledge, self-reflection and relational autonomy (emancipatory domain). This mix of learning domains helps to make the FFS experience successful. The increased farming knowledge among FFS participants raises their power in the community, while the collective capabilities gained through the FFS group help participants to break through constraints of powerlessness (Duveskog, 2013) and give them capacity to aspire (Westerndorp, 2012).

Empowerment is seen as a process of social transformation (Westerndorp, 2012) and encompasses individual, institutional and structural levels. Participation should thus be seen as a strategic, methodological goal of development. Through FFS, both men and women (with increased knowledge and development of critical thinking) acquire the ‘power within’ (increased self-esteem and confidence), the ‘power to’ (improved livelihoods) and the ‘power with’ (the set-up of farmers’ networks and increased ability for collective action). Some outcomes include:

- **Changes in the individual and collective awareness and perspectives** (critical thinking and self-confidence);
- **Gaining agency,** where farmers take greater control over their lives specifically in PGRFA management; where women’s role as managers of biodiversity and food security are supported and participation and decision making is enhanced; and where farmers reach out to other communities to train other farmers and share knowledge and seeds;
- **Social change** resulting from collective action, where participation in FFS and increased interaction with more stakeholders enables farmers to: (a) be more gender and socially inclusive at intra- and inter-household levels (this includes women’s control of assets and the quality and diversifications of diets); (b) be better organized in demanding their right to access resources (e.g. PGRFA), services, information (e.g. extension, weather data, credits) and equitable market participation; (c) actively pursue **policy engagement and reforms** in relation to, for example, Farmers’ Rights and the Right to Food; and (d) concrete gains in **food and nutrition security**, including elimination of the periodic hunger period.

Empowerment through increased knowledge and engagement with diverse stakeholders can help farmers to be better equipped to cope with changes.

The FFS is also an important instrument for scaling up.
FFS in the context of scaling up

Scaling-up pathways describe how programme outputs can be used within and outside programme coverage in such a way that the impact on social, environmental or economic conditions is enhanced. In other words, such pathways describe how impact can be spread.

Figure 9: Scaling up pathways

Source: Oxfam, ANDES, CTDT, SEARICE, and CGN-WUR (2015)

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- **PGRFA participatory toolkit scale-up pathway.** The development of an elaborated participatory toolkit is essential for establishing a baseline to guide programme planning. Without a properly established baseline, it will not be possible to measure progress or attribute change to programme interventions.

- **FFS scale-up pathway.** This entails the development of a self-explanatory FFS curriculum that is user-friendly and can be adapted by a wide range of stakeholders within and outside the programme scope. Given the limited availability of professional experts and funding, the autonomous organization of FFS is a vital community formation. FFS provides the means to move from an anecdotal to a high-impact phase in terms of programme results, sustainability and outreach.

- **PGRFA access pathway.** Farmers’ access to PGRFA is an important right. Often the major limitation to the proper functioning of farmer-managed seed systems is the lack of access to a portfolio of diverse crops and varieties. Without access to diversity, investments in local PGR management are meaningless. Properly addressing this pathway may also benefit from a framework that integrates multiple land use options such as a landscape approach in bio-cultural territories.

- **Policy-influencing scale-up pathway.** The strengthening of farmer-managed seed systems requires favourable policies to be sustainable. Collective policy analysis and advocacy are needed to promote and mainstream the local and global importance of farmer-managed seed systems.

- **Climate change response pathway.** Today’s food production takes place against the backdrop of climate change. The scale-up pathways above cannot be separated from the effects of climate change and the responses of indigenous peoples and smallholder farmers to them.

- **Gender inclusion pathway.** Men and women play different roles in food production and seed management. In order to effectively improve food security, seed security and farmers’ livelihoods, it is essential to recognize these different roles and to promote optimal, fair and equitable division of labour and decision making.
11.3 Participatory Action Research

Participatory Action Research (PAR) is a research methodology developed by practitioners across disciplines and fields interested in using research to change a problem faced in their practice. Its main feature is the bridging of theoretical and analytical processes for understanding a development problem with action for social change. Due to the expanse of fields of practice that use PAR (education, health services, development, social work, etc.), there are several streams of PAR methodologies. The most interesting stream for developing a common framework for this programme is one that emerged from the disappointment over the failure of scientific and academic approaches to solve real life development problems. This form of development-focused PAR engages directly with emancipatory development approaches as described by Fals-Borda (2006; 1991; 1987). It challenges traditional research by arguing that: people’s wisdom must be included in research in order for it to be useful; theory and practice must come together through research praxis, and; research carried out collaboratively allows movement beyond subject/object boundaries. Stringer (2007) refers to a similar approach that he calls community-based action research. He points out that the social values that underpin it make the research process democratic, equitable, liberating and enhancing to all participants.

Within the field of development (through the practice of NGOs, development agencies and communities), participatory development approaches grew out of the need to include the ‘local’ in development planning and practice. Commonly known as ‘bottom-up’ approaches to development, they advocate development for the poor by the poor, and are often coupled to a livelihoods approach (de Haan and Zoomers, 2005; Scoones, 1998). Underlying many participatory approaches is a goal of emancipation. Emancipatory development emerged from the work of Neo-Marxist scholars such as Paulo Freire (1986; 1998; 2004), who argued for empowerment and liberation education as central to the process of development of the marginalized. Methodologically, organizations that facilitate participatory and emancipatory development use tools that are based on horizontal learning, empowerment and reflection upon practice (e.g. Chambers, 1983; 1994; 1997). Today, these tools are used by NGOs and development practitioners under the banner of PAR. Use of a PAR approach provides an explicit process for planning analysis and reflection towards emancipatory and social change goals.

The proposed programme focuses on realising the Right to Food and Farmers’ Rights through empowerment and participation of communities, particularly

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women, in building resilient farming and food systems in the context of climate change. Calls for democratization of agricultural research and policy development argue for the need to use PAR methodologies to strengthen the voices of communities, building solutions and influencing agricultural and food policies based on their knowledge and realities (IIED, 2010). PAR facilitates a process of empowerment, dialogue and critique of mainstream and top-down farming and food policies, creating a space for linking traditional knowledge and science to build innovative solutions. Thus the PAR methodological approach and associated tools, which have been developed through emancipatory development practice, are well suited to this scaling-up initiative for climate change adaptation and food sovereignty.

Features of PAR for Scaling-up Innovation

Aiming to build a common understanding of PAR among project partners and ensure that methodological planning leads to the necessary steps for action-oriented learning and social change, the following presents a list of generic characteristics of action research from a variety of approaches (Cardno, 2003; Fals-Borda, 2006; Flood, 2006; Gaventa and Cornwall, 2006; Herr and Anderson, 2005; Oja and Smulyan, 1989; Piggot-Irvine and Bartlett, 2008; Reason and Bradbury, 2006; Stringer, 2007):

- Uses group experiential learning - learning is facilitated in a group and is an experiential process of learning through doing;
- Uses iterative action and reflection - uses iterative cycles consisting of phases of planning, acting, observing and reflecting;
- Is a transformative process - the collaborative and critical nature of inquiry gives it the ability to be transformative both for individuals and their social worlds;
- Learning outcomes are practice-based - because of the focus on producing action and working with real-life problem situations, the learning outcomes of action research are centred on how practice is improved upon by it;
- Uses transdisciplinarity - recognizes that knowledge is contested and can only be gained through a process of interacting with others towards a common goal.

The central methodological feature of all PAR initiatives is that knowledge is generated through a collaborative, interactive research process. Most action researchers claim that several interactions of a cyclical learning process are conducted systematically, generating knowledge through reflection on a planned action that has been taken (Reason and Bradbury, 2006; Stringer, 2007). Each cycle contains four stages as shown in Figure 10 below.
This generic action research cycle must be adapted in this action research endeavour to the scaling-up innovation nature of the proposed programme. The process of scaling up, as defined by the International Fund for Agricultural Development (IFAD), entails six steps:

a. Define the scale of the issue to be addressed and the appropriate scale of intervention;
b. Define suitable pathways of scaling-up;
c. Explore the institutional, organizational and policy context that allows scaling up;
d. Define the partners and what needs to be done to bring them on board;
e. Define the appropriate operational instruments required;
f. Monitor and evaluate the pilot or experimental project.

11.4 Establishing the ‘State of Plant Genetic Resources’

Introduction

It is safe to presume that more PGR diversity is needed in the marginal and dry semi-arid cropping areas of Zimbabwe. The challenge is to understand the ‘state’ of the PGR of those crops that will be studied in the FFS-PPB project. The baseline data forms the benchmark from which the results of the project will later be measured. It also ensures that the project’s response and intervention will be realistic and well grounded.
The greater challenge is in ensuring that the processes of understanding the state of the PGR of the ‘focus’ crops are conducted by the farmers themselves. Thus, the principles and approaches of PAR must be used. This is the most decisive step in the whole process of community research and development of PGR. It will ensure that the diagnosis identifies the real problems, needs and interests of local farmers, and that the process of understanding the PGR situation is an exercise that the farmer participants lead and own. It will further ensure that the diagnosis is influenced by their individual perceptions and emotions, and is reaffirmed in a collective and collaborative process. Finally, the commitment of local farmers to act and improve the PGR situation shall be intellectual and emotional, deep within each farmer’s thinking and feeling.

**Objectives of the establishment of a PGR baseline**

**Technical Objectives**

a. Farmers to measure and analyse the level of diversity of selected crops in their own community;
b. Farmers to understand the strengths and weaknesses of the current level of diversity in their community, in particular the agronomic strengths and weaknesses of the current varieties they cultivate;
c. Farmers to understand the pattern of loss and introduction of cultivars in the community, and – if the trend is towards reduction of PGR – to identify the causes of this erosion.

**Learning and Empowerment Objectives**

a. Farmers to understand and interpret their own perceptions on the use of PGR diversity to provide food and livelihood for their families and communities;
b. Farmers to analyse the strengths and weaknesses of the cultivars they are cultivating, as a basis for setting up their research, breeding and development objectives in the FFS.
11.5 Use of PGR Tools (Diversity Wheel, Timeline Analysis and Simple Scoring)

Introduction

The FFS-PPB has two main objectives: (a) to strengthen farmers’ management of PGR (varieties and seeds); and (b) to increase the genetic diversity of cultivated crops. Both objectives aim to increase the resilience of small-scale crop production under changing socio-economic, political and agro-ecosystem conditions, help ensure food security and improve farmers’ livelihoods.

Laying down the foundation of the FFS-PPB

The FFS-PPB takes the concrete situation of PGR of the farmer participants and their communities as a starting point. In particular, it starts with an effort to establish how farmer participants perceive and analyse the features of their PGR. This is a necessary condition for ensuring farmers’ commitment to the implementation and success of the FFS-PPB.

It is therefore important to use participatory tools to help farmers systematically understand their situation as a basis for realizing the objectives of the FFS-PPB.

Participatory Action Research Tools

The Diversity Wheel (crop level)

The ‘diversity wheel’ is based on the ‘four-square’ analysis tool developed by staff of the Biodiversity Institute. The importance of this tool is that it provides insight into the level of crop diversity in a village, the value of these crops and varieties to farmers’ livelihoods, and the reasons due to which the cultivation of some crop species and varieties has decreased or disappeared altogether.

The diversity wheel is a tool in the form of a circle which is divided into four segments and a space at the center (see Figure 11). Villagers should list crops (and then varieties within a single crop) in the following categories:

a. Crops cultivated by many farmers on larger portions of their farms, i.e. crops that are important in fulfilling farmers’ needs;
b. Crops that are cultivated by many farmers but on smaller plots, i.e. crops with certain uses that fulfil farmers’ needs of lesser importance;

c. Crops grown by a few farmers on large plots, i.e. usually crops grown by better-off farmers for commercial markets;

d. Crops grown by a few farmers on small plots, i.e. crops with limited use and value, and at risk of being completely lost. However, if these crops have been cultivated in the village for a long time, it may also mean that they have important traits and uses;

e. Crops that are no longer cultivated by the villagers, i.e. crops that are no longer useful to the community or that have been inadvertently lost due to weather conditions or other interferences.

Figure 11: The Diversity Wheel at Crop Level

Source: Adapted from Oxfam Novib (2013), based on Sthapit et al. (2001)

**The Diversity Wheel (varietal level)**

The Diversity Wheel can also be used at the variety level. The importance of using this tool at the variety level (see Figure 12) lies in the fact that it shows the level of within-crop diversity and brings out the characteristics or traits that farmers prefer. As a first step, the villagers should list the different varieties of the main staple crop in the village. They should then be invited to place each variety in one of the following categories:
a. Varieties cultivated by many farmers on major plots of their farms, i.e. varieties that have traits or characteristics which farmers appreciate, or varieties of which seeds are readily available;

b. Varieties that are cultivated by many farmers on smaller plots, i.e. varieties with traits that are appreciated and which fulfil a clear function, but to a lesser extent or for specific purposes;

c. Varieties grown by a few farmers on large plots, i.e. varieties produced by better-off farmers for external commercial markets;

d. Varieties grown by a few farmers on small plots, i.e. varieties that run the risk of being entirely lost. However, such varieties may also fulfil specific niche functions in the community;

e. Varieties that are no longer cultivated in the village, i.e. varieties that have lost value or have been inadvertently lost due to bad weather conditions or other negative interferences.

For each category, the farmers should be requested to list the positive and negative traits of the varieties considered. This tool facilitates a discussion of the
different traits in these varieties and the value of such varieties to the community.

‘Timeline’ Analysis (varietal level of a certain crop)

The Timeline Analysis aims to track the changes in the availability and use of PGR in the community. At the variety level, the Timeline Analysis helps the farmers to see the changes in the number, features and sources of varieties over time (see Table 13). It requires farmers to challenge their memories. The table can also be used to list major characteristics highly appreciated by farmers.

Table 13: Timeline of varieties for one commune or village

<table>
<thead>
<tr>
<th>Types of varieties</th>
<th>1985</th>
<th>1995</th>
<th>2005</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of varieties cultivated</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of modern varieties</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of traditional varieties</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sources of varieties</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The objectives of this tool are the following:

a. To track the changes in the number of varieties that a community cultivates. A decrease in the number of varieties will normally indicate a narrowing of the genetic diversity in the crop.

b. To track the increase or decrease of the use of farmers’ varieties vis-à-vis the increase or decrease of the use of modern varieties. A decrease in the number of farmers’ varieties and a corresponding increase in the use of modern varieties indicate that farmers’ varieties are being replaced by varieties bred by research institutions or seed companies.

c. To track the sources of the varieties identified, by both men and women farmers.
Setting Breeding Objectives (using a simple scoring technique)

Participants list the most important traits of the identified varieties. A ranking of these traits through simple ‘scoring’ techniques will help in setting the breeding objectives. Simple scoring can be done by providing each farmer in a group with a fixed amount of seeds or stones (e.g. 20). The farmers should then distribute these stones among the traits, allocating the highest number of seeds or stones to their most favoured traits and the least number of stones (or none at all) to traits that are of least importance to them. The total number of seeds/stones per trait will indicate the level of popularity of each trait and thus help in setting breeding objectives.

11.6 The FFS Curriculum

An FFS is a ‘school without walls.’ The FFS-PPB brings farmers together for intensive training in participatory plant breeding and selection methods, and issues regarding the life cycle of the crop. Normally, FFS participants meet for 14-16 weeks, i.e. an entire cropping season, starting with land preparation and ending with the harvest. Each FFS has a ‘learning field’ of at least 1,000 sq. m, which is used for a farmer-run comparative study of crop varieties and other relevant field experiments. Each week, farmers practice AESA in the ‘learning field’, which includes plant health, water management, weather, nutrient management, weed density, disease surveillance, and observation and collection of insect pests, beneficial predators and parasitoids.

Through direct experience and critical analysis, farmers interpret their AESA observations to make field management decisions. Thus, FFS trains farmers to become experts in their own fields. The FFS training team (i.e. the facilitators) is assisted by agricultural technicians assigned to the crop production area where the FFS-PPB is located. The principles that guide an FFS learning process are:

- **The field is the primary learning resource.** All learning activities take place in the field and are based on what is happening in the field.

- **Experience forms the basis for learning.** The activities that take place in the field and their farms form the basis for discussions and analyses by farmers, who arrive at concepts that they test and improve through further field activities.

- **Decision-making guides the learning process.** Training focuses on analysis of the crop ecosystem. The combination of analytical methods, ecological principles and basic PPB methods helps farmers gain insights into the ecological
interactions in a crop field and provides them with greater confidence in making crop management decisions. In many circumstances, gender bias may hinder women from making and taking decisions. It is the collective responsibility of the FFS participants to provide space and support for women’s participation and decision making at the FFS.

- **The training curriculum is based on the local conditions of the FFS.** The FFS curriculum and materials must be appropriate for and based on the local conditions, problems and needs of farmers participating in the FFS.

- **Training lasts the entire cropping season.** Farmers acquire a firm understanding of the relevant integrated pest and production management (IPPM) concepts for each growth stage of the crop, as well as the factors that influence crop management decision making at all stages of the plants’ growth.

The andragogic and experiential approach of the FFS is a direct contrast to the top-down extension methods of the Green Revolution. Government agencies involved in the Green Revolution were basically target-oriented and rigid in fulfilling their mandates. These agencies prescribed small farmers to use inputs in accordance with centrally-determined recommendations, resulting in a ‘deskilling’ of rural communities. Farmers were expected to be passive recipients of new technologies rather than active innovators.

An FFS-PPB consists of 25-30 farmers meeting for half a day each week to share and discuss AESA observations and plan out activities for the following week. The crop growth stage and agro-physiological issues related to these stages form the core of the FFS curriculum. Field monitoring through AESA culminates with the development of an agro-ecosystem drawing. This is then used for analysis and shared through small and large group discussions guided by facilitators.

In small group discussions, farmers share their ideas on what is happening in the field and why it is happening. Facilitators circulate among the group and help farmers analyze their observations by posing problems and scenarios. In large group discussions, the subgroups share their ideas with the whole FFS group. Facilitators help participants in the discussions, posing ‘what if’ scenarios. They also share additional information related to plant growth and ecosystem not covered by the group discussions.

Aside from serving as an experiential learning tool for farmers, the FFS also caters to the socio-cultural aspect of crop production. Hence, group dynamics exercises are regularly included in FFS activities. Group dynamic exercises aim to:
• Develop participants into a closer knit FFS team that is gender- and socially inclusive;

• Establish a learning climate that is enjoyable as well as fruitful;

• Help participants experience and identify aspects of teamwork such as mutual support, the importance of individual roles to a team’s success, and behaviors that can build or hamper teamwork; and

• Help participants experience what can be accomplished by working together.

Together with group dynamics exercises, special topics are an integral component of FFS-PPB activities. Special topic sessions concern specific problems like PVS or any field study being carried out in the learning field. Special topics usually reflect individual FFS needs. Some special topics are planned ahead of the FFS, while others are developed as the FFS progresses.

A typical profile of a FFS-PPB for rice, corn, pearl millet, sorghum, groundnut and other crops on any given day is:

• **Field observation**: 07.00-08.00. Farmers form small groups, make observations of the whole field and then examine 5-staked plants per plot, recording agronomic data per plant, type and number of insects, and any other details.

• **AESA**: 08.00-09.00. Each group prepares a drawing of their field observations, including information on the condition of plants, pests and diseases, natural enemies of insect pests, weather, soil and water conditions.

• **Presentation and discussion**: 09.00-10.00. Each small group presents their drawings and discusses their observations and conclusions in front of the whole group. The whole group reaches consensus about crop management practices that they will carry out during the coming week.

• **Break**: 10.00-10.15. A short break allows participants and facilitators to refresh and invigorate themselves in preparation for the succeeding activities.

• **Group dynamics exercise**: 10.15-10.30. This activity aims to stimulate attention and participation, as well as strengthen group communication and increase solidarity.

• **Special topics**: 10.30-11.30. The facilitator guides the group in experiments, lessons, exercises and discussions on special topics related to what is actually occurring in a crop field.
• **Evaluation and planning: 11.30-12.00.** This activity allows the group to identify ‘what went well’ and ‘what needs improvement’ of the day’s activities and plan activities to be undertaken in the coming week. It also provides an opportunity to assess whether women are able to participate in all exercises and decide what the collective can do to help facilitate women’s participation.

### 11.7 FFS Facilitation

Facilitation is defined as a learner-centered process which encourages creative participation and reflection. It is a process where there is joint learning between the learner and the facilitator.

This section describes: (a) the qualities of an effective facilitator; (b) the fundamental steps of facilitation; (c) the use of supporting materials; and (d) how to deal with different types of participants.

#### Objectives

The overall aim of an FFS facilitator is to facilitate learning. Thus, a good facilitator must:

- Be motivated to work with farmers;
- Be able to ‘make a difference’ and run an FFS programme so that: (a) the community and the FFS members feel it is adding value to the community stock of knowledge and opportunities, (b) all resources available to the FFS are focused on achieving set goals, and (c) FFS is run with a minimum level of conflict.

#### Qualities of a Good Facilitator

A good facilitator must be able to: (a) communicate clearly with the farmers; (b) enthusiastically listen to farmers; (c) recognize the importance of group dynamics; and (d) be a good problem solver, as farmers are likely to have numerous problems for which they seek solutions. S/he should have:

---

• Personality (willing to learn from others, demonstrative, tolerant, time conscious, and considerate);
• Knowledge (knowledgeable about the topic, competent, intelligent, experienced, and able to communicate effectively);
• Ability to facilitate women’s participation and give equal value to women’s knowledge and skills.

Considerations in FFS Facilitation

Fundamental Steps of Facilitation

The fundamental steps in FFS facilitation include:

• Setting objectives (indicating what participants should achieve by the end of the topic); and
• Preparation, which consists of: (a) defining a presentation plan, (b) designing the structure of presentation, (c) articulating specific objectives, (d) outlining the steps to be followed in making the presentation, and (e) planning for evaluation of the presentation.

Factors That Need Consideration During Planning

The following must be taken into consideration during the planning of a presentation:

• The profile of the trainees, their level of education
• The relevance of the subject matter to the trainees
• Resources available for the training and constraints
• Thorough revision of material before presentation
• Don’t start your session with an apology

Use of Supporting Materials

Supporting materials are necessary to ensure clear understanding of the messages during a presentation. In this regard, a presentation should be visible, simple, accurate, interesting, practical and sequential (do not display all the material at once).

Learning and Teaching

People learn through seeing, hearing and doing. Effective learning takes place when there is a knowledge gap. In this case, learning becomes a process whereby change in behavior can influence the development of skills, attitudes and knowledge. This is the aim of a participatory session designed and administered by a facilitator with the intention of attaining an objective through guided activities.

**Participants and Their Behavior**

It is also very important for a facilitator to know how to deal with participants with diverse characters and behavior, such as:

- Non-participants (those who act as if they are detached from the activity)
- Super-participants (those who act as if they know it all)
- Disrupters (those who are easily intimidated and tend to be aggressive and quarrelsome)
- Negatives (those who are impatient and uninterested)
- Arguers (those who tend to argue to defend their positions)
- Ramblers (those who just don’t care about the activity)

**Tips for Making Presentations**

Some vital tips for an FFS facilitator to follow:

- Be audible.
- Facilitate two-way communication (i.e. make the presentation attractive).
- Provide handouts at the end of the presentation.
- Make the presentation short, precise and simple (i.e. be mindful of duration).
- Speak slowly to give participants the chance to think, repeat points (i.e. pace).
- Ask questions frequently to keep participants active and alert.
- React to participants’ questions by giving them an opportunity to think about the answer.
- Refer to training notes but do not read from them.
- Establish and maintain individual eye contact to stimulate interest and check understanding.
- Illustrate points with clear and specific examples that participants can relate to.
- Promote joint ownership of learning by posing difficult questions to participants while you are thinking of the appropriate answer and/or search for answers together with participants.
Check whether the participants have understood the material by asking for commitment to change and referring to objectives to see if they have been covered.

- Summarize by picking up the main points of learning from the presentation.

A good FFS facilitation process can be summarized as in Table 14.

Table 14: Difference between teaching and facilitating in a learning process

<table>
<thead>
<tr>
<th>TEACHING</th>
<th>FACILITATING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formal learning</td>
<td>Informal learning</td>
</tr>
<tr>
<td>Individual decision making</td>
<td>Collective decision making</td>
</tr>
<tr>
<td>Directs</td>
<td>Shares ideas</td>
</tr>
<tr>
<td>Top-down approach</td>
<td>Down-up and lateral approach</td>
</tr>
<tr>
<td>Question and answer</td>
<td>Involves discussions</td>
</tr>
<tr>
<td>Less participation</td>
<td>Full participation</td>
</tr>
<tr>
<td>Introduces mainly new ideas</td>
<td>Promotes existing and new ideas</td>
</tr>
<tr>
<td>Vertical communication</td>
<td>Horizontal communication</td>
</tr>
<tr>
<td>Curriculum centralized</td>
<td>Curriculum developed</td>
</tr>
<tr>
<td>Learning materials teacher-generated</td>
<td>Learning materials learner-generated</td>
</tr>
<tr>
<td>Objective</td>
<td>Objective</td>
</tr>
<tr>
<td>Educate</td>
<td>Facilitate acquisition of knowledge skills and sharing of experiences</td>
</tr>
</tbody>
</table>

Source: adapted from Callo et al. (1999)

11.8 Pearl Millet Topics

Introduction

In the drier semi-arid tropics of the world, pearl millet (\textit{Pennisetum americanum} [L.] Leeke=\textit{Pennisetum typhoides} Stapf. and Hubbard) is one of the most important crops of the smallholder farmer. It is particularly adapted to conditions of nutrient-poor soils and low rainfall, yet is capable of rapid and vigorous growth under favorable conditions. It is grown both as a grain and as a forage crop and is the major cereal for the people in the drier and semi-arid areas, such as Mali and Zimbabwe. Yet until very recent times, pearl millet received comparatively little attention from governments and the scientific community (Newman et al., 2010).

Pearl millet is an upright bunch grass that tillers from the base and has an extensive root system that provides drought tolerance. Stems are $\frac{1}{2}$–1 inch in
diameter. It is a leafy plant, with leaf blades that are 8-40 inches long and ½–3 inches wide. The ligule, or junction of leaf blade to leaf sheath, is a fringe of hairs 0.08-0.1 inch long. The sheath has very sparse hairs at the base of the collar and is often hairless. The inflorescence (flower) is a single raceme – 4-20 inches long - that resembles the flower of the aquatic plant known as cattail. The fruit (or caryopsis) is cylindrical, white or pearl in colour, or sometimes yellow or brown, and occasionally purple.

11.8.1 Growth Stages of Pearl Millet

The growth cycle of pearl millet may be divided into three major developmental phases: the vegetative phase (GS$_1$) from emergence to panicle (floral) initiation of the main stem; the panicle development phase (GS$_2$) from panicle initiation to flowering of the main stem; and the grain-filling phase (GS$_3$) from flowering to the end of the grain-filling period (physiological maturity) of the crop (Maiti and Bidinger, 1981). These phases are illustrated in Figure 13.

Figure 13: The growth stages of pearl millet plant

Source: Maiti and Bidinger (1981)
Vegetative phase (GS₁)

This phase starts with the emergence of the seedlings and continues up to the point of panicle initiation. During this phase, the seedlings establish their primary root system (seminal roots) and produce adventitious roots. All leaves are initiated during GS and, in early varieties, six or seven leaves (including the embryonic leaves) are fully expanded by the end of this phase. Tiller buds are formed, their leaf primordia initiated, and several tillers emerge by the end of the phase (Figure 14).

![Figure 14: The tillering stage of pearl millet plant](image)

There is little internode elongation, however, and the apical meristem remains at or below the soil surface. Dry-matter accumulation is almost entirely confined to leaves and roots. Floral or panicle initiation is marked by the elongation of the apical dome and the formation of a constriction at the base of the apex. The size of the apex at floral initiation ranges from as little as 0.5mm in early varieties to as much as 1.0mm in late varieties in which floral initiation may not occur until 50-80 days after sowing.

Panicle development phase (GS₂)

During this phase all the remaining leaves expand fully and the earliest expanded leaves at the base of the stem begin to senesce. Stem elongation occurs by sequential elongation of internodes beginning at the base of the stem (Figure 15). Tillers emerge, undergo floral initiation, leaf expansion, among others, in patterns similar to that of the main stem. The first-formed tillers follow the main stem closely in their development, whereas the development of the late tillers frequently ceases due to competition and/or suppression by the more advanced main stem and early tillers. Dry-matter accumulation takes place in roots, leaves and stem. During stem elongation, the panicle undergoes a series of distinct morphological and developmental changes. These include the development of
spikelets, florets, glumes, stigmas, anthers, and finally stigma emergence (flowering) and pollination, which marks the end of the GS₂ phase.

**Figure 15: The panicle development stages of pearl millet**

*Source: Maiti and Bidinger (1981)*

**Grain-filling phase (GS₃)**

This phase begins with the fertilization of florets in the panicle of the main shoot and continues to maturity of the plant (main stem and tillers), as shown in **Figure 16**. Increases in total plant dry weight during this period are largely in the grain but, as tillers in many varieties elongate and flower after the main shoot, there is also some increase in non-grain components, mainly tiller stems. Senescence of the lower leaves continues and, by the end of the grain-filling phase, normally only the upper two to four leaves remain green. Some varieties develop small tillers in the upper nodes of the stem, particularly towards the end of the grain-filling phase. These tillers have a shorter developmental cycle than the basal tillers, producing only a few leaves and a small panicle. The end of the grain-filling phase (physiological maturity) is marked by the development of a small dark layer of tissue in the hilar region of the grain. This occurs in an individual panicle about 20-25 days after flowering. The grain-filling period for the entire plant (i.e. from flowering of the main shoot to the end of grain filling of the tillers) is longer where tillers flower after the main panicle.

**Figure 16: The grain filling phase of pearl millet plant**

*Source: Maiti and Bidinger (1981)*
11.8.2 Floral Biology of Pearl Millet

The Pearl Millet Inflorescence

Pearl millet inflorescence is a compound terminal spike or panicle with length that generally varies between 20-25 cm and a circumference of 7-9 cm. The panicle may be cylindrical to conical in shape. Inflorescence consists of a central rachis covered with soft and short hairs and bears fascicles on rachillae (Figure 17). The density of fascicles and the length of rachillae determine the compactness or looseness of the panicle. Each fascicle contains spikelets surrounded by a wall of bristles (i.e. involucres). The prolongation of the fascicle axis gives rise to shorter or longer bristle. There are about 800-3,000 or an average of 1,600 spikelets per panicle. A spikelet consists of two glumes and may contain two to four flowers or florets, but generally two. The lower floret is masculine or staminate and the upper floret is bisexual or hermaphrodite (Figure 18).

Figure 17: Floral parts of pearl millet plant

Source: Mero (2015b)

Stigma Emergence in Pearl Millet

Pearl millet is a protogynous species (stigma emerge before the anthers [cross pollination]), as Figure 19 illustrates. The styles start protruding two to three days after the emergence of the panicle. The astylar branches protrude first from the florets in the upper middle region of the panicle and then proceed both upwards and downwards.

In the hermaphrodite flowers, the stigmas emerge faster than the anthers and hence stigmas receive pollen from inflorescence of other plants. The time required for complete stigma emergence varies from two to three days. They remain fresh and receptive for two to three days.
Anthesis in Pearl Millet

The emergence of the first anther usually begins about three to four days after the first stigma has emerged. The anther emergence occurs in two phases. The first phase involves solely the hermaphrodite flowers, and the second phase includes the staminate flowers (Figure 20).

Figure 20: Flowering sequence in perfect and male floret

Source: Mero (2015b)

When the first phase of the emergence of anthers has reached the basal spikelets, the second phase begins when the staminate flowers are functional from the upper part of the panicle (Figure 21).

Figure 21: Anther dehiscence in pearl millet

Source: Mero (2015b)
A panicle continues shedding pollen for about 3 days. The anther emergence continues throughout the day and night. The greatest anthesis takes place between 8 p.m. and 2 a.m., with a peak at about 10 p.m. The increase in humidity and a decrease in temperature have been noted to retard anthers emergence, while lowering of humidity and a rise in temperature speeds up anthesis.

**Natural Cross Pollination in Pearl Millet**

Pearl millet is a highly cross-pollinated species (*Figure 22*). Wind is supposed to be the major cross-pollinating agent. However, insects also effect cross pollination. Protogyny and the time lag between stigma emergence and anther dehiscence favour complete cross pollination, but asynchronous flowering of tillers prevents its full realization. The protogyny in pearl millet is exploited for controlled cross pollination without resort to emasculation.

*Figure 22: Cross pollinated inflorescence of pearl millet plant*

![Cross pollinated inflorescence of pearl millet plant](source: Mero (2015b))

**11.8.3 Crossing Procedures in Pearl Millet**

**Important Considerations**

Pearl millet is a highly cross-pollinating crop. The flowering nature of pearl millet is protogynous (stigma emerge first before the anthers) – the style starts protruding two to three days after the emergence of the panicle. This characteristic allows hybrid development without employing emasculation. This sequence of flowering practically excludes self-pollination in the same inflorescence. Usually, there are 900-3,000 spikelets per panicle, averaging 1,600 spikelets. Each spikelet has two florets, one bisexual and other staminate. The bisexual or hermaphrodite floret consists of a pistil and three anthers. The staminate florets have three anthers.
Controlled Pollination in Pearl Millet

The inflorescence to be used as a female or male is covered with glassine paper bag before any stigma is visible. Generally, the safest stage is when about one-third of the inflorescence is out of the flag leaf sheath. Water repellent brown paper bags or Kraft paper bags are used as pollination bags (selfing). When all stigmas have emerged, the panicle can be considered ready for cross pollination. At this time, pollen is dusted on the female head.

Selfing and Crossing Techniques

If selfed seed of the male parent is not required, then fresh pollen from dehiscing anthers – visible as yellow powder in the transparent selfing bags – can be collected by evenly tapping the inflorescences in which stigmas have completely emerged. The pollination is carried out by quickly removing the bag from the female inflorescence, dusting the pollen collected from the male inflorescence, and then bagging the pollinated inflorescence. For controlled pollination, various traits are used for exploitation of heterosis, such as: (a) days to maturity, (b) plant height, (c) fodder yield quality, (d) grain colour quality, (e) panicle size, (f) hybrid vigor, (g) grain yield, (h) threshability, and (i) resistance to biotic and abiotic stresses.

Mating Design in Pearl Millet

There are several mating or artificial crossing designs, which can be used in breeding. The purpose of mating is to obtain information for a breeder to understand the behavior of a trait and to generate a base population (diversity) in order to initiate a breeding programme. In mating, the choice of parents, frequency of each parent, and the number of offspring produced in each mating as a cross are important considerations. Since pearl millet is a predominantly crossing species, the following mating designs can be used:

- Intra-population improvement - refers to selection within a specific population for its improvement. This is applicable when the end product will be a population or synthetic cultivar;

- Inter-population improvement - refers to selection based on the performance of a cross between two populations. This is applicable when the final product is a hybrid cultivar.
Pedigree Selection in Pearl Millet

In pedigree selection, it is of paramount importance to understand the ancestry of the cultivars to be used as parents. It is therefore essential to keep a record of their ancestry. In this method, hybridization is used to generate variability. It is followed by selections in a segregating population to create variability. Pedigree selection is used mainly for crop plants requiring the improvement of quantitative traits. The procedure in selection involves: (a) establishing a base population, (b) spacing plant progenies of selected plants, and (c) keeping records of generations. The steps in breeding by pedigree selection are illustrated in Figure 23.

Figure 23: Steps in breeding by pedigree selection

Pedigree selection involves not only on phenotype but also on genotype selection. Thus, plants are usually observed and described over several generations, resulting to high degree of genetic purity of the selected materials. However, it is expensive and it takes about 10-12 years to develop a desired variety. To increase homozygosity in each subsequent generation, self-hybridization is conducted as shown in Figure 24.
Backcross Breeding in Pearl Millet

The purpose of backcross breeding is to replace a specific undesirable gene with a desirable alternative, while preserving all other qualities of an adapted cultivar. This process requires backcrossing to ‘recurrent parent.’ It is particularly useful for: (a) improvement of established cultivars, (b) introgress genes from wild relatives, and (c) isogenic lines. This is done by crossing between donor parent and recurrent parent. Repeated backcrossing done to recurrent parent is necessary to replace undesirable genes with desirable ones.

Figure 24: Steps in self-hybridization by pedigree selection

Source: Mero (2015b)
Recurrent Selection

Recurrent selection is a cyclical and systematic technique in which desirable individuals are selected from a population. Improvement of a population is accomplished without losing variability. Thus, this method requires that parents should be highly diverse. This results in a new population that is superior to the original population in performance. Improved population can be released as a new cultivar or used as a future breeding parent.

Recurrent selection is needed to establish a broad genetic base. In this method, it is possible to add new germplasm during the process when a genetic base narrows due to selection. A simple recurrent selection (phenotypic selection) is similar to mass selection, where no tester is involved and selection is based on phenotypic scores. A simple recurrent selection is shown in Figure 25.

![Figure 25: Simple recurrent selection method](source: Mero (2015b))

Line Development Mass Selection

A simple procedure for line development mass selection is briefly described below:
**Year 1**: Plant the source population (local variety, synthetic variety, bulk population, among others). Rouge out undesirable plants before flowering, and then select several hundreds of plants based on the phenotype. Harvest and bulk.

**Year 2**: Repeat the procedure in Year 1. Grow selected bulks in a preliminary yield trial, including a check. The check is the unselected population (original), if the goal of the mass selection is to improve the population.

**Year 3**: Repeat the procedure in Year 2 for as long as progress is made.

**Year 4**: Conduct advanced yield trials. The mass selection may be longer, depending on the progress being made.

**Synthetic Cultivars**

A synthetic cultivar is an advanced generation of cross-fertilized seed mixture of parents (random mating in all combinations). Yield reduction in advanced generations is less when compared to single or double cross, so it is unnecessary to obtain new seeds every season. An advantage of a synthetic cultivar is that it becomes better adapted to the local production environment over time. It is genetically heterogeneous and hence performs stably over changing environments.

### 11.9 Maize Topics

#### 11.9.3 Origin and Diversity of Maize

Maize is one of the most important cereal crops in the world. It was domesticated by indigenous people in Mesoamerica in prehistoric times. There are many varieties of maize and it is consumed in many different ways.

#### 11.9.4 Growth Stages of the Maize Plant

Researchers divide the growth stages of maize into two broad phases: vegetative [V] and reproductive [R] phases, as illustrated in Figure 26. Not all plants in a field reach a particular stage at the same time. Therefore, researchers assume that

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a crop reaches a specific stage when at least 50 percent of the plants show the corresponding feature.

**Figure 26: The growth stages of maize plant**

Source: Chikoshane (2015)

**Vegetative Growth Stage**

Vegetative growth includes stem, leaves and roots.

**Maize leaves**

A single leaf grows from each node. The leaves grow from opposite sides of the plant in an alternating pattern. Each leaf consists of a leaf sheath, blade and collar (see Figure 27a). All leaves are initiated within the first 4-5 weeks after planting. As the internode elongate, a ‘new’ leaf emerges from the whorl every 3 days (depending on the temperature), for a total of 16-23 leaves (depending on variety and environment). The first 4-7 leaves decay and drop-off and are not usually identified from 4 weeks after planting. The last leaf emerges shortly before tasseling. The number of leaves is generally used to describe the different stages of vegetative growth ($V_n$), e.g. the 6-leaf stage is called $V_6$. 
Maize roots

Roots consist of brace roots and crown roots, which form the adventitious roots (see Figure 27b). Most brace roots form after tasseling and concentrate in the top soil. By the eighth week, the root system may be well developed. Individual roots can reach a depth of 2.5m in a good soil.

Figure 27a: The leaves of a maize plant

Figure 27b: The roots of a maize plant
Table 15: Seedling emergence to tasseling

<table>
<thead>
<tr>
<th>Stages</th>
<th>Name</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>VE</td>
<td>Emergence</td>
<td>The seedling emerges from the soil surface</td>
</tr>
<tr>
<td>V1</td>
<td>1st leaf</td>
<td>The collar of the 1st leaf is visible</td>
</tr>
<tr>
<td>V2</td>
<td>2nd leaf</td>
<td>The collar of the 2nd leaf is visible</td>
</tr>
<tr>
<td>Vn</td>
<td>nth leaf</td>
<td>The collar of the nth leaf is visible</td>
</tr>
<tr>
<td>VT</td>
<td>Tasseling</td>
<td>The last branch of the tassel is completely visible</td>
</tr>
</tbody>
</table>

Source: Chikoshane (2015)

Figure 27c: The vegetative stages of a maize plant

Source: Chikoshane (2015)

The Reproductive Stages

Table 16: Reproductive stages

<table>
<thead>
<tr>
<th>Stages</th>
<th>Name</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>R₀</td>
<td>Anthesis</td>
<td>Anthesis or male flowering. Pollen shedding begins</td>
</tr>
<tr>
<td>R₁</td>
<td>Silking</td>
<td>Silks are visible</td>
</tr>
<tr>
<td>R₂</td>
<td>Blister</td>
<td>Kernels are filled with clear fluid and the embryo can be seen</td>
</tr>
<tr>
<td>R₃</td>
<td>Milk</td>
<td>Kernels are filled with a white, milky fluid</td>
</tr>
<tr>
<td>R₄</td>
<td>Dough</td>
<td>Kernels are filled with a white paste. The embryo is about half as wide as the kernel. The top part of the kernels are filled with starch</td>
</tr>
<tr>
<td>R₅</td>
<td>Dent</td>
<td>If the variety is a dent type, the grains are dented. The ‘milk line’ is close to the base when the kernel is viewed from the side in both flint and dent types</td>
</tr>
<tr>
<td>R₆</td>
<td>Physiological maturity</td>
<td>The black layer is visible at the base of the grain. Grain moisture is about 35%</td>
</tr>
</tbody>
</table>

Source: Chikoshane (2015)
**Anthesis**
- Most tassels shed pollen for 5-8 days (Figure 28a).
- A vigorous maize plant can produce 25,000,000 pollen grains.

*Figure 28a: The anthesis of a maize plant*

![Figure 28a: The anthesis of a maize plant](source: Chikoshane (2015))

**Silking Stage**
- Silks are visible (Figure 28b)
- Silk are receptive for pollination

*Figure 28b: The silking stage of a maize plant*

![Figure 28b: The silking stage of a maize plant](source: Chikoshane (2015))
**Blister Stage**
- Ear size is nearly complete.
- Fertilized silks are starting to dry out.

**Milk Stage**
- Kernels are becoming yellow on the outside.
- Silks are dry.
- Kernels are at 80% moisture.
- Stress becomes less of a factor as kernels start to dry down.

**Dough Stage**
- Fluid in the kernel has a consistency similar to dough (70 percent moisture).
- Almost half of the dry weight has been accumulated.
- Five embryonic leaves have formed in the kernel. These will be the first five leaves of a new plant as it emerges next year.

**Dent Stage**
- Most of the kernels have dented on the top.
- Most kernels are about 55 percent moisture at the start of R5.
- A starch layer has formed and begins to progress down the kernel.

**Physiological Maturity**
- The black layer is visible at the base of the grain (Figure 28c).
- Grain moisture is about 35 percent

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**Figure 28c: The maturity stages of maize seeds**

![Blister Stage](image1.png)

![Milk Stage](image2.png)

![Dough Stage](image3.png)

![Dent Stage to Physiological Maturity](image4.png)

*Source: Chikoshane (2015)*
11.9.5 Development of Maize Hybrids

What is a hybrid?

A hybrid is a cross between two or more unrelated parents. It is the finest and most productive innovation in plant breeding, which started a revolution in:

- Agricultural productivity
- Uniformity of products
- Fixing specific traits that serve as trademarks
- Seed production and marketing (breaking the organic link between the production of seed and grain)

The creation of hybrids became the catalyst for the establishment of a specialized business sector, which aimed to meet the increasing demand for food supply by enhancing the productivity of crops. Hybrids allow the optimal exploitation of *heterosis* (hybrid vigor). This is manifested as increased size, yield and performance, resulting from the heterozygosity created in hybrids.

How are hybrids formed?

Breeders are able to create *genetically superior cultivars* with high yield potential by mixing the genes of two or more parents. Heterosis occurs when a hybrid exhibits phenotypic characteristics that are superior to:

- The average of the two parents (mid-parent heterosis)
- The better of the two parents (high parent heterosis)

Hybrids are formed by:

- Crossing two or more unrelated inbred lines;
- Crossing an open-pollinated variety or a synthetic to an unrelated inbred line;
- Crossing two unrelated open-pollinated varieties, or synthetics, or populations.

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Hybrid Maize

Hybrid maize is a product of North American agriculture, where its commercial seed production began in 1926. Over the next three decades, the production of hybrid maize in the USA increased dramatically and, by 1955, covered 100 percent of maize acreage due to its better performance under drought years. It subsequently spread to Europe, where increased hybrid production started from 1984. Expansion in hybrid maize production in Eastern and Southern Africa began in the 1960s and 1970s.

What are the properties of parents of maize hybrids?

Inbred lines

These are homozygous and homogenous parents of hybrid maize.

- **Homozygous** – a genotype with identical alleles present at a gene locus on each of the two homologous chromosomes that control a particular trait.

  ![Figure 29: Homozygous](source: Menkir (2010))

- **Homogenous** – an inbred line is homozygous at almost all gene loci and has a uniform (homogenous) population of true breeding plants (uniform composition)

- **Importance of homozygosity and homogeneity:**
  - The inbred lines with desirable traits can be maintained indefinitely without major genetic changes; and
  - Seed companies can duplicate the exact characteristics of a particular hybrid every time it produces seeds from the parental inbred line.
Open Pollinated Varieties, Synthetics, and Populations

These parents consist of individual plants that are both heterozygous and heterogeneous:

- Heterozygous – each plant contains two different alleles at each locus

![Figure 30: Heterozygous](Source: Menkir (2010))

- Heterogeneous – a mixture of individual plants with different alleles at each locus

Types of Maize Hybrids

Double-cross hybrid

![Diagram](A \times B \rightarrow C \times D)

Heterotic group A

![Diagram](A \times B)/(C \times D)

Heterotic group B

Three-way cross hybrid

![Diagram](A \times B \rightarrow C)

Heterotic group A

![Diagram](A \times B)/C

Heterotic group B
Maize hybrids can be categorized as follows:

- **Conventional maize hybrids (involve inbred parents):**
  - Single cross \((A \times B)\)
  - Three-way cross \(((A \times B) \times C)\)
  - Double-cross \(((A \times B) \times (C \times D))\)

- **Non-conventional low-cost hybrids (involve one or two inbred parents):**
  - Top-cross \((\text{Variety} \times \text{Inbred})\)
  - Double top-cross \((\text{Single cross} \times \text{Variety})\)

- **Non-conventional low-cost hybrids (do not involve inbred parents):**
  - Variety cross \((\text{Variety A} \times \text{Variety B})\)
  - Synthetic cross \((\text{Synthetic A} \times \text{Synthetic B})\)
  - Population cross \((\text{Population A} \times \text{Population B})\)
  - Family cross \((\text{Half-Sib A} \times \text{Half-sib B} \text{ or Full-sib A} \times \text{Full-sib B})\)

The most common types of maize hybrids are described below.

**Single-Cross Hybrid**

A single-cross hybrid is a cross between two unrelated inbred lines \((A \times B)\).

**Advantages:**

- Such hybrids provide better opportunity for expression of heterosis (hybrid vigor). Genetic uniformity of single-cross plants offers a particular advantage for high-yield environments, where they yield better than other types of hybrids;
- A field planted with single-cross seed is impressive, as plant height, ear height, tasseling, silking, pollen shedding and all other characteristics are extremely uniform;
- Because of the availability of excellent inbred female parents, single-cross hybrids represent almost 90 percent of hybrid corn seed market;
- Only two inbred parents are involved, hence a higher level of resistance to diseases, insects and unfavorable weather is evident;
- Production and maintenance of two parental lines is easier.

**Disadvantages:**

- The female parental linen is usually low-yielding, resulting in a high cost of seed production and, therefore, the price of seed;
• If any component is susceptible, it will affect all of the single-cross plants, resulting in lower performance.

**Modified Single-Cross Hybrid**

A modified single-cross hybrid is formed by crossing an F₁ hybrid between two related inbred lines (A x A’) as a female parent to an unrelated inbred line, C, as a male parent: (A x A’) x C).

**Advantages:**

• Use of an F1 hybrid between related lines as a female reduces the cost of seed production and, therefore, the price of seed to growers.

**Disadvantages:**

• Such hybrids require the production and maintenance of three parental inbred lines;
• Pollen shed occurs during a shorter period since all of the plants are genetically alike, with the potential for lower yields, especially under stress conditions.

**Three-Way Cross Hybrid**

This is a cross between a single-cross (A x B) hybrid as a seed parent and an unrelated inbred line (C) as a pollen parent: (A x B) x C).

**Advantage:**

• Lower cost of production and price to growers due to the high yield of the single-cross hybrid used as a seed parent.

**Disadvantages:**

• The hybrid is less uniform in height and other traits than the single-cross hybrid;
• As the pollinator is an inbred parent, this may add some cost to seed production;
• Requires the production and maintenance of three parental inbred lines.
**Modified Three-Way Cross Hybrid**

This is a cross between a single-cross \((A \times B)\) hybrid as a seed parent and a single-cross \((C \times C')\) between related lines as a pollen parent: \((A \times B) \times (C \times C')\).

Advantages:

- Use of an F1 hybrid between related lines as a male produces large quantity of pollen, which ensure good seed setting;
- Use of an F1 hybrid between unrelated lines as a female can significantly reduce cost of seed production and price of seeds.

Disadvantages:

- The hybrid is less uniform in height and other traits than the three-way cross hybrid;
- Requires coordinated production of two hybrids for making the modified three-way cross hybrid;
- Requires the production and maintenance of four parental inbred lines.

**Double-Cross Hybrid**

This is produced by crossing two different single crosses \([\((A \times B) \times (C \times D)\)]\), which permits breeders to bring more different desirable traits together into one hybrid than is possible in a single cross.

Advantages:

- The plants may be ‘buffered’ more against unfavorable situations, which frequently occur at one or more times during the growing season;
- Use of different F1 hybrids as both female and male parents produces abundant pollen and plenty of seeds and thus reduces the cost of production and price of seeds;
- Double-cross plants also have a longer pollination period, which tends to provide more complete filling of the ear with seed, often resulting in higher yields.

Disadvantages:

- The hybrid is less uniform in height and other traits than the three-way cross hybrids;
• Requires coordinated production of two hybrids for generating the double-cross hybrid;  
• Requires the production and maintenance of four parental inbred lines.

**Top-Cross Hybrid**

This is a crossing between an open-pollinated variety (OPV) or synthetic (SYN) and an inbred line: (OPV x A or SYN x A).

Advantages:

• Use of an open-pollinated variety as a female produces plenty of seed and thus reduces the cost of production and price of seeds to growers;  
• The inbred parent harvested from detasseled production fields can be used as a male parent, allowing the seed company to multiply only the female parent in a separate field.

Disadvantage:

• The hybrid is not very uniform for the different traits

**Variety-cross, Synthetic-cross and Population-cross Hybrids**

These are produced by crossing two unrelated open-pollinated varieties, synthetics or populations: (VAR A x VAR B, or SYN A x SYN B, or POP A x POP B).

Advantages:

• Use of an open-pollinated variety (synthetic) as a male produces abundant pollen that enhances seed setting;  
• Use of an open-pollinated variety (synthetic) as a female produces plenty of seeds and thus reduces the cost of production and price of seeds;  
• Better synchrony between tasseling and silking.

Disadvantage:

The hybrid is the least uniform and the least productive among the group.
Main Steps in Hybrid Maize Development

Step 1: Development of inbred lines and classifying them into heterotic groups

To exploit heterosis effectively for increasing the productivity of hybrids, inbred lines should be separated into heterotic groups. This is because parental crosses within a heterotic group result in a low level of heterosis. Greater heterosis is obtained by crossing lines from divergent heterotic groups. Heterotic groups represent broad but distinct sources of germplasm. The number and choice of heterotic groups are arbitrary decisions: two or many.

Advantages of separating inbred lines into heterotic groups include:

- Heterotic patterns provide defined structures to breeding materials;
- Simplifying the management of germplasm;
- Providing a suitable tester for assessing the breeding value of exotic germplasm;
- Facilitating the selection of parents for developing: (a) bi-parental crosses for inbred line development [same heterotic group]; and (b) hybrid combinations for testing [opposite heterotic groups].

Step 2: Dividing breeding materials into heterotic groups

Small numbers of lines

- Evaluate di-allele crosses of a limited number of genotypes (GCA and SCA); this may be impractical for a large number of genotypes.

Large numbers of lines and available testers

- Evaluate test crosses with testers chosen from opposite heterotic groups: (a) significant and negative SCA with tester B and positive SCA with tester A is assigned in one group [A]; and (b) significant and negative SCA with tester A and positive SCA with tester B are assigned in second group [B].
- Lines that combine well with the two testers, but which cannot fit into the two heterotic groups can be (a) maintained as a separate group, or (b) assigned by the breeder where appropriate.

Large number of lines and no established testers

- Group germplasm based on genetic similarity: (a) DNA markers; and (b) pedigree information.
Make factorial or di-allele crosses among lines representing different clusters and ancestry (pedigrees).

Use testers: (a) initial testers can be inbred parents of hybrids with proven performance in your breeding programme; (b) use established testers from other breeding programmes; and (c) adapted populations isolated by time and space are promising candidate testers to define heterotic groups.

Test cross evaluation in multiple locations in a single season would provide adequate data to classify the lines into heterotic groups.

It should be noted that:

- All inbred lines included in a particular heterotic group may not be related.
- Sub-groups within a group allow use of inbred lines from the opposite heterotic groups to improve defects of a line.
- Heterotic groups are not constant; the genetic composition changes over time.

**Step 3: Testing inbred lines in hybrid combinations**

The goal of inbred line development is to identify lines that produce high-yielding hybrids. The correlation between traits of inbred lines and their hybrids is weak: empirical and simulation studies show correlations of less than 0.40. Inbred lines should thus be tested in crosses to identify promising parents of productive hybrids. Testing a large number of inbred lines in all possible combinations is not practically feasible, as the following calculations demonstrate:

Formula for all possible single crosses: \( \frac{n(n-1)}{2} \)

- \( n = 10, \ 45 \) hybrids
- \( n = 20, \ 190 \) hybrids
- \( n = 100, \ 4950 \) hybrids
- \( n = 500, \ 124750 \) hybrids

It is necessary to identify promising lines with good combining ability before their extensive evaluation in hybrid combinations.

All inbred lines are crossed to form a limited number of hybrids for testing. New inbred lines are crossed to a common parent referred to as a **tester**. This approach is called top-crossover or testcross evaluation. With a common tester parent, any difference in hybrid performance can be ascribed to differences in the
combining ability of the inbred lines. A desirable tester has the following characteristics:

- Allows differentiation of lines for combining ability and desirable agronomic traits;
- Permits identifying productive hybrids for direct use;
- Simple to use in a breeding programme.

The choice of a tester depends on:

- Type of gene action
  - Broad-based testers (including open pollinated varieties, synthetics, populations, composites and double-crosses) are presumed to provide tests for additive effects (GCA).
  - Narrow-based testers (inbred line and single-cross) provide tests for non-additive effects (SCA).
  - Studies have shown that inbred testers provide tests for both GCA and SCA.

- Type of hybrid product
  - Use inbred testers to identify lines that form superior single cross hybrids.
  - Use single cross tester to identify lines that form superior 3-way cross and double-cross hybrids.
  - Use a non-inbred tester for identifying lines that form superior non-conventional hybrids.

Crossing to an inbred tester: This is currently the most commonly used line. The process entails: (a) crossing all inbred lines to an inbred tester [testers]; and (b) evaluating the agronomic performance of testcrosses in a few locations using two replications.

Crossing to a broad-based tester: This is mostly used in developing countries. The process entails: (a) crossing all inbred lines to an open-pollinated variety; and (b) evaluating agronomic performance of top-crosses in a few locations using two replications.
Step 4: Evaluating the potential of selected best inbred lines for developing different types of hybrids

Once a few promising lines are identified based on the results of test cross performance, they can be used in the production of single-cross, three-way cross and double-cross hybrids. The following formulas determine the number of possible crosses:

- Number of single crosses = \( \frac{n(n-1)}{2} \)
- Number of three-way crosses = \( \frac{n(n-1) \times (n-2)}{2} \)
- Number of double crosses = \( \frac{n(n-1) \times (n-2) \times (n-3)}{8} \)

For example, if there are 25 promising inbred lines, then the total number of possible crosses would be:

- Single crosses = 300
- Three-way crosses = 6,900
- Double crosses = 37,950

Clearly, the number of three-way and double crosses would be too large for evaluation. A predictive formula developed by Jenkins (1934)

- Three-way crosses = \( 0.5 \times \{ (P1 \times P3) + (P1 + P4) \} \)
- Double crosses = \( 0.25 \times \{ (P1 \times P3) + (P1 + P3) + (P2 + P3) + (P2 + P4) \} \)

The agronomic performance of the resulting hybrids should be evaluated with a few replications in a few locations.

Critical Factors in the Development of Hybrids Suitable for Production and Marketing

- **Target Production and Marketing Environment and Farmers Needs**

  In order to fulfil the requirements of both markets and farmers, the chosen types of hybrids should meet the following criteria:

  - Adaptation to prevalent climatic conditions
  - Resistance to major diseases and insect pests
  - Resistance to parasitic plants (*Striga hermonthica*)
  - Tolerance to drought and low soil nitrogen
  - Resistance to stalk and root lodging (good standability)
- Cost of seed production and purchasing power of the growers

- **Stage of Development of the Private Sector and Other Seed Producers to Multiply, Harvest, Process, Store and Market**

  The capacities of the local private sector should be taken into account when deciding which types of hybrids to develop:

  - Emerging indigenous companies – low-cost hybrids
  - Established seed companies – single-cross and three-way cross hybrids
  - Multi-national and other companies with established breeding programmes – genetically enhanced inbred lines

- **Maturity Groups Appropriate to Target Market Niche**

  The chosen hybrids should be suitable for the local agro-ecological conditions.

  Short-season hybrids (early):

  - Areas with short growing seasons
  - In all production zones where planting is delayed due to shift in the start of the rain

  Full-season hybrids (intermediate-late):

  - Areas with long growing seasons and adequate rainfall

- **Productive Capacity of the Seed and Male Parent**

  Hybrid seed production should be cost-effective:

  - Grain yield of the female seed parent determines the cost of production of hybrid seed (use female parents that are high yielding).
  - Choose male parents with good pollen production capacity and high yield potential.
Summary

- Facilitates precise identification of productive hybrids for on-farm testing and commercialization
- Allows the development of hybrids that meet the demands of the consumers fairly quickly
- Permits staking of multiple traits into a single cultivar
- Increases gain in yield potential through improvements in defensive traits

11.9.6 Composite Breeding/Open Pollinated Variety (OPV) Development

Objectives

- To develop OPV using diverse materials
- To develop farmer varieties adaptable to the local conditions

Materials

In this study, use six or more well-performing varieties as parent materials. The amount of seed to be used per variety must be equal. Bulk the seeds and mix well. These materials can be a combination of hybrid, inbred and traditional varieties

Plot size

- Plant the materials in 4-6 rows, each 5m long. No replications are needed.

Density of Planting

- The density of planting for this study is 25cm between hills x 70cm between rows at one plant per hill

Procedure

- Farmers should identify the different varieties to be used for this study. Refer to the breeding objectives set and the parentals identified by farmers during the community baseline establishment meeting.

Aban, A. and P. Abonete (ed). (2011). Field Guide on Participatory Plant Breeding and Developing Corn Seed System in Farmer Field School. Department of Agrarian Reform (DAR) and Southeast Asia Regional Initiative for Community Empowerment (SEARICE), Diliman, Quezon City, Philippines
- Source out the identified parentals from different sources (from other villages, or from research and breeding institutions).
- Prepare the same amount of seeds (for the identified parentals). Bulk and mix the seeds to ensure uniformity during planting.
- Plant the seeds at 25cm between hills and 70cm between rows at single plant per hill.
- Ensure time isolation of 18-20 days or space isolation of 300m to ensure that there will be no contamination of foreign pollen aside from the plants used as parent materials.
- Allow the plants to cross pollinate for two seasons or cycles.
- Select 300-500 ears/plants and bulk them as materials for the next season.
- Store properly the remnant seeds of 300-500 ears as a source of breeder seeds for the formation of OPV; each ear should be tagged in a single pocket.
- Select 300-500 ears and plant in ear-to-row at 5m long. Before harvest, select 8-10 best families (plants) among the 300-500 ears based on the performance. Go back to the remnant seeds of the 8-10 families and bulk in equal number of seeds and plants in isolated area.
- Employ detasseling; assign two rows of male plants and four rows of female plants. All female plants must be detassled before the maturity of pollen or even before the onset of tassel until the population become stable.
- At the seventh cycle, employ variety enhancement (variety maintenance).

11.9.7 Inbred Line Development

Objectives

- To develop inbred lines for possible use as parent materials
- To enhance farmers’ skills on inbred development

Materials

- F1 hybrid of single cross or composite (at least 15 lines)

Plot Size

- The plot size should be 8 rows, each 5m long

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29Aban, A. and Abonete, P. (ed). 2011. Field Guide on Participatory Plant Breeding and Developing Corn Seed System in Farmer Field School. Department of Agrarian Reform (DAR) and Southeast Asia Regional Initiative for Community Empowerment (SEARICE), Diliman, Quezon City, Philippines
Density of Planting

- The density of planting for this study is 25cm between hills x 70cm between rows at one plant per hill.

Procedure

- Evaluate the hybrids; ensure to keep remnant seeds.
- Identify the superior families or plant.
- Go back to the remnant seeds of superior family or plant.
- Plant the remnant seeds in ear-to-row.
- During tassel initiation, employ bagging of tassel and ear.
- Pollinate the ear with its own pollen. Do not mix the pollen from other plants even if they come from the same family.
- Select and tag superior plants or family weeks before harvests.
- During harvest, collect the selected plants, dry and shell.
- Plant again in ear-to-row, single plant per hill at 5m long.
- Repeat the method up to cycle 6. When using composite, repeat the process until cycle 8.

11.10 Sorghum Topics

11.10.1 Introduction

Sorghum (Sorghum bicolor (L.) Moench) is a self-pollinated diploid C4 grass with a high photosynthetic efficiency. Its small genome size, about 25 percent the size of maize or sugarcane, is fully sequenced and makes sorghum an attractive model for functional genomics of C4 grasses. Sorghum is one among the few resilient crops that can adapt well to future climate change conditions, particularly frequent droughts, increasing soil salinity and high temperatures.30

Sorghum is a major crop in the semi-arid tropics of Africa and Asia, and is an important component in traditional farming systems and diets of millions of people. The crop belongs to an elite handful of plants that collectively provide more than 85 percent of all human energy. Wide diversity exists within the crop,

with different types of sorghum being grown in different parts of the world. As such, the crop has great potential because of its diverse uses. Unfortunately, this potentially promising crop has not realized its full potential because of several drawbacks that have kept its production at lower levels as compared to other cereals.

The area under sorghum and its production in Eastern and Southern Africa has increased significantly from the early 1970s to 2009, while there has been a marginal (18 percent) increase in productivity from 800 kg/ha to over 940 kg/ha during the same period. In Zimbabwe, low sorghum yields are attributed to the prevalence of drought, high variation in the amount and distribution of rainfall, use of traditional and unimproved varieties, and lack of access to seed of improved varieties, among others.

11.10.2 Growth Stages of Sorghum

Figure 31: Growth stages of sorghum

Stage 0 (Emergence)

Emergence occurs when the coleoptile is visible at the soil surface, and generally occurs 3 to 10 days after planting. During emergence, growth is dependent upon soil temperature and moisture, planting depth and seed vigor. Disease organisms

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are favoured by cool, wet conditions and such conditions would result in reduced stands. Therefore, planting should be timed so that germination and early plant growth occur during warm temperatures, and the reproductive phase occurs prior to the hottest part of the growing season.

**Stage 1 (Three-Leaf Stage)**

The three-leaf stage occurs when the collars of three leaves can be seen without dissecting the plant. This stage will occur approximately 10 days after emergence, with great dependence upon temperature. It is important that the planting date is late enough to ensure that plants can grow rapidly at this stage. Slow growth and poor weed control during this stage can seriously reduce yields since the plant is small. Although sorghum does not recover as vigorously as corn, much of the leaf area can be removed since the growing point is below the soil surface.

**Stage 2 (Five-Leaf Stage)**

The five-leaf stage occurs when the collars of five leaves can be seen without dissecting the plant and occurs about 3 weeks after emergence. The root system develops rapidly at this stage. Dry matter accumulates at nearly a constant rate, assuming growing conditions are satisfactory. During this stage, the potential for the plant to develop is determined. Stresses from weed competition, nutrients, water, or insects can dramatically reduce yields if not corrected.

**Stage 3 (Growing Point Differentiation)**

At this stage, the growing point of the sorghum plant changes from vegetative to reproductive. The total number of leaves has been determined, with potential head size following shortly thereafter. Nutrient uptake is rapid and adequate supplies of nutrients and water are necessary to provide maximum growth. Sorghum plants are quite competitive, helping to maintain good weed control over the remainder of the season. This stage occurs approximately 30 days after emergence and is about one-third of the time from planting to physiological maturity.

**Stage 4 (Final Leaf Visible in Whorl)**

At this point, all except the final 3 to 4 leaves are fully expanded, representing approximately 80 percent of the total leaf area potential. The lower 2 to 5 leaves of the plant have been lost and any reference to leaf number from this stage on should be from the top, counting the flag leaf as leaf number one.
Stage 5 (Boot Stage)

At this stage all leaves have fully expanded, which provides maximum leaf area and light interception. The head is full size and is encompassed by the flag-leaf sheath. Potential head size has been determined by this stage. Rapid growth and nutrient uptake continue. Stress from lack of moisture may prevent the head from exiting completely from the flag-leaf sheath, thus preventing complete pollination at flowering.

Stage 6 (Half Bloom Stage)

At this stage, half of the plants in a field are in some stage of bloom. Flowering progresses from the tip of the head downward over a period of 4 to 9 days. At half-bloom, nearly half of the total dry weight of the plant has been attained. This stage usually represents two-thirds of the time between planting and physiological maturity. Severe moisture stress can result in poor head filling. However, if environmental conditions are favorable, the sorghum plant can compensate for limitation in plant size, leaf area or plant numbers by increasing both seed number per head as well as seed weight.

Stage 7 (Soft Dough)

At this stage, the grain has a dough-like consistency and grain fill is occurring rapidly. Approximately half of the seed dry weight is accumulated between Stage 6 and Stage 7. Lower leaves continue to senesce with 8 to 12 leaves remaining at this stage.

Stage 8 (Hard Dough)

By this stage, approximately three-fourths of the grain dry weight has been attained. Nutrient uptake at this point is essentially complete. Severe moisture stress or an untimely freeze before the grain reaches physiological maturity will result in a light, chaffy grain.

Stage 9 (Physiological Maturity)

Maximum total dry weight of the plant has occurred. This stage is determined by the dark spot seed on the opposite side of the kernel from the embryo. Grain moisture at physiological maturity depends on the hybrid, with typical moisture ranging from 25 to 35 percent. Hybrid and weather conditions affect the time between maturity and the proper harvest time.
11.10.3 Hybridization in Sorghum

Important Characteristics of Sorghum

Sorghum is a highly self-pollinating crop. It is about 5 percent natural crossing, but can be as high as 50 percent depending on type (loose). Anthesis in the inflorescence of sorghum (see Figure 32) starts from the panicle tip and proceeds downwards at a progress of 2-5 cm per day (Google, 2015). Anthesis occurs between 3 a.m. and 6 a.m., and completes in 7-10 days. Pollen grains are viable for a short period and stigma remain receptive for 8-16 hours.

Cross Pollination Method in Sorghum

Crossing in sorghum can be accomplished in two ways: either by means of male sterility or by emasculation. The use of male sterility is simple as long as one has the A-, B- and R-Lines (the most critical is the A-line which is male-sterile). Emasculation may be accomplished by hand or hot water treatment.

Hand Emasculation in Sorghum

Emasculation is the removal of anthers in a floret. There are many florets, hence only a part of the panicle is emasculated and the rest is clipped away. The techniques require one to choose a panicle suitable for emasculation. A hand emasculation kit is needed, consisting of a pair of scissors, pair of tweezers, a sharpened pencil, a needle (not a sharp one), and some covering paper.
Procedure for hand emasculation

a. Clip away (with scissors) the tip and lower part of the panicle
b. Retain the part ready to flower in a day’s time
c. Retain a manageable number of florets
d. Insert the needle/tweezers in the middle of the floret
e. Move the needle gently across the glumes
f. Hold the panicle tactfully so as not to skip some florets
g. Rotate the needle at about 90 degrees
h. Take note of the following:

- Try not to damage the stigma; if damaged by mistake then remove the floret
- Make sure 3 anthers are lifted out
- Cover the emasculated panicle with a pollination bag
- Check the following day for skipped florets before crossing

11.11 Groundnut Topics

11.11.1 Introduction and Origin

Groundnut is known botanically as *Arachis hypogaea* L. of Fabaceae (Legume) family. It is a native of South America. The primary centre of origin is a Brazil bordering Bolivia, Uruguay and Paraguay. Africa is considered as the secondary centre of origin. The cultivated species *A. Hypogaea* probably originated from a wild tetraploid, species *A. monticola*, and is most likely a progenitor of *A. hypogaea*.

11.11.2 Botany and Floral Biology

Groundnut is an herbaceous annual plant, basically interlineate in growth habit (Figure 33). The habits are bunch (erect), semi-spreading (ovate) and spreading (prostate). In spreading forms, the axis is very short and erect, and primary branches spread horizontally along with ground. In bunchy type, the main axis is long and erect, and primary branches are oblique to the main axis. The intermediate forms between these two are classified as semi-spreading.

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The plant has a tap root system consisting of numerous lateral roots. Being a leguminous crop, groundnut develops root nodules that help fix atmospheric nitrogen. An inflorescence produces cataphylls at first node that give rise to a flower. The flowers develop above the ground level and the fruits develop below the ground. The flowers are sessile, orange to yellow in colour, and complete and papilionaceous in nature. Each flower has five petals, i.e. a standard two wings and partially united two keels (Figure 34). It is positioned at the end of the long calyx tube having five sepals in gamosepalous condition with three lobes. It has 8–10 stamens and only 8 bear anthers which are in monoadephous condition. The stigma usually protrudes above the anther level.

Figure 33: The groundnut (peanut) plant

Figure 34: The groundnut flower
11.11.3 Groundnut Growth Stages

Seedling stage (Figure 35a): Groundnut seed consists of two cotyledons (also called seed leaves) and an embryo. The embryo comprises the plumule and hypocotyl. The plumule eventually becomes the stems and leaves of the plant. The hypocotyl develops into the root system. Germination process begins when the seed imbibes water.

Vegetative growth stage (Figure 35b): As the plant grows, the root develops very rapidly in comparison to the shoot. The seedling develops slowly, showing as few as 8 to 10 fully expanded leaves 3 to 4 weeks after planting. The main stem develops first and, in runner type plants, the secondary eventually become longer than the main stem. Additional branches arise from nodes on the main and secondary stems.

Reproductive stage (Figure 35c): This stage is characterized by flowering, pegging, developing pods, and pod filling. This stage is also characterized by the development of new leaves and stems (vegetative growth). Several flowers can be produced from one node, however, only about 15 to 20 percent will produce a harvestable pod. Pods attain full size about 3 to 4 weeks after the peg enters the soil, but kernel or seed development barely begins at this point. Mature, harvestable pods require 60 to 80 days of development.

Maturity and harvest stage (Figure 35d): The indeterminate fruiting habit of the groundnut (3-8 weeks flowering) means the plant will have pods of varying maturity. For this reason, groundnut harvest determinations are based on the presence of 70 to 80 percent mature pods. Mature pods turn brown to black on the inside, while immature pods retain a fresh, white appearance. The skin of the seed coat turns to the characteristic colour of that particular variety. The seed is difficult to remove with fingers. The plants of short season varieties usually lose a greater percentage of their leaves, the exception being Virginia types.

Figure 35: Growth stages of groundnut
11.11.4 Hybridization in Groundnuts

Flowering Habit

Groundnut is a self-pollinated crop, but outcrossing may occur in up to 2.5 percent. Crossing is extremely difficult for groundnut. Its flower opens early in the morning (between 6 a.m. and 9 a.m.) and anthers dehisce 1 to 2 hours before that. The next day, all flower parts (except the small sessile ovary) wither. Normally, the flowering period lasts 3 to 6 weeks in the case of bunch types and 6 to 8 weeks in the case of spreading types. After fertilization, the gynophore (i.e. the stalk of the ovary) elongates and curves downward, forming a peg that pushes the ovary into the soil where the pod subsequently develops.

Emasculation

Flower buds that will open the following morning are selected for emasculation. Each flower bud is gently held in the left hand and, with the help of forceps, the standard petal, wings and keels are opened and all anthers are removed. Petals are then placed in their original position to serve as the protective covering on the stigma.

Pollination

In the morning of the next day, between 5 a.m. and 10 a.m., the flowers of selected parents are directly used for pollination. Alternatively, pollen grains are collected in a petri dish and applied over the stigma of the emasculated flower with the help of a hair brush. The pollinated flower is closed and labelled by tying a string around the stem just above it. After fertilization, the gynophore starts elongating to form a peg, which grows into the soil and develops into a pod.
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