MANUAL FOR THE TRAINING OF TRAINERS FOR FARMER FIELD SCHOOLS ON PARTICIPATORY PLANT BREEDING

Developed by the Sowing Diversity=Harvesting security (SD=HS) programme

OXFAM Novib

Community Technology Development Trust (CTDT)

A GUIDE FOR TRAINERS AND FACILITATORS OF FARMER FIELD SCHOOLS ON PARTICIPATORY PLANT BREEDING (FFS ON PPB)

This field guide is developed by the Sowing Diversity=Harvesting Security program (www.sdhsprogram.org) and its consortium partners Community Technology Development Trust (CTDT), Asociación ANDES, Southeast Asia Regional Initiatives for community empowerment (SEARICE) and Oxfam Novib. It is based on Farmer Field School training experience in Zimbabwe, Peru, Myanmar, Lao P.D.R. and Vietnam.

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A few notes on the use of this document

Throughout the document FFS refers to Farmer Field School(s), and PPB to Participatory Plant Breeding. Unless specified otherwise, the term PPB will not only refer to participatory plant breeding in a narrow sense, involving crossings and the selection from segregating plant populations, but also to Plant Variety Selection (PVS), i.e. selecting from genetically stable lines and varieties by comparison, and Plant Variety Enhancement (PVE), i.e. the recreation of a local variety or a deteriorated modern variety by selection according to farmers' description of the variety and its adaptation to new agro-ecological conditions and/or farmers' preferences.

As a rule, each season-long FFS will be facilitated by two trainers, who may be lead farmers, extension service staff or development organization officers. The Training of Trainers (ToT) serves to prepare the trainers of these community-based FFS for their role as FFS facilitators. The participants in the ToT discuss the principles and elements of the FFS, in turn facilitated by a group of master trainers. This document describes the topics that the ToT may address.

Preliminary actions are always needed to introduce the FFS PPB (concept and planning) to local authorities, traditional leaders and other stakeholders. This is an essential step that needs to ensure the buy-in of important stakeholders and their support to the FFS PPB. After the first step of introducing the FFS PPB to official and traditional leaders to gain their endorsement and support follows the second step, consisting of community meetings to introduce the FFS PPB to the community members. Based on these meetings community members are encouraged to register as FFS participants.

TABLE OF CONTENTS

1. HOW TO START THE TRAINING OF TRAINERS

The start of the Training of Trainer (ToT) course is important as it should set a "happy atmosphere, while being determined on purpose and discipline".

a) **Introduction of participants**
Suggestion: the kick-off can be used to "break the ice". A creative and lively form must be used. The simplest is for each participant to introduce another participant. Such introduction may involve sharing of what makes the introduced participant happy, sometimes resulting in funny moments.

b) **Short welcome or opening speech followed by a short introduction of the agenda** explaining what the next 10 days (for a group of 'fresh' trainees to three days (for already active trainees) of the ToT will address.

c) **Organizing the plenary ToT into smaller groups** (a model for how the FFS should also be organized).
Remark: The FFS must be organized in small groups. The small groups form the organizational heart of the FFS. Its objectives are:
- to facilitate active participation of all participants
- to practice collective discussion and decision making
- to allow assignment of tasks and responsibilities to be shouldered by each small group
- to build team spirit within each team (identity, belonging, competitive spirit versus the other teams, etc.).

Suggestion: Small groups may be formed at random, e.g. by participants counting from 1 to 5 and groups formed according to these numbers; or consciously composed by the facilitators to ensure a proper combination of capacities in each small group, e.g. both literate and non-literate farmers, or female and male groups. Each small group can choose a team "name" and logo or even a slogan as part of team spirit building. The tasks and responsibilities of the small groups should be discussed.

d) **Expectation setting**
Suggestion: The expectations may be discussed and agreed upon in the small groups and then shared in plenary. These expectations should be written and "pasted" on the wall of the ToT workshop venue (or the later FFS facility), or otherwise kept for later reference.

e) **Setting the ToT rules**
Suggestion: The rules of the ToT must be drafted by the participants themselves. Later on, the rules of the FFS must also be drafted by the participants. The guiding idea here is that it is not easy for the master trainers to manage a ToT if the trainees are not self-governing. The trainees are expected to observe the effectiveness of the regulations set by themselves. This approach will enable these trainees to follow the same approach when managing an FFS. This step should be carried out in the small groups and may be combined with the previous step of expectation setting. Then each group must present their recommendations for these rules in plenary. The role of the master trainers is simply to facilitate the presentation, discussion and agreement on the rules.

2. INTRODUCTION OF THE FFS PPB

2.1 THE TECHNICAL CONTENT OF THE FFS PPB

ToT participants will discuss the technical objectives of the FFS PPB. In that context, they need to prepare for a number of technical issues that will be addressed in the FFS, in relation to the following questions (just a sample):

- How to strengthen farmers' seed systems?
- How to facilitate the introduction of new cultivars through PVS?
- How to enhance the potential of locally important cultivars through PVE?
- How to obtain new varieties involving farmers as breeders?
- Which steps should be taken in preparing for the FFS PPB programme?
- How to elaborate an action plan in order to apply agreed FFS procedure in the communities?

Brief background on some technical and biological aspects of the FFS

A major learning objective of the FFS is to identify the most important morphological and agronomic traits that contribute to yield under local conditions. In that context, it is useful to provide a short background of what plant genetic resources (PGR) are, and why genetic diversity is important. The following aspects may be addressed:

- First, encourage participants to recite and list the diverse crops found in their local farming systems (using the Diversity Wheel for crops).
- Then, facilitate the appreciation of genetic diversity at the within-crop level by encouraging participants to list the different varieties of their most important crops (using the Diversity Wheel varieties).
- To illustrate, bring a set of photos or living samples of these crops and varieties.
- Let participants list which traits contribute to yield under local conditions, including under conditions of stress (listing of traits and ranking of traits follows after the Diversity Wheel exercise for varieties).
- Introduce a list of traits reported in the literature or normally used by professional breeders in the region on these crops, if feasible.
- Compare both lists and discuss commonalities and differences, if feasible.
- Define which traits may be considered in the FFS PPB curriculum (in the FFS addressed as prioritizing and ranking of traits after the Diversity Wheel exercise on varieties).
- Develop the steps to be taken in the FFS to identify the most relevant traits, that will now translate into breeding objectives.
- Elaborate an action plan to arrive at a procedure in the communities on the above. (Below in chapter xx, a brief introduction is given of what PVE, PVS and PPB can do. Based on their breeding objectives, the FFS participants will choose which intervention they will use.
- Discuss with the farmers (We do not "explain". We allow farmers to make their own analysis and conclusions.) how this is instrumental for the strengthening of farmers' seed systems and farmer-breeding.

Short background to PVS, PVE and PPB

It is important for the trainer to briefly describe how PVS, PVE and PPB are implemented in terms of the technical process. What is even more important is to discuss the potential yield improvement and harvest security, as well as other gains related to taste and processing, that can be achieved by undertaking PVS, PVE and PPB in relation to the efforts needed. This is an initial "vision" to raise expectations and interest.

Under PVS, FFS participants evaluate advanced stable lines from research and breeding institutions and compare these with their own best varieties of the same crop. Evaluations occur under farmers management conditions. This will facilitate the introduction of valuable new cultivars for farmers to meet their production challenges. PVS on a given set of lines can be undertaken in a single or in multiple subsequent seasons, the latter to compare lines under different seasonal conditions. PVS requires access to new materials from research and breeding institutions, and relatively modest time investments, and is the approach that a new FFS can best start with.

Under PVE, superior plants with best characteristics/traits of a preferred local variety that has lost some of its described traits, has become more heterogeneous, or does no longer optimally fit changing seasonal conditions, are positively and/or negatively selected, with its seeds saved for the next season. The inferior plants with inferior characteristics/traits are thus eliminated. Participants discuss the possible impact if they are successful in selecting the superior plants and in eliminating inferior plants. It can be stated that PVE can increase yields with up to 20 % under the same farmer management conditions. The difference in details between PVE in cross-fertilizing and self-pollinating crops will be discussed later. No external genetic materials are required. Whereas selection in the framework of PVE may encompass a single or several seasons, time investments are still modest. A certain capacity to evaluate the selected traits and to identify the best performing plants are essential.

Under PPB, FFS participants select the superior plants from heterogeneous, unstable and often segregating populations, either in the form of lines, breeding populations and accessions, acquired from research institutions and genebanks, or in the form of local heterogeneous varieties. By relying on cross pollination and subsequent selection of elite plants within superior families, farmers can obtain new varieties adapted to their environmental conditions, cultural requirements and market demand. Not only will PPB increase yield and incorporate new characteristics into the resulting stable varieties, but also can farmer-breeders be socially and economically recognized. This form of PPB requires several seasons of selection, and well-trained farmers who are able to carefully select the best plants from a heterogeneous population. PPB in its narrow sense is the most ambitious approach, that can be best undertaken after successful PVS and/or PVE seasons in a community.

Participants should discuss the expected pro’s and con’s of these approaches in the FFS communities, in terms of expected outputs and impact as well as in terms of efforts and necessary conditions to be fulfilled.

The following background texts, in the form of questions and answers, has been partially adopted from the Facilitators’ Field Guide for Farmer Field Schools on Participatory Plant Breeding in Maize, Pearl Millet, Sorghum and Groundnut (Oxfam Novib and CTDT. 2016. Chapters 1.1 to 1.3), as they are similarly useful for FFS on PPB in other countries and agro-ecosystems.

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 are maintained by genebanks and other 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 programs in the public and private sectors, as well as for participatory approaches involving farmers.

In most countries, PGRFA encompass cultivated and semi-cultivated crops, in particular cereals, legumes, root and tuber crops, as well as vegetables. The most important among these are often cereal and legume crops such as maize, pearl millet, sorghum and groundnut in Zimbabwe, potato and other tuber crops, amaranth and quinoa in Peru, and rice, soy bean and pepper in Laos.

Together, these crops provide calories, and many additional nutrients, the latter in particular in the form of vegetables.

Where do the seeds that farmers use come from?
The seeds that farmers use come from informal as well as formal sources. Informal seed sources include farmer-saved seeds directly used or exchanged and traded in local markets. Formal seed sources include seeds from private companies and public institutions, including multi-national companies and international agricultural research centers (see **Table 1**). Seeds may also be obtained from relief organizations and local seed businesses, and these often have a mixed origin. Informal sources may provide both farmers' varieties (i.e. local varieties) and formally registered varieties developed by the public and private sectors.

Table 1: Seed sources of farmers in Zimbabwe. Source: Kasasa (2015)

Farm-saved/ Community-	Relief Aid	Local Seed	National Compa-nies (private &	Multi-national Companies
▪ Mainly crops for household consumption ▪ Maize, millets, sorghum, banana, cassava, beans, cowpea, pigeon pea, green grams, groundnut, Bambara nut, potato ▪ Farmers' varieties & formal varieties (public and pri-vate sector) ▪ Locally produced seed ▪ For household use, ex-change and local markets ▪ Seed normally not certified	▪ Crops creating food security (subsistence) Beans, maize, cassava ▪ Mainly formally released varie-ties ▪ Free distribution, based on voucher schemes ▪ Seed may be certified	▪ All crops ▪ Beans, rice, maize, sorghum, potato ▪ Mainly formally released varie-ties Seed nor-mally certified ▪ Distribution through local markets	▪ All crops ▪ Maize (hybrid & open-pollinated variety [OPV]), sunflower, sor-ghum, wheat, rice ▪ Formally re-leased varieties ▪ Seed certified ▪ Marketing through national and local markets, or through input schemes	▪ All major crops, including export crops ▪ Maize (hybrids), exotic vegeta-bles ▪ Formally re-leased varieties ▪ Seed certified ▪ Marketing through national and local markets
Informal Sources	Intermediary Sources		Formal	

How are plant genetic resources maintained on-farm?
Plant genetic resources for food and agriculture (PGRFA) do change over time. They evolve through the combined effects of natural processes and human selection. The role of farmers and their practices (including 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 the on-farm management, PGRFA are also 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).

Small-scale farmers in developing countries, especially 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 PGRFA conservation?
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.

In Zimbabwe, 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). Cheap, subsidized conventional grains distributed through non-government organizations (NGOs), public distribution systems and food-for-work programmes has further depressed the demand for local 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, tends to leave only marginal lands for local varieties. Consequently, farmers tend to grow local varieties in plots that cannot be used for alternatives that provide better yields and income.

How did domestication of crops result in current crop 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 and have been called centres of origin.

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).

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.

How about drivers of diversity and the role 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. 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.

What is the role of farmers in PGRFA management?
The role that farmers have traditionally played in PGRFA management regards the on-site (*in situ*) selection, improvement and maintenance of local crop varieties (including by positive or negative

mass selection sometimes complemented by pedigree selection of favoured plant types). As mentioned earlier, diversity is the cornerstone for breeding, and hence for adaptation to climate change and for global food security. The conservation and development of diversity requires the contribution by small-scale farming systems and given the threats to these systems (see 3.1.3 above) these need to be strengthened through participatory plant breeding (PPB). The *in situ* management of crop diversity performed by farmers is better 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 also Special Topic 10.7). Therefore, special attention is needed to ensure women's participation in the Farmer Field Schools (FFS).

Given 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 have been analysed in a recent SD=HS study[1] .

2.2 ORGANISING A FARMER FIELD SCHOOL ON PARTICIPATORY PLANT BREEDING

The FFS trainer is expected to paint a general picture of what the FFS PPB will look like and how it will be managed). In this context, the trainer also needs to describe the participatory and learning principles of the FFS. Trainers are advised to review the following sections on non-formal education methods used in FFS and on the FFS as a school without walls.

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.

FFS as a 'School Without Walls'

The FFS involves education and training of adults within their own community and in their own fields. 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:

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[1] The impact of national seed laws on the functioning of small-scale seed systems. A Country Case Study. See www.sdhsprogram.org.

- 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);
- 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.

The trainer should also announce and explain these activities. The FFS trainer also needs to discuss that the FFS PPB plot and the plants on it are the sources of learning and education in this "school without walls", and that the FFS will ensure that data is gathered and analysed by small groups of farmers and reported to the FFS plenary once per week. That because plant growth is influenced by the environment, (Genotype by Environment or G x E), AESA is also conducted once per week.

- 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);
- 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;
- The FFS PPB meet once per week from research plot preparation and sowing until harvest.

The following components will be part of all FFS on PPB:

- Agro-ecological Systems Analysis (AESA) or Gene x Environment Interaction (GEAN) and observation on crop growth and important traits will be done by small groups and reported in plenary: 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
- Group dynamics will be addressed in plenary to maintain a spirit of liveliness and competition. Team-building and leadership training form a major part of the FFS. Some group dynamics exercises are detailed in *Special Topic 10.3 of the facilitators' field guide.*
- Special topics will feature in some weeks, e.g. morphology and growth stages at vegetative stage, reproductive/flowering systems at flowering stage of the crop, etc.
- Final evaluation of the FFS PPB plots will take place at the end of the season, first by the small groups, then reports and discussions at the plenary to come up with an evaluation of the PVS, PVE and/or PPB experiments in plenary by all FFS participants.

3. ESTABLISHING THE BASELINE, SELECTION OF CROP, AND SETTING BREEDING OBJECTIVES

Reference is made to Chapter 4 of the Facilitators' Field Guide, in particular sections 4.1, 4.2, 4.3 for further detail.

The establishment of the community baseline is a crucial step to ensure that the FFS will address the primary needs and objectives of the farmers in the community. Their commitment to the FFS can only be assured if it focuses on their needs. The baseline should be disaggregated by gender in order to distinguish and specifically address women's positions and needs. The community baseline is based on farmers' collective diagnosis of their situation, and the problems and challenges they encounter in growing their crops and varieties.

These baseline data provide 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 and impact of the project will be measured. Establishing the baseline also ensures that the FFS intervention is realistic and well grounded.

Suggestion. As guidance for facilitators to facilitate the FFS process, emphasize that the problems and needs to be addressed by the FFS must all be important to the farmers, and that the objectives of the FFS is to provide solutions. This is to ensure sustained interest and motivation for participants during the entire FFS season.

As part of the baseline establishment, the Diversity Wheel tool is used to assist farmers in assessing diversity at the crop level (usually a list of 10 to 20 crops); in identifying their cop varieties and in evaluating the positive and negative traits of these varieties. The Diversity Wheel experiment is normally carried out before the start of the FFS.

3.1 TIMELINE ANALYSIS ON PGR CONTEXT AND TRENDS

This tool aims to understand the changes in context and trends in relation to socio-economic and bio-physical conditions that contribute to the changes in agricultural systems and genetic diversity over time.

The tool contains the following steps:

1. A simple timeline is drawn on a large piece of paper. Ask the participants to discuss the period of time in the past that could best represent the changes in context and trends (i.e. a period starting 30 years ago). Indicate clearly the points between "now" and "the past".
2. Ask the participants to reflect on the changes in context and trends, such as
   - changes in farming infrastructure,
   - changes in market access,
   - changes in socio-economic context,
   - changes in government policies and programmes
3. Discuss with the participants the impact of these changes on their production systems, crop genetic diversity and implications to PGR development and research.
4. Capture the results of discussion in **Table 2**.

Table 2. Timeline analysis of the context and trends. NB: The text in italics are examples of results of a discussion

Context and trends	**Past situation**	**Current situation**	**Impact on production systems**	**Impact on PGR**	**Implication to PGR development and research**
Infrastructures	*Rainfed*	*Irrigated*	*Several cropping seasons per year from only one*	*Photo-sensitive and long duration varieties replaced*	*Genetic base broadening should address short duration and non-photo-sensitive types*
Market access	*Transport problems Weak urban demand*	*Better roads Urban export market*	*New crops Market standards and preferences Pressure for uniformity*	*Change in crop importance Traits of varieties define by market Diverse varieties for home consumption replaced.*	*Genetic base broadening should address 2-3 important crops for subsistence (food and nutrition security) and livelihoods*
Socio-eco changes	*Mainly subsistence system*	*Off-farm sources of income*	*Reduced labour available for the farm*	*Short duration traits preferred Buying seeds cheaper than processing own seeds*	*Focus on women as their role in farming has increased*
Government policies and programmes	*Few policies with little impact*	*Support intensively mechanized systems, high yields, and market response*	*Mechanization*	*Government support defines which crops /varieties can be marketed*	*Policy work*

3.2 THE DIVERSITY WHEEL (CROP LEVEL)

The Diversity Wheel is based on the 'four-square' analysis tool developed by staff of Bioversity. The importance of this tool is that it provides insight into the level of crop and variety diversity in a community, 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 discontinued altogether.

The Diversity Wheel takes the form of a circle which is divided into four segments and a space in the centre (see **Figure 1**). FFS participants are requested to list crops (and subsequently varieties within a single crop) in the following categories:

- Crops cultivated by many farmers on larger plots of their farms, i.e. crops that are most important in fulfilling farmers' food security needs
- Crops that are cultivated by many farmers but on smaller plots, e.g. in home gardens, i.e. crops with certain uses that fulfil farmers' needs of lesser importance
- Crops grown by a few farmers on large plots, e.g. crops grown by better-off farmers for sales in commercial markets
- Crops grown by a few farmers on small plots, i.e. crops with limited use and value, and at risk of being lost or maintained because of some traits of value and specific uses
- 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, but that have remained in farmers' memories.

Figure 1: Diversity Wheel at Crop level. Source: Adapted from Oxfam Novib (2013), based on Sthapit et al. (2001)

The following steps are taken in using the Diversity Wheel at the crop level:

1. Farmers are divided into five subgroups.
2. The facilitator assigns a chairperson for each subgroup to lead the subgroup discussions (with support from the facilitator) and each subgroup independently starts the exercise.
3. Farmers discuss and list their 8-10 most important crops.
4. Farmers discuss and assign each crop to a 'block' in the wheel that best represents its position in the cropping pattern.
5. Farmers agree on two crops out of the larger group of 8-10 that are most important to them.
6. Each subgroup presents the result of their Diversity Wheel exercise in plenary.
7. The plenary discusses the results of all subgroups and agrees on the most important crops (usually one to three).

3.3 THE DIVERSITY WHEEL (VARIETY LEVEL)[2]

The Diversity Wheel should also be used at the crop variety level. The importance of using this tool at the variety level (see **Figure 2** below) lies in the fact that it shows the level of within-crop diversity and brings out the characteristics or traits within their crops 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:

- Varieties cultivated by many farmers on major plots of their farms, i.e. varieties that can be easily sold against a good price, or have traits or characteristics which farmers appreciate, or varieties of which seeds are readily available;
- 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;
- Varieties grown by a few farmers on large plots, i.e. varieties produced by better-off farmers for external commercial markets;

[2] Annex 11.5 of the Facilitators' Field Guide

- Varieties grown by a few farmers on small plots, i.e. varieties that run the risk of being entirely lost, but which also fulfil specific niche functions in the community;
- 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 interferences, but that have still remained in farmers' memories.

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.

Figure 2: Diversity Wheel at Variety level
Source: Adapted from Oxfam Novib (2013), based on Sthapit et al. (2001)

The following steps are taken in using the Diversity Wheel at the variety level:

1. Farmers are divided into five subgroups.
2. The facilitator assigns a chairperson for each subgroup to lead the subgroup discussions (with support from the facilitator) and each subgroup independently starts the exercise.
3. Farmers choose one of the selected crops that is most important to them, e.g. either maize, rice, potato, wheat.
4. Farmers discuss and list all varieties for that particular crop that are grown in or are available to the community.
5. Farmers discuss and agree in which 'block' each variety belongs in the Diversity Wheel.
6. Farmers subsequently list the positive and negative traits of the varieties in the different segments of the Diversity Wheel.
7. Each subgroup presents the results of their Diversity Wheel exercise to the plenary.
8. The plenary group discusses the results of the Diversity Wheel exercises and agrees on the most important crop varieties.

3.4 SETTING BREEDING OBJECTIVES BASED ON THE LISTING OF POSITIVE AND NEGATIVE TRAITS

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, that can 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. Finally, new crosses to be performed, or segregating populations derived from such crosses, may be subjected to PPB. The results are also used as input information for partnering breeding institutions, enabling the latter to determine which lines may best be provided to a particular FFS site.

The following aspects are addressed in the exercise setting the breeding objectives:

- Each subgroup focuses on the crop(s) and on the varieties of these crop(s) that was/were selected in the Diversity Wheel exercise.
- Farmers discuss and agree on 8 to 10 most important traits that they would like the ideal new variety/varieties to have. These traits must be expressed in morphological and agronomic terms. For example, high yield is caused by a number of underlying traits, like number of tillers, panicle size, etc. Also, the traits must be quantifiable. For example, short duration should be expressed in number of days, e.g. 75 to 80 days to maturity from day of sowing, and preferred height should be expressed in centimetres or inches.

- Each farmer is given a number of seeds (e.g. 20) and is asked to use these to ‘score’ the importance of each of the identified traits.

The results of each subgroup are reported to the plenary for discussion and agreement.

4. ORGANIZING THE FFS PPB

4.1 RULES AND REGULATIONS

It is important to have rules to have an efficient FFS PPB. These rules and regulations must be set by the participants themselves. They must own and be responsible for following up imposing these rules. It is undesirable and impossible for the FFS PPB trainers to “police” the FFS.

4.2 SMALL GROUP FORMATION

The participants should preferably be organized 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 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.

Small subgroups of approximately 5 farmers are created to optimally involve all participants and to improve the functioning of the FFS. In particular, the following considerations are important.

- Farmers learn more and become stronger through collective action.
- Small groups are the key units for data gathering, analysis and reporting.
- Tasks and responsibilities are a collective responsibility of each small group.
- Team building, cohesion and feeling of belonging can be established easier in small groups.
- New leaders and high potential farmers emerge easier from small group activities where more opportunity for participation exists.
- Small groups are responsible for documentation of all experiments, results and analysis.
- The small groups must have a team leader and record keeper.

4.3 ELECTION OF FFS PPB LEADER AND RECORD KEEPER

The plenary FFS shall elect an FFS PPB leader and record keeper for the entire FFS at the community level. The FFS PPB leader shall:

- convene and initiate the FFS PPB
- encourage small group activities
- ensure that all participants are active and that all tasks and responsibilities of the FFS PPB are fulfilled
- encourage the discussion of problems occurring during the FFS and of possible solutions.

5. BASIC BACKGROUND IN PLANT BREEDING

This subject is best covered at crop flowering stage. The following topics are discussed.

- What are morphological and agronomic traits within a selected crop?
- How are traits inherited?

5.1 MORPHOLOGICAL AND AGRONOMIC TRAITS

- Discuss which morphological traits are expressed at harvest time (the traits that can be seen like plant height, leaf shape and orientation, root system, panicle size, seed colour, etc.), and let farmers identify the morphological traits that they like, especially related to stable and/or high yield.
- Then discuss the morphological traits that appear at two additional growth stages, i.e. at seedling stage and at flowering stage.
- Discuss similarly which agronomic traits are important, such as disease resistance, drought tolerance, taste, nutrient content, etc., and when these are expressed and/or most important.

5.2 TRAITS AND HOW THESE ARE INHERITED

- Discuss how genes are the carriers of traits inherited to the next generation. Give simple examples: a gene for grain colour, a gene for plant height, a gene for aroma, etc.
- Discuss how these genes are inherited to the next generation (the principle of sexual reproduction, e.g. male and female flowers, as well as asexual, clonal propagation, through vegetative parts such as cuttings, tubers, shoots, etc.). This step prepares for the next topic.

5.3 TWO MAIN REPRODUCTIVE SYSTEMS

- Discuss how flowers enable the exchange of genes by pollen fertilising the female flower parts.
- Discuss how a self-pollinating crop ensures that its female flowers are pollinated by its own pollen and not by pollen from another plant.
- Discuss how a cross-pollinating crop exchanges pollen with other plants and by which mechanisms a cross-pollinating species ensures that its female flowers are pollinated by pollen from another plant and not by the pollen of the same plant.
- Use living materials, drawings or pictures of a cross pollinating flower and a self-pollinating flower to illustrate the divergent pollination processes.
- Furthermore, discuss how the type of pollination affects how we can manage PVS, PVE and PPB experiments. For example:
    - In a PVS where 10 maize (cross-pollinating) lines are evaluated and farmers like two lines, can the seeds from the FFS PPB plot be used for the next season or not? Why or why not?
    - Under PVE for a cross-pollinating crop, how can superior plants be selected so that they will not carry traits from inferior plants? Why is this?
    - In a first selection cycle of PPB, 25-35 maize families are evaluated, the elite plants from the superior families are selected, afterwards in a second selection cycle cobs from the superior plants will be sowed following the cob-row method. Subsequently, in a third selection cycle, cobs from the superior plants are mixed to create a composite population. In order to reach a stable variety, the superior plants from the composite population will be selected during the next (fourth and fifth selection cycles). If you want to obtain new varieties, should on encourage cross pollination?

5.4 SELECTION

- What is negative selection: to eliminate the inferior plants showing negative traits. Why is it important and when is it applied?
- What is positive selection: to select superior plants with strong positive traits to be used for the next planting/generation. Why and when?
- Under PVS for cross-pollinating crops, can the seeds of the “best lines” be used as seeds for the next season? If not, explain why. Explain where seeds for the “best lines” will come from.
- Under PPB (composite selection method) for cross-pollinating crops, can the seeds of the superior plants be used as seeds for the next season? Why?
- For negative selection under PVE, at what stage of the plant does negative selection no longer works Why?
- For PVE on self-pollinating crops, how is positive selection conducted? How strong should selection be?

6. FFS SITE AND PLOT DESIGN AND ESTABLISHMENT FOR FIELD RESEARCH

6.1 SITE LOCATION AND ESTABLISHMENT

This subchapter applies to PVS, PVE and PPB. In the next sub-chapters specific discussion will address each of these approaches specifically.

The site design and the location of each variety, line or population within the site in separate plots should minimize the risk of distortions of the experimental results. The following parameters (requirements) should be taken into account by trainers in selecting the FFS site and plot locations.

- Avoid distortion by factors such as slope and fertility gradient. Discuss with FFS participants why this is important.
- The plots should be representative of the farms in the ward. Discuss with FFS participants why this is important.
- The sites and plots should be safe from livestock.
- The location of the FFS sites should well accessible and easy-to-see for villagers who are not FFS participants.

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 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. maximally), whether for PVS, PPB or PVE. All members of the FFS should be involved in sowing their respected plots.

During the FFS curriculum the AESA will form a key activity that will be carried out every FFS session. More details on how to design FFS studies have been presented in the facilitators' field guide (Annex 11.6).

The planting density depends on the crop species and should be based on farmers' practice. Alternatively, the following densities are recommended for the following crops, of major importance in Zimbabwe:

- *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 the size of the 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, totalling 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 seed 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.

For cross-pollinating crop like maize and pearl millet, a distance of 300m from the nearest stand of crops is advised, or an isolation by time where the FFS plot is sowed around 20 days before or after the sowing of the community farms. For self-pollinating crops, there is no need for isolation from community farms. In the case of PVS involving cross-pollinating crops, isolation is not essential for the purpose of the experiment, which is to compare the performance of stable varieties or lines. However, if farmers plan to use the seeds from plants compared in the PVS, then farmers may best select plants in the centres of the plots where the effects of cross-pollination will be smallest.

Avoid selecting seeds between borders (even of self-pollinating crops), as cross pollination, at very low level, can still occur. Special care of avoiding the border in the case of sorghum is recommended as higher level of out-crossing can occur especially under stressful conditions.

Suggestion. At this stage of site selection and plot design and planting, the following questions could be discussed with farmers. These questions are not to be presented as such but be used as a guide in the discussion with the participants.

- Should the FFS site have similar agro-ecological conditions as regular farmers' fields in the ward? Why?
- Should the FFS site be easily accessible or not? Why? Easily seen by non-participants or not? Why?
- How can the design of the site and the individual plots avoid distortion caused by factors such as slope and fertility gradient?
- How should the FFS site be subdivided in consideration of the number of small groups that have each been assigned their own sub-plots?
- What are the responsibilities of the small groups in the management of their plots, and in gathering data from each plot?
- What is the planting density (according to type of crops?)
- What is size of the total site and the plots within the site?
- Who shall be responsible in preparing the plots for planting?
- Who shall sow each plot?

6.2 PARTICIPATORY VARIETY SELECTION

This sub-chapter discusses the objectives and specific aspects of PVS.

Participatory variety selection (PVS) is performed between stable varieties or lines. All individuals in a sample are identical or very similar. The qualities of the different varieties or lines are compared and the most preferred varieties or lines are selected and retained. In other words, PVS concerns the comparison in performance for preferred traits between stable varieties and lines, possibly of different origin. These varieties and lines will exhibit the same traits in another location or in another season, provided the conditions (rainfall, temperature, soil, etc.) are similar. Materials qualifying for a PVS may include farmers' varieties, either from the FFS community itself or from other communities, as well as varieties bred by public or private sector breeders, either registered and released, or not available in the market yet. Candidate varieties and lines should be sourced based on the selection objectives that the FFS has set. PVS is a relatively simple whole season experiment, which is normally a good choice for a newly established FFS.

In the case of PVS, the number of plots in the site is determined by the number of lines received by the FFS group. For example, 10 lines plus 1 or 2 local controls need 12 plots. These plots should then be allocated to the small groups. Each small group should be responsible for managing their own plots and for data gathering. In the case of 12 lines and plots, each group will be responsible for 2 lines and plots. The local control can be the responsibility of all groups as the control plot is used as reference against all the other lines.) Plot size per line/variety is about 50 to 60m2.

Often, plant breeding institutions strongly appreciate the value of FFS sites and may want a larger number of lines to be evaluated. However, under their protocol, each evaluation site must contain all lines, and data, results and motivated ranking are expected for all lines from each FFS community. However, an FFS is a learning site. Farmers need to gather and analyse data per plot per week, in addition to the performance of AESA and the discussions of special topics. The quality, rigor and the learning processes of an FFS plummets when FFS participants have to handle tasks beyond what is viable for a 3-hour session once per week. The inclusion of a larger number of lines than 10 in a single FFS is therefore not recommended.

At the start of the FFS and during the season, trainers should communicate the following messages with the FFS participants:

- What is being evaluated, based on the breeding objectives, is the overall productive potential of each variety or line in the PVS. Discuss how/on which traits farmers will evaluate.
- Interested FFS participants can select the best plants in the field for their use in the next season.
- For self-pollinating crops: incidental cross-pollination can happen, so it is advised to avoid plants on the borders of individual plots.
- For cross-pollinating crops: participants need to have "reserve seeds" or request seeds from the provider of the varieties or stable lines. Discuss why.

It is important to note that the setting up of clear breeding objectives is very important and serves to motivate farmers. However, one should be careful in jumping to conclusions regarding the outcome of FFS experimentation. Whereas a single line might be selected as best, this has not always predictive value of what farmers will subsequently adopt. A good example is the successful PVS on 11 sorghum lines in lower UMP, Zimbabwe. After three seasons, one line was considered the best, based on the breeding objectives set by the farmers. But, there were five very close "seconds" in ranking. All 6 cultivars are now grown on at least half an acre per household in more than 50 households in the ward. Secondary traits such as livestock fodder appeared important for the adopters.

6.3 PARTICIPATORY VARIETY ENHANCEMENT

Participatory Variety Enhancement (PVE) is sometimes also called variety restoration to which it is very similar. It is performed to recreate an appreciated local or modern variety that has deteriorated. It may have become more heterogeneous or it may have lost some traits or acquired new unwanted traits. First, breeding objectives must be set. In three seasons strong positive and negative mass selection may result in much better seeds. For example, each season only the best 10% of the plants, panicles or seeds may be retained for the next season.

Varietal restoration (or rehabilitation, a term used in Vietnam) was used for "deteriorated" modern varieties. The original traits of these varieties at the time of release are well documented. Seed samples of these original cultivars are available and are used as a reference/control. The current concept of PVE was first used by farmers in North Vietnam when they applied "seed rehabilitation" of traditional varieties, for which no data on original traits exist. So, the agreement was not to bother about going back to original traits but to improve these cultivars through strong selection pressures according to set selection objectives. This is how the term PVE was coined.

So, PVE is used for traditional and/or local cultivars as well as for modern varieties that have been cultivated in a community for some period of time.

A good example is a PVE on the traditional "garaba" variety, a maize OPV in UMP, Zimbabwe. Garaba has been grown in Zimbabwe for at least 100 years, as farmers claim. The PVE experiments in different FFS are going into two directions: a) strong selection pressure to return to its original traits, versus b) strong selection pressure to improve the cultivar without reference to its original traits.

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.

In sum, PVE is an approach where very popular and important "local" varieties are subjected to strong selection pressure to reduce or eliminate the negative traits and enhance the positive traits. The seeds to be used should be seeds from the same community where the FFS is conducted.

The number of plots in the FFS site should correspond to the number of small groups formed under the FFS. Hence, even if there is only one cultivar, the FFS plot is still divided into smaller plots each assigned to a small group. This is consistent with the learning dynamics needed in participatory research.

For cross-pollinating crops, rouging (the elimination of inferior plants with negative traits) should be conducted starting from germination stage, and in particular before flowering. Discuss with FFS participants why this timing is important. Selection of superior plants with positive traits can be conducted at harvesting time. The seeds from these selected plants are bulked for replanting and continued selection in the next season.

For self-pollinating crops, strong positive selection should be done by selecting the most superior plants at harvesting time that are not located near the borders. The seeds shall be used for the next season. There is no need for negative selection or rouging. Inferior plants can be allowed to mature, since they will be disregarded at the time of positive selection at harvesting time.

PVE requires more selection capacity from the FFS participants than PVS. One of the advantages of PVE is the local nature of the plants that are the object of selection, meaning that many FFS participants know the features and peculiarities of such variety. Usually, PVE can result in highly improved varieties within three seasons.

Plot design should allow the performance of comparisons between the local variety to be improved, selections from the line to be improved, and a relevant local control variety.

6.4 PARTICIPATORY PLANT BREEDING

Participatory plant breeding (PPB) is more complex. Selection takes place within a single and large population of different individuals. This population might have been obtained from farmers' own crossings or from breeders. Usually, mass selection and bulking of preferred individuals is used in the first generations, i.e. the first rounds after a crossing (F1 to F4), whereas later pedigree selection may be preferred. The number of samples selected in later generations should be limited because only a limited number of individual panicles or plants can be used for planting panicle-to-row or ear-to-row in the next generation. In other words, there is a need to balance the need for a limited number of pedigree lines out of management considerations, with the aim to capture as much of the genetic potential of the segregating population as possible. The “error” of taking only one or two pedigree lines, or even single hill selections at F5 should be avoided, as the risk that the isolated materials in the end do not perform according to expectations is too high. After six to eight rounds of selection normally the progeny is sufficiently homogeneous and stable. A new variety has been created.

PPB focuses on the creation of entirely new varieties in farmers’ fields with superior yield and qualitative characteristics (traits). These varieties often exhibit a wider genetic diversity than the stable lines and varieties analysed in PVS or enhanced in PVE. Different methods can be used to achieve the objective of creating a new variety through PPB. This manual only describes the composite selection method as the method of choice for a cross-pollinating crop such as maize.

In order to develop a new variety of maize (a cross-pollinating crop) different sources of seeds can be used. One important source is formed by seed samples of local varieties that show a good performance in the FFS community or region. Another source can be materials (varieties, accessions or breeding populations and breeding lines) from research organizations that potentially show good adaptation to the farming systems of the FFS participants. A third source may be formed by commercial hybrid varieties to which no plant patents apply. In order to create a new variety through PPB, FFS participants should consider each seed sample as a family of distinct and different individuals, and then identify elite plants within the superior families that the FFS wishes to consider in shaping and selecting in a composite population (gene pool).

In case the FFS participants collect samples from their own or neighbouring communities it is important to take into consideration that farmers often recognize a local variety which is in fact a heterogeneous population, whereas the rest of the plant characteristics may be less stable and can vary. In other words, the FFS participants should assume that farmers’ populations are genetically diverse, and that each sample collected in the community should be considered as genetically distinct, representing a particular population of individuals.

In an open-pollinated variety the individual plants are all genetically different. Any of the plants in the variety may have been the male or female parent of one or more of the harvested seeds by acting as the pollen parent or the seed parent. Since the parent plants may all be slightly different, also the individual seeds in the offspring are different. In order to develop a new open pollinating variety (OPV) with a wide genetic base it is recommended to include between 25 and 35 seed samples which are as different as possible. Each sample should consist of 50 to 60 plants. One or two popular varieties can be used as references in the first and second selection cycle. This number of samples offers enough potential to allow for positive selection.

In creating a composite population, it is important to synchronize flowering of the different parent cultivars. Earlier maturing seeds may be planted later, and late maturing varieties should be planted earlier. Alternatively, a segregating population resulting from a cross between two attractive parents and performed by a breeder may be obtained for further selection and creation of a new stable variety. Usually, such populations are in their third or fourth generation after the initial crossing. Yet another option is that the initial cross is not performed by a breeder but by a farmer, and that the FFS selects a new variety from the first generation onwards.

In conventional plant breeding, the process to develop a new variety from an original crossing experiment may take 10 to 15 years. A professional plant breeder normally seeks to develop varieties that are adapted to large areas, providing a sufficiently large market for the company. In that context, new varieties are tested in many locations and over several years before these are released.

In PPB, farmer-breeders participating in the FFS focus on the development of new varieties that are adapted to the specific conditions of their own communities by using simpler selection methods. That condition allows for the creation of a new PPB variety in a period of 5 to 6 years. However, even then the creation of a new variety based on PPB thus still requires a sustained commitment and capacity of farmers participating in the FFS, strong mass selection pressure during every growing season being recommended. For PPB, depending on the selection cycle and the type of propagation of the crop (self-fertilizing or cross-pollinating), various populations resulting from positive or negative selection (early generations), or from pedigree selection, may be planted in adjacent sub-plots, whereas controls might be planted as well.

The following approach, taken from the PEDIGREA Field Guide[3], can be adopted in developing a new variety of a self-fertilizing crop such as rice, from a segregating population.

The aim of this element of the field studies is to practice line selection in segregating materials. The use of segregating rice materials received from breeding stations allows farmers to study selection techniques as early as in the first FFS-PPB season. This segregating material may involve either F2, F4 and/or F6 generation seeds.

Selection from heterogeneous populations resulting from crossings
In most start-up FFS PPB experiments, farmer-generated segregating materials are introduced for learning and development purposes. In this way novice farmer-breeders and more experienced farmer breeders can benefit.

1. During the FFS-PPB participants will conduct up to four different selection rounds in the field: in the vegetative stage, the flowering stage, the ripening stage and at maturity. Selection criteria for each stage should be applied based on the breeding objectives, and field observations should be documented. Note measurements on traits such as germination, tillering, panicle length, early maturity, etc.
2. During each selection round, walk through the plot and inspect each individual plant. Mark outstanding plants with a bamboo stick or ribbon. Assign different sticks, ribbons or colours per selection round to identify the plants. Make drawings of outstanding plants.
3. Perform the final selection round just prior to harvest. Select as many plants as possible for the next generation. Do not select less than 10% of the total population since preferred characteristics or special combinations of characteristics may not yet be visible and otherwise may be lost. If in the F2, the selected number of plants may be slightly more (20%) than in later generations. For example, when a F2 plot consists of 500 plants, select between 100 and 150 plants.
4. After harvest, dry the panicles or thresh the seed and put the seed in a bag. Panicles or seed may be bulked, depending on the selection technique used. Attach a label to identify the parent varieties in the cross and the generation.
5. Dedicate some time to explain the breeding cycle of rice, the cause and use of segregation, and the techniques involved in bulk selection. Let farmers practice by drawing the diagrams of rice breeding involved in bulk selection.
6. Optionally, elaborate on the principles of pedigree selection and modified bulk selection. This may depend on the FFS situation.
7. Further topics for discussion:
    a. What is the reason for the high amount of variation in the plots under study?
    b. Are the plants in the segregating plot very different from the parent varieties?
    c. How many generations are needed to select a new stable variety?

Bulk selection
In the bulk selection method, after making the initial cross, the segregating progenies are propagated till F4 or F6 without selection. Once a high degree of homozygosity is reached, individual selection

[3] http://edepot.wur.nl/3663

with progeny testing is applied. Each field is about the same size (2000-5000 hills). Plant or panicle (pedigree) selections are made in the F6 and planted in rows for selection in the F7. Preliminary yield tests are conducted in the F8. Finally, the best populations are multiplied and tested for adaptability starting from the F9 onwards. There are some variations on this selection procedure, such as negative and positive bulk selection respectively. In this method only individuals with trait values greater or less than some threshold level are used for breeding. Values are set either by rouging poor performing plants (negative selection), or by selecting plants above the specified level (for example all plants above 100 cm). This modification of the bulk method slightly increases selection pressure. In the latter (positive) selection method, at least 30-40% of plants in the population should be selected to avoid a loss of plant genotypes.

Pedigree selection
In the pedigree selection method, the progeny (or offspring) of a single plant is tested, which allows for a much more precise selection technique. Pedigree selection may start in the F2: single well performing plants are selected and separately harvested. The seed is then grown in plant rows in the F3. Complete rows may be accepted or rejected. In the accepted rows well performing plants are selected and again separately harvested for continued progeny testing in the F4 and F5. Plots in the F5 can be slightly larger to allow for preliminary observations for yield. In the F6 the rows have become fairly uniform, which allows for wider testing, including eating quality, in the F7 and F8.

Modified pedigree/bulk selection (semi-pedigree)
This is a combination of the above selection techniques. In this method bulk selection is applied from the F2 until the F4, which is followed by pedigree selection. Application of each of these methods depends on the situation, the available area and capacity of the farmers to manage the field studies, and the number of varietal crosses. Figure 3 (next page) is a presentation and discussion of a selection method involving a heterogenous population of maize for the purpose of creating an open pollinated variety modified from Acosta (2015)[4].

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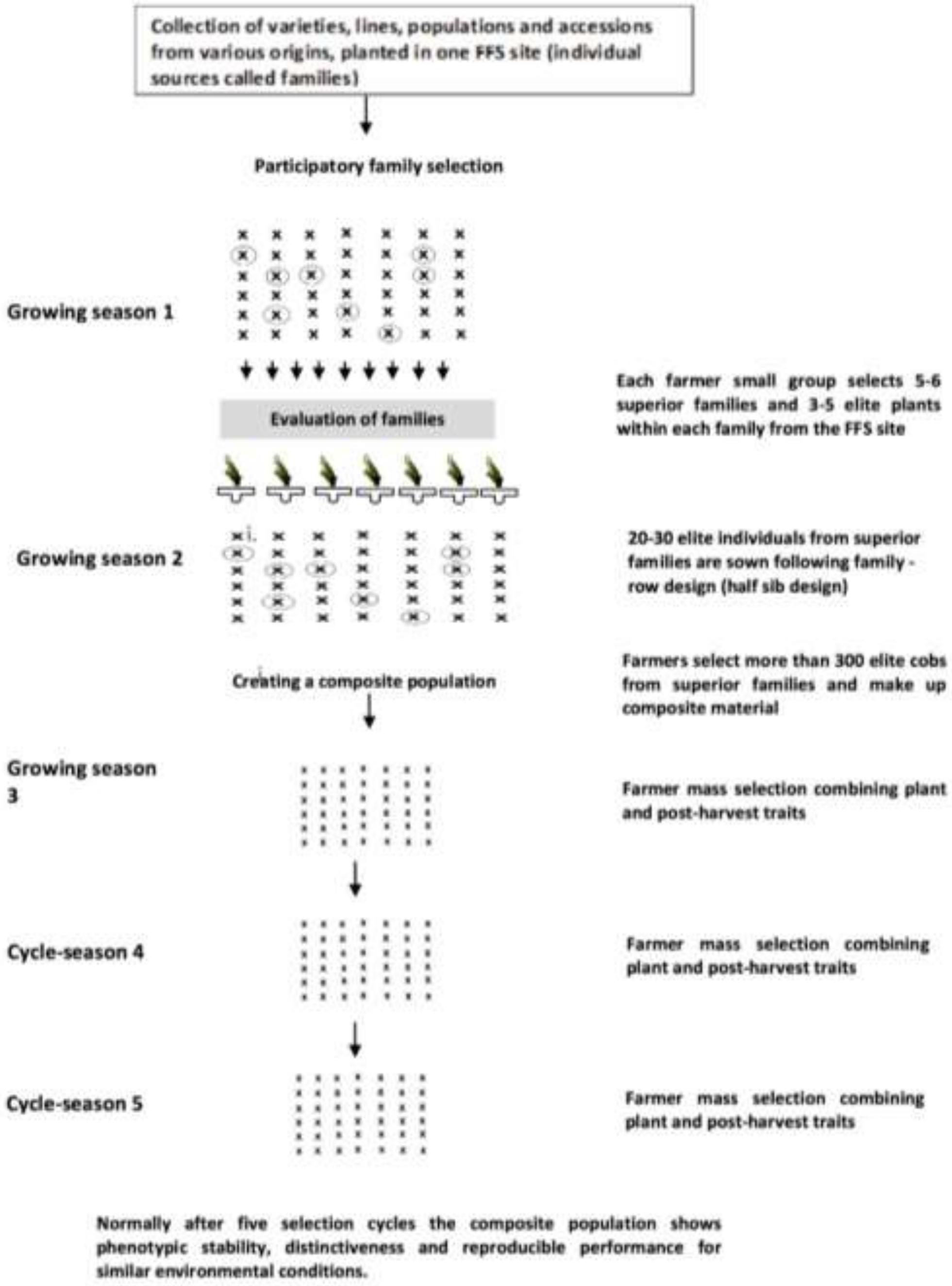
[4] Acosta-Roca Rosa (2015), Mejoramiento genético participativo de una población de maíz (Zea mays L.) en condiciones de polinización abierta en el Municipio Batabanó, Mayabeque. PhD Thesis, La Havana.120p

Figure 3: Composite selection scheme of maize varieties under open pollinating conditions



In order to initiate the first selection cycle:

- Discuss from where and how to access varieties, lines, populations or accessions from various sources, including research organizations
- Plan to bring these materials to the FFS community
- Consider each sample of collected seeds as a family and elaborate a site layout. Include one or two popular varieties as references.
- Allocate 25-30 families in the FFS site. Each family should be represented by 50-60 plants.
- Discuss by whom and when selection will be done. Use as reference table Maize Agro-ecosystem analysis (AESA) sheets at vegetative (Table 6, Annex 1) and maturity stages (Table 8, Annex 1).
- Select 5-6 superior families and 3-5 elite plants from these superior families (in total equivalent to 15-30 rows in the next growing season).
- Keep the seeds from each elite plant as a family to be sown in the next season.
- Discuss the selection process needed in the next seasons following the abovementioned scheme.

7. WEEKLY ACTIVITIES

7.1 DESCRIPTION OF THE ONCE PER WEEK, 3HR FFS ACTIVITIES

Each FFS meeting will start with a plenary and will include a role call and a discussion of the activities of the day (including special topics, if any and if the facilitator and/or resource person has planned to address special topics). The small groups will then visit their assigned specific plots in the FFS PPB research site to

- observe plant growth and, if appropriate, gather morphological and agronomic data
- perform AESA: soil condition, moisture condition, frequency of pest and diseases and weeds, temperature and other relevant conditions that affect plant growth
- discuss in small groups the collected data and prepare for plenary reporting
- take care of management of their plots (e.g. weeding) and make decisions (e.g. need to re-sow, or need to rogue, etc.).

The group reports will be presented in plenary, and the plenary will make decisions and prepare plans for the next week. Problems will be raised, and solutions agreed upon.

7.2 SHORT OVERVIEW OF THE SEASON-LONG FFS ON PVS/PVE/PPB

Find below a hypothetical overview of weekly activities, showing the sequence of FFS activities.

Weeks	General Activities	Specific activities
Week 1	Organization of the FFS	Review of FFS objectives Organization into small groups Setting the rules and regulations for the FFS
Week 2	Establishing baseline and setting breeding objectives and identifying plant materials	Diversity wheel for crops, diversity wheel for varieties, ranking of traits, setting of breeding objectives Acquiring plant materials for the FFS (varieties, lines, populations, accessions, including local varieties)
Week 3	Site selection and preparation Acquiring/sourcing plant materials	Site selection and land preparation. Acquiring plant materials as in week 2
Week 4	Establishment and sowing of FFS plots	Seeds have been received or prepared earlier Review of FFS objectives Plots assigned per small group
Week 5	AESA performance Assessment of germination	Assess if re-sowing is needed Monitor if pests or diseases threaten seedling survival
Week 6	AESA Assessment of plant vigour	Special topic on morphology of the FFS crop and its growth stages Rouging in case of PVE Tagging selected plants in case of PPB
Week 7	AESA Assessment of plant vigour	Rouging in case of PVE Tagging selected plants in case of PPB

	Morphological measurements of selected plants	
Week 8	AESA and assessment of plant vigour, plus morphological measurements	Rouging in case of PVE Tagging selected plants in case of PPB Special topic on the role of farmers in seeds management and breeding
Week 9	AESA and assessment of plant vigour, plus morphological measurements	Final rouging before flowering Tagging selected plants in case of PPB
Week 10	AESA	Final rouging before flowering Special topic on inheritance of traits / genes
Week 11	AESA	Special topic on different reproductive systems. Exercise in pollination control

Notes on various forms of AESA

The results of the field observations should be documented in tables and graphs.
Several methods exist for the comparison of performance between varieties, e.g. the scoring card method, pair-wise ranking, and index ranking. Here only pair-wise ranking and the scoring card method will be discussed and used. An exercise on these evaluation methods to acquaint farmers with the two alternative methodologies is recommended.

On a weekly basis, each small group is requested to present the results of their observations from the past week in plenary. This allows farmers to discuss the various issues related to these observations and to compare the reported with their own observations. The following questions should be answered.

- Describe the features of plant development for each observed variety, line or population. Do the different varieties or families develop in the same way? How did the weather conditions influence plant development? Which fertilizer and other management practices were applied during the week? How did this affect crop development for each variety or family?
- Compare the frequency of occurrence of pests and diseases with that of the previous week. Do more pests and diseases occur in the field or in/on the plants occur? Is it possible to understand why? Is the development of pests and diseases similar on all varieties and/or families? Do some varieties or families have a lower frequency of insect pests or few symptoms of disease infection?
- Compare growth development and performance of the varieties or populations tested. Identify the best performing varieties (PVS), lines (PVE and PPB) or populations (PPB), based on observations and the weekly data gathered, and explain why these were selected and which stage was important for the selection:
    - vegetative stage
    - flowering stage
    - maturity stage
- Arrange the varieties, lines or populations in the order according to their overall levels of performance.
- Compare with the observations of other small groups (farmers not in the reporting small group), what varieties, lines or populations do they prefer? Are these the same? Why? Are there any other important characteristics mentioned by other small groups that were not included in the observations? Why are these characteristics important?
- At flowering, ripening and harvesting stage:

    - Is there any difference in the time of flowering between varieties, lines or populations?
    - Is there any difference in the time of ripening between varieties, lines or populations?
    - Do some varieties. Lines or populations shatter more easily compared to others?
    - Do some elite plants occur within promising liens or populations (PVE or PPB)?
    - What are the characteristics of the pods, cobs and panicles?
    - Do you observe any difference in seed characteristics?
- At the end of the season:
    - After comparing the yields, do you see major differences?
    - Are the varieties, lines or populations with the least disease damage also the best yielding?
    - Do you observe any difference in the cooking qualities and taste of the varieties or lines?
    - Note and discuss specific problems, advantages observed for each variety, line or populations. Are there important observations that were missed out during the season's activities?
    - How can we improve the study for the next season?
    - Prepare a summary table of all the characteristics observed.

8. DISASTER RISK REDUCTION IN PLANT GENETIC RESOURCES FARMER FIELD SCHOOLS

This chapter forms a learning Module for use in the Farmers' Field Schools in Zimbabwe. It focuses on the management of plant genetic resources in such a way that the risks resulting from climate and weather disasters can be optimally reduced, and that food and nutrition security is improved.

8.1 BACKGROUND

Disaster Risk Reduction (DRR) seeks to protect livelihoods from shocks and aims to make food production more resilient and more capable of absorbing impact of and recovering from disruptive events (according to the FAO Framework Guideline).

This module will focus on ways by which the management of biodiversity can facilitate DRR. More especially, this module will focus on farmers' management of plant genetic resources for food and agriculture in times of stress.

One of the most important strategies in building agricultural resilience against biotic and abiotic stresses is the management and broadening of the genetic base of agriculture. The FAO DRR for Food and Nutrition Security (FNS) Framework and Guideline, and the Hyogo Framework of Action[5] identified improved biodiversity management as a major tool in DRR. Rebuilding under disaster conditions should aim at an improved agro-biodiversity status.

Genetic base broadening can be achieved by farmers, based on their capacities and knowledge. Farmers' fields have been the source of PGR diversity for millennia. Small farmers with their diverse needs and cultures located in diverse environments have remained a most important source of PGR diversity. In the last century, the role of specialized research institutions and private commercial seed companies has also become important. Their breeding efforts, however, have focused on a limited number of crops. Institutional policy and commercial interest have resulted in a breeding focus on major crops in favourable environments and on farmers with higher resources.

The DRR objective of increasing resilience in food production through the broadening of the genetic base of crops is rooted in the need to strengthen the resilience of smallholder farmers. The DRR module within the FFS curriculum addresses the unreliable weather patterns and the resulting biotic and abiotic stresses that smallholder farmers increasingly experience.

The DRR module is of paramount importance for Zimbabwe as the country is prone to drought which has become increasingly disruptive as a result of recent climate change. The country contains five agricultural zones. Zones 3 to 5 are the drier zones, where most smallholder farmers of the country live. However, also the higher rainfall zone 2b does not escape from drought stress as rain patterns change and wet seasons have become shorter.

In addition, farmers of Zimbabwe face political instability, and challenges in governance, coupled with serious economic problems.

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[5] It was endorsed by the UN General Assembly in the Resolution A/RES/60/195 following the 2005 World Disaster Reduction Conference and adopted by 168 countries

Elements of DRR addressing the role of PGR

The FAO DRR Guidelines and the Hyogo Framework of Action proposed improved management of biodiversity as one of the major tools for DRR addressing Food and Nutrition Security. Taking these as a point of departure, the following elements have been included in the DRR module on PGR:

- Building Resilience
- Safeguarding diversity
- Preparing to respond and to rebuild

Interventions of the module aim at the following levels:

- Household level
- Community Level
- Institutional level

8.2 CAUSES OF DISASTERS

Many disasters are caused by nature.

- Drought is characterized by lack of rainfall, high temperature and/or shortened rainy periods. As a result:
    - after sowing, seeds may fail to germinate and may require re-sowing
    - heat stress may severely reduce yields
    - long-duration and medium-duration crops and varieties may fail as growing season become shorter
    - short-duration varieties may not have enough time to recover from drought periods.
- Floods may be caused by heavy rainfall and denuded forest cover, and also follow from uneven rainfall distribution over the season, and in particular in the presence of water-logged soils. As a result:
    - planted seeds and young seedlings may be damaged
    - water-logged soils may cause plant stress, reducing harvests.
- Massive pests and disease outbreaks, sometimes due to climate change and sometimes due to trans-boundary movement of seeds, plants and produce that allow migration of pests and the surge of pathogens with few natural enemies and diseases that meet low resistance or tolerance. As a result:
    - massive crop damage may occur, reducing harvest or even causing total crop failure
    - seeds for the next season may be lost.
- Wild fires when not contained, may also damage or destroy crops in the field.

Disasters may also be caused by humans and their institutions.

- Civil disturbances and violence may disrupt agricultural activities.
- Economic crisis may disrupt flow of agricultural inputs, reduce prices of farmers' produce or lead to a collapse of markets in general.

The potential impacts on farmers and their livelihood systems may include

- severely reduced harvests and even total crop failure
- lack of food causing malnutrition
- disruption of farmers' seed systems
- lack of sufficient resources, including crops and varieties, which may not be sufficient to rebuild the farming systems after a disaster.

8.3 ELEMENTS OF A DRR INTERVENTION

Building Resilience

The main objective is to protect livelihoods from shocks, rendering food production more resilient and capable of absorbing disaster impact and the capacity to recover. It this context it is important to understand the specific role of PGR management in building resilience.

Potential measures to build more resilience using PGR and related farming measures include:

- increasing the number of crops, in particular through the introduction of more drought tolerant species (e.g. dryland legumes, and small grain cereals such as sorghum and pearl millets)
- enhancing the role of women's crops and their home gardens where stresses can be better managed
- increasing the number of varieties of a specific crop, especially in the form of short-duration and drought-tolerant varieties, and/or water-logging tolerant varieties
- undertaking plant selection and breeding initiatives which address stresses caused by recurrent disaster conditions (through PPB, PVE and PVS)
- increasing (doubling to tripling) the amount of seeds maintained (this is not difficult for small grains cereals and maybe not too difficult for home garden seeds) to allow potential repeated sowing
- adjusting the cropping calendar by introduction of short-duration varieties
- using integrated pest and production management (IPPM)
- involving research and breeding institutions in sourcing better adapted crops and varieties.

Safeguarding ("watch" to be prepared)
The objective is to foresee possible upcoming disasters, to adjust livelihood and farming strategies, and to prepare to be able to respond. Potential developments to watch and prepare for include the following:

- long-term weather forecasts for the entire growing season (e.g. El Niño or La Niña or normal seasons) and predictions of severity (resulting in adjustments of crops, varieties and/or cropping calendars)
- short-term weather forecasts within an ongoing season predicting rain patterns on a week-to-week basis (allowing adjustments of sowing dates, weeding dates, fertilizer applications, etc.)
- pests and diseases trends in adjacent and other parts of the country and in adjacent countries
- economic and political trends and its potential impacts on agricultural production and consumer behaviour.

Responding to disasters
The objective is to minimize the negative impact of disasters, and to rebuild livelihoods and especially food production with the help of stronger and more resilient measures and tools. Potential approaches to respond to disaster, and options to prepare for rebuilding, include:

- accessing and using NUS and increasing the use of home gardens
- accessing food aid when necessary
- accessing and ensuring access to seeds of appropriate varieties for the next cropping season
- ensuring that information and views from farmers, especially women, are received by community-based and other aid organizations

8.4 FFS ACTIVITIES ADDRESSING DISASTER RISK MANAGEMENT

Any FFS may undertake DRR activities, by assessing disaster experiences, its impacts, and potential sources of resilience, and measures to take. An FFS exercise has been developed for this purpose.

The aims of this exercise to assess how farmers in the FFS are able to prepare for disasters, and in particular:

- to facilitate farmers' assessment of the impacts of disaster as a basis for addressing the resulting problems
- to identify the areas of vulnerability in the community's agro-ecosystems and in particular in their crops and varieties
- to evaluate the potential resilience of introduction of new particular crops and varieties

- to evaluate options of upgrading home gardens and women's crops to contribute to more resilience
- to appreciate further options for farmers to adapt to disaster situations.

Potential outputs include:

- increased appreciation of crop diversity and varietal diversity (e.g. reliability of dry land legumes, the resilience of short duration varieties of pearl millet and sorghum) as an approach to cope with disaster conditions
- increased appreciation of home gardens and other women's crops as a contribution to increased resilience and nutrition security
- appreciation of options for adaptation or adjustment to respond to the crisis (e.g. repeated sowing, adjustment of cropping calendar).
- a plan to maximize access to information and forecasts of potential disasters and to understand reasons for failures to adequately prepare
- identification of concerns regarding the availability of seeds of important crops and varieties, such as adequate numbers of seeds for possibly required repeated sowing, the bulking (multiplication) of seeds of better adapted drought tolerant crops and varieties, etc.
- expansion of plots for drought tolerant crops and increased attention for home gardens
- increased interactions with development institutions to help ensure that the recovery and increased resilience agenda can include crop diversification, participatory selection and the breeding of more appropriate varieties.

Initial tools and activities include:

- a comparative assessment of the performance of major and minor crops under El Niño and La Niña conditions, as well as their performance under major biotic and abiotic stresses directly caused by disaster situations (e.g. heavy rain spells army worm outbreaks during La Niña)
- a comparative assessment of the performance of varieties of major crops under El Niño and La Niña conditions, as well as their performance under major biotic and abiotic stresses directly caused by disaster situations
- an assessment comparing the 12-month cropping calendar with the seasonal risk hazard calendar, in order to identify which major crops would be affected most and to see which alternative crops could play a role for food security at months when food is scarce (by questioning "when do hazards usually occur?", "how long?", a seasonal hazard risk calendar can be established)
- an assessment of how families and the community as a whole have appreciated and made use of the forecasts of potential disasters and of the result of the actions taken (e.g. multiplication of seeds of appropriate crops and varieties)
- an assessment of the contribution of NUS during and after disaster conditions (list of available NUS and potential usefulness)
- an analysis of the reasons for strong and weak preparation by families and/or FFS communities to cope with disaster conditions
- an analysis of initiatives towards rebuilding that utilised crop diversification and a wider use of varieties, as opposed to initiatives that did not result in building more resilience (conditions remained "the same")
- a listing of main adaptation strategies that have been used during disaster conditions and a collective ranking of strategy effectiveness (e.g. late sowing, repeated sowing, use of short duration varieties)
- an assessment of the preparedness and "watchfulness" approaches (this may include the effective mapping of seed sources, ranking of these sources and the establishment of quantities required for re-planting; the potential role of a community seed bank).

ANNEXES

ANNEX 1: AESA SHEETS

Table 3: Sorghum/pearl millet. Agro-ecosystem analysis (AESA) sheet at vegetative stage

AGRO-ECOSYSTEM ANALYSIS (AESA) SHEET AT VEGETATIVE STAGE											
AESA NO.			GROUP				DATE				
VARIETY/LINE/ POPULATION					CROP						
CROP AGE					CROP STAGE						
WEATHER CONDITION (Sunny, Cloudy)					CROP CONDITION (Poor, Fair, Good)						
SOIL CONDITION (Dry, Moist)					Comments on Crop Condition (If not good)						
Sample No.	Date Planted	Date of Emergence	% Seed Germination	Stand establishment	Leaf Color	Plant Height (cm)	No. of Leaves (before tillering)	No. of Tillers (before flowering)	Disease Name & Intensity (Low, Medium, High)	Pest Name/ Number/ Intensity	Natural Enemies Name/ Number/ Intensity
1											
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19											
20											
Total											
Average											
Weed Spectrum (Grasses, Sedges, Broadleaves, Annual, Perennial)						Weed Density (Low, Medium, High)					

Table 4: Sorghum/pearl millet. Agro-ecosystem analysis (AESA) sheet at Reproductive stage

<table>
<tr><th colspan="9">AGRO-ECOSYSTEM ANALYSIS (AESA) SHEET AT REPRODUCTIVE STAGE</th></tr>
<tr><td colspan="2">AESA NO.</td><td></td><td>GROUP</td><td colspan="2"></td><td>DATE</td><td colspan="2"></td></tr>
<tr><td colspan="2">VARIETY/LINE/ POPULATION</td><td></td><td></td><td></td><td>CROP</td><td colspan="3"></td></tr>
<tr><td colspan="2">CROP AGE</td><td></td><td></td><td></td><td>CROP STAGE</td><td colspan="3"></td></tr>
<tr><td colspan="2">WEATHER CONDITION (Sunny, Cloudy)</td><td></td><td></td><td></td><td>CROP CONDITION (Poor, Fair, Good)</td><td colspan="3"></td></tr>
<tr><td colspan="2">SOIL CONDITION (Dry, Moist)</td><td></td><td></td><td></td><td>Comments on Crop Condition (If not good)</td><td colspan="3"></td></tr>
<tr><td>Sample No.</td><td>Plant Height (cm)</td><td>No. of Tillers</td><td colspan="2">Disease Name & Intensity (Low, Medium, High)</td><td>Pest Name/Number/ Intensity</td><td>Natural Enemies Name/Number/ Intensity</td><td>Days to 50% Flowering</td><td>Others</td></tr>
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<tr><td>Total</td><td></td><td></td><td colspan="2"></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Average</td><td></td><td></td><td colspan="2"></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="3">Weed Spectrum (Grasses, Sedges, Broadleaves, Annual, Perennial)</td><td colspan="3"></td><td>Weed Density (Low, Medium, High)</td><td colspan="2"></td></tr>
</table>

Table 5: Sorghum/pearl millet. Agro-ecosystem analysis (AESA) sheet at maturity stage

AGRO-ECOSYSTEM ANALYSIS (AESA) SHEET AT MATURITY STAGE											
AESA NO.			GROUP				DATE				
VARIETY/LINE/ POPULATION					CROP						
CROP AGE					CROP STAGE						
WEATHER CONDITION (Sunny, Cloudy)					CROP CONDITION (Poor, Fair, Good)						
SOIL CONDITION (Dry, Moist)					Comments on Crop Condition (If not good)						
Sample No.	Plant Height (cm)	Days to Physiol. Maturity	TILLERS		PANICLE			Grain Pests/Diseases (Name/% Incidence)	Lodging (%)	Yield (kg/ha)	Gross Margin ($/ha)
			Productive	Unproductive	Exertion (Partial, Full)	Length (cm)	Circumference (cm)				
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20											
Total											
Average											

Table 6: Maize. Agro-ecosystem analysis (AESA) sheet at vegetative stage

AESA NO.		GROUP	
VARIETY/LINE/ POP-ULATION		CROP	
CROP AGE		CROP STAGE	
WEATHER CONDITION (Sunny, Cloudy)		CROP CONDITION (Poor, Fair, Good)	
SOIL CONDITION (Dry, Moist)		Comments on Crop Condition (If not good)	

Sample No.	Date Planted	Date of Emer-gence	% Seed Emer-gence	Stand Es-tabli-shment	Leaf Color	Plant Height (cm)	Disease Name & In-tensity (Low, Me-dium, High)	Pest Name/ Number/ Intensity	Natural Enemies Name/ Number/ Intensity
1									
2									
3									
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Total									
Average									

Weed Spectrum (Grasses, Sedges, Broadleaves, Annual, Perennial)	

Table 7: Maize. Agro-ecosystem analysis (AESA) sheet at reproductive stage

AESA NO.		GROUP		DATE			
VARIETY/LINE/ POP-ULATION			CROP				
CROP AGE			CROP STAGE				
WEATHER CONDI-TION (Sunny, Cloudy)			CROP CONDITION (Poor, Fair, Good)				
SOIL CONDITION (Dry, Moist)			Comments on Crop Condition (If not good)				
Sample No.	Plant Height (cm)	Disease Name & Intensity (Low, Medium, High)	Pest Name/Num-ber/ Intensity	Natural Enemies Name/Number/ Intensity	Days to 50% male flowering	Days to 50% female flowering	Others
1							
2							
3							
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19							
20							
n..							
Total							
Average							
			Weed Density (Low, Medium, High)				

Table 8: Maize. Agro-ecosystem analysis (AESA) sheet at maturity stage

	AGRO-ECOSYSTEM ANALYSIS (AESA) SHEET AT MATURITY STAGE											
AESA NO.			GROUP					DATE				
VARIETY/LINE/ POPULATION						CROP						
CROP AGE						CROP STAGE						
WEATHER CONDITION (Sunny, Cloudy)						CROP CONDITION (Poor, Fair, Good)						
SOIL CONDITION (Dry, Moist)						Comments on Crop Condition (If not good)						
Sample No.	Plant Height (cm)	Days to Physiol. Maturity	Husk cover (Good/ fair/ Bad)	No. of cobs per plant	Cobs size	No of grain rows in the cob	Ear rot (Absent/Present)	Grain Texture (hard/ Soft)	Grain Pests/Diseases (Name/% Incidence)	Lodging (%)	Yield (kg/ha)	Gross Margin ($/ha)
1												
2												
3												
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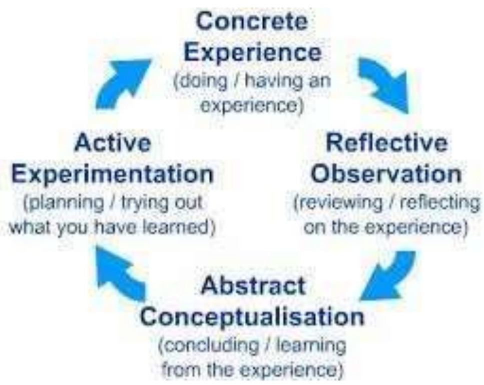
ANNEX 2: THE FFS APPROACH

Principles of Adult Learning applied in Farmer Field Schools

This section explains the experiential learning theory and how it is applied within the FFS activities. It further highlights the suitability of this approach for the FFS: as for many adult conditions, farmers' knowledge is by nature experiential and therefore the experiential learning methodology is instrumental to support farmers' experiments, observations, decisions and practices in their management of plant genetic resources for food and agriculture (PGRFA). The section includes an explanation of the scale-up pathways in which the FFS is one of the six components.

Facts (concrete experiences) 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 analyse the outcomes of their experiments, which are the basis of farmer's decisions and actions (Hagiwara, 2012). New and/or additional knowledge is produced through transformation of experience.

Figure 4: Kolb's learning styles. Source: http://www.simplypsychology.org/learning-kolb.html http://www.businessballs.com/kolblearningstyles.htm



Following FFS group discussions, experimentation based on ideas and practices (that 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, farmers' experimentation and learning also has the potential to increase awareness of their rights, to improve their negotiating skills and, ideally, to result in the establishment of farmers' networks (Iqbal, 2014). Critical analysis (i.e. reflection, which is part of Kolb's learning cycle and integrated in 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)
- allow collaboration with scientists (through farm experimentation, participatory breeding methods).

The participatory activities undertaken within the FFS allow gathering information which is not only relevant to the local context, but also makes 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 a 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 decisions (Tadesse and Bahiigwa, 2015). For farmers, more interactive forms of working in the FFS result in better learning results (Francis *et al*., 2011). Knowledge has to be developed 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). With regard to 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 enables participants to question traditional norms and practices that restrict their behaviour and actions; the safe environment/space is key for the learner to undertake critical reflections and develop 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 collectively among group members. This gives room to a change of mind at the individual level as well as to wider social change, because it links impact on the individual with impact on social structures, in addition to inducing technological innovations (Duveskog, 2013).

FFS in the context of scaling up

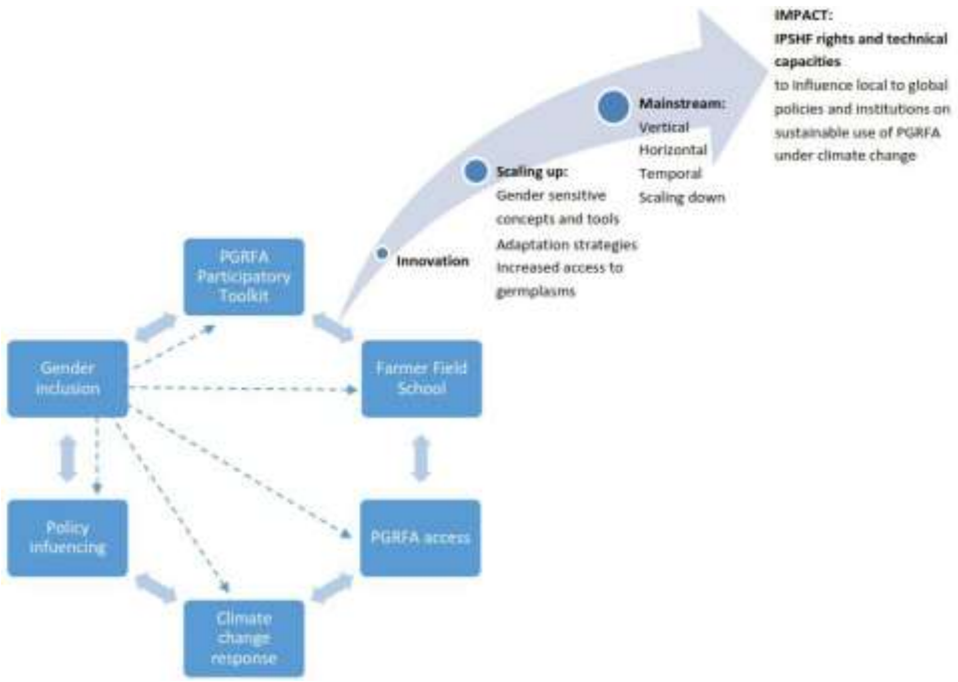


Figure 5: Scaling up pathways. Source: Oxfam, ANDES, CTDT, SEARICE, and CGN-WUR (2015)

The FFS is an important instrument for scaling up. The Scaling-up pathways (Figure 5) describes 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.

***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.

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 practice. Its main feature is the use of theoretical and analytical processes to understand a development problem in order to arrive at action for social change. 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; research carried out collaboratively allows movement beyond subject/object boundaries.

Methodologically, organizations that facilitate participatory and emancipatory development use tools that are based on horizontal learning, empowerment and reflection on practice (e.g. Chambers, 1983; 1994; 1997). Use of a PAR approach implies an explicit process for planning, analysis and reflection towards emancipatory and social change goals.

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 aiming for climate change adaptation and food sovereignty.

Features of PAR facilitating Scaling-up

The following presents a list of generic characteristics of action research from a variety of approaches. Participatory action research:

- 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 enquiry gives it the ability to be transformative both for individuals and their social worlds;
- Is 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 a trans-disciplinary approach - recognizes that knowledge is contested and can only be gained through a process of interacting with others towards a common goal.

Most action researchers claim that learning follows a cycle. Each cycle contains four stages as shown in Figure 6. The action research cycle must be used in the FFS activities.

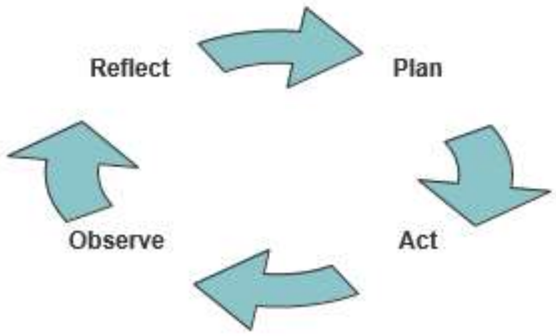


Figure 6: Action Research Cycle. Source: Oxfam, ANDES, CTDT, SEARICE, and CGN-WUR (2015)

ANNEX 3: PEARL MILLET TOPICS

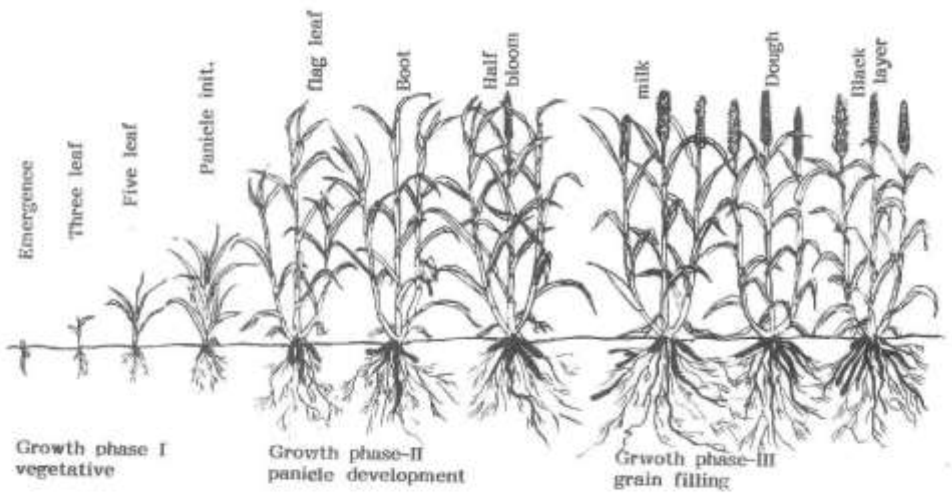
In the semi-arid tropics of the world, pearl millet *(Penniseturn americanum* [L.] Leeke**=***Penniseturn typhoides* Stapf. and Hubbard) is an important crop of the smallholder farmer. It is particularly adapted to conditions of nutrient-poor soils and low rainfall, yet is capable of rapid and vigorous growth under favourable conditions. It is grown both as a food grain and as a forage crop and is the major cereal for the people in semi-arid areas, such as in the Sahel and in parts of Southern Africa, as well as in India. Yet until 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 ½–1 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, shows a fringe of hairs 0.08-0.1 inch long. The sheath has very sparse hairs at the base of the collar and is rather 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, sometimes yellow or brown, and occasionally purple.

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 from 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 7**.

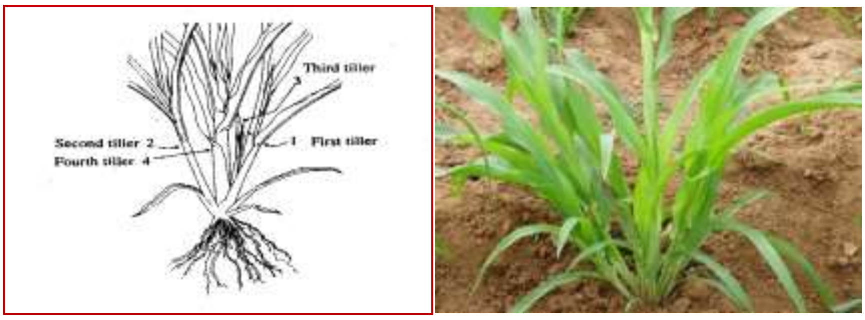
Figure 7: The growth stages of pearl millet. Source: Maiti and Bidinger (1981)



The 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 also produce adventitious roots. All leaves are initiated during **GS1** 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 8: The tillering stage of pearl millet plant. Source: Maiti and Bidinger (1981)



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 second 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 9**). Tillers emerge, undergo floral initiation, leaf expansion occurs, 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 GS_2 phase.

Figure 9: The panicle development stages of pearl millet. Source: Maiti and Bidinger (1981)

Grain-filling phase (GS3)

This final 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 10**. 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.

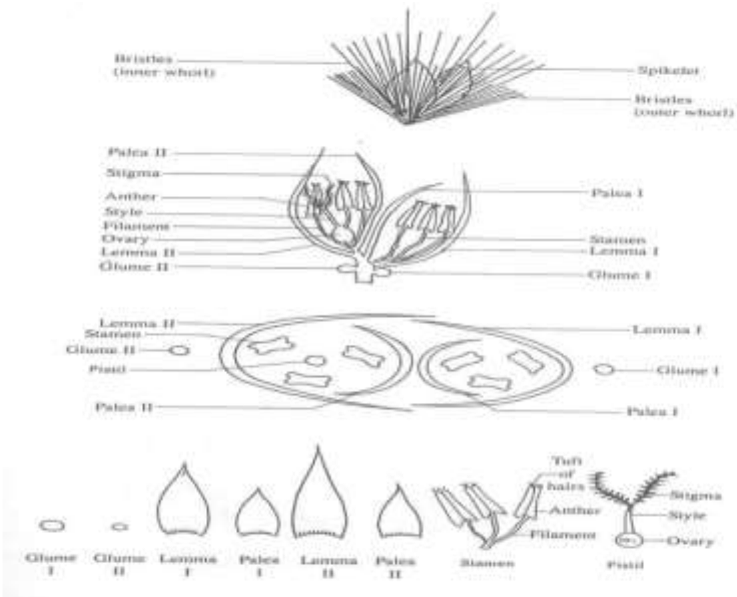
Figure 10: The grain filling phase of pearl millet plant. Source: Maiti and Bidinger (1981)

Floral biology of pearl millet

The pearl millet inflorescence

Pearl millet inflorescence is a compound terminal spike or panicle with a length that generally varies between 20-25 cm and a circumference of 7-9 cm. The panicle may be cylindrical to conical in shape. The inflorescence consists of a central rachis covered with soft and short hairs and bears fascicles on rachillae (**Figure 11**). The density of fascicles and the length of rachillae determine the compactness or looseness of the panicle. Each fascicle contains spikelets surrounded by bristles (i.e. involucres). The prolongation of the fascicle axis gives rise to shorter or longer bristles. 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 12**).

Figure 11: Floral parts of the pearl millet plant. Source: Mero (2015b)[6]



[6] Mero, M. (2015b). Pearl Millet Biology. Presentation made during a 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, 16-31 July 2015

Figure 12: The inflorescence of the pearl millet plant. Source: Mero (2015b)

Stigma Emergence in Pearl Millet

Pearl millet is a protogynous species (stigma emerge before the anthers to promote cross-pollination), as **Figure 13** 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.

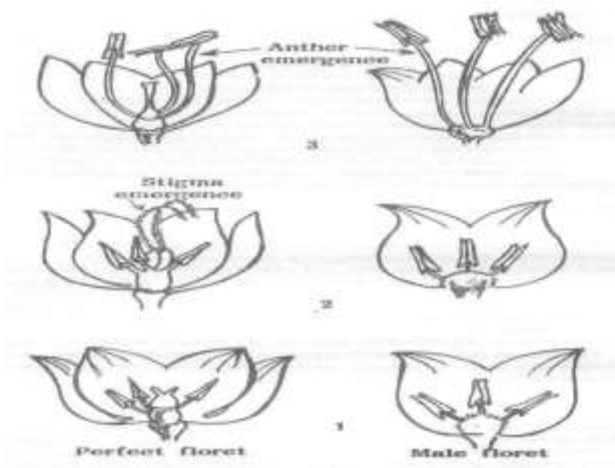
In the hermaphrodite flowers, the stigmas emerge faster than the anthers and hence stigmas receive pollen from inflorescence of other plants. The time required for complete stigma emergence varies from two to three days. They remain fresh and receptive for two to three days.

Figure 13: Stigma emergence in pearl millet. Source: Mero (2015b)

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 14**).

Figure 14: Flowering sequence in perfect and male floret. Source: Mero (2015b)



When the first phase of the emergence of anthers has reached the basal spikelet, the second phase begins when the staminate flowers are functional from the upper part of the panicle (**Figure 15**).

Figure 15: 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 16**). 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 can be exploited for controlled cross pollination without having to resort to emasculation.

Figure 16: Cross pollinated inflorescence of pearl millet plant. Source: Mero (2015b)

Breeding approaches

Crossing procedures in pearl millet
Pearl millet is a highly cross-pollinating crop. The time lag between stigma emergence and anther dehiscence excludes self-pollination in the same inflorescence and allows hybrid development without employing emasculation.

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. By controlled pollination, various traits can be improved through heterosis, such as: (a) days to maturity, (b) plant height, (c) fodder yield quality, (d) grain colour quality, (e) panicle size, (f) hybrid vigour, (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 behaviour 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 can be applied 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 applied when the final product is a hybrid cultivar.

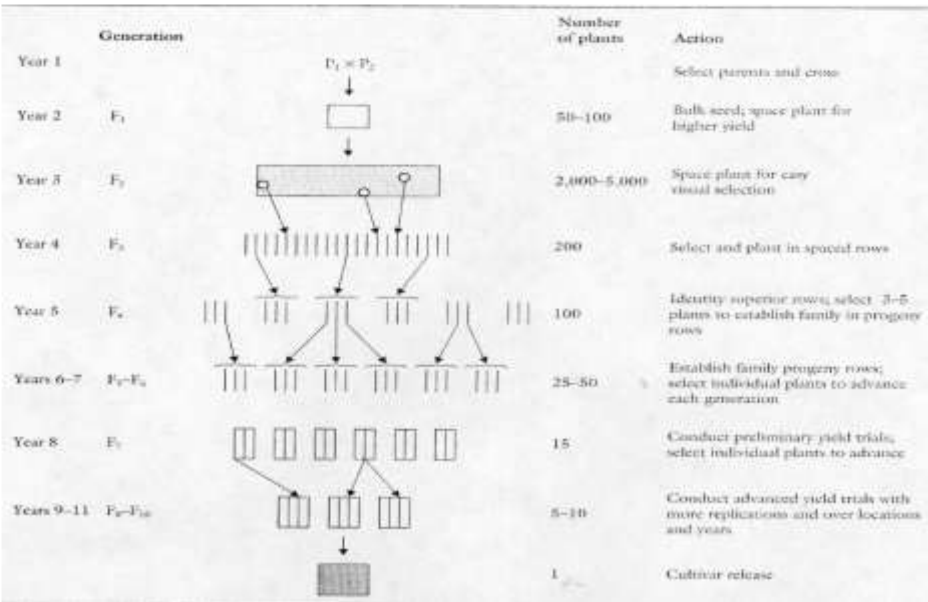
Pedigree selection in pearl millet

In pedigree selection, it is of paramount importance to understand the ancestry of the cultivars that are 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 selection 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:

- establishing a base population,
- spacing plant progenies of selected plants,
- keeping records of generations.

The steps in breeding by pedigree selection are illustrated in **Figure 17**.

Figure 17: Steps in breeding by pedigree selection. Source: Mero (2015b)



Plants are usually observed and described over several generations, resulting in a high degree of genetic purity of the selected materials. However, 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 18**.

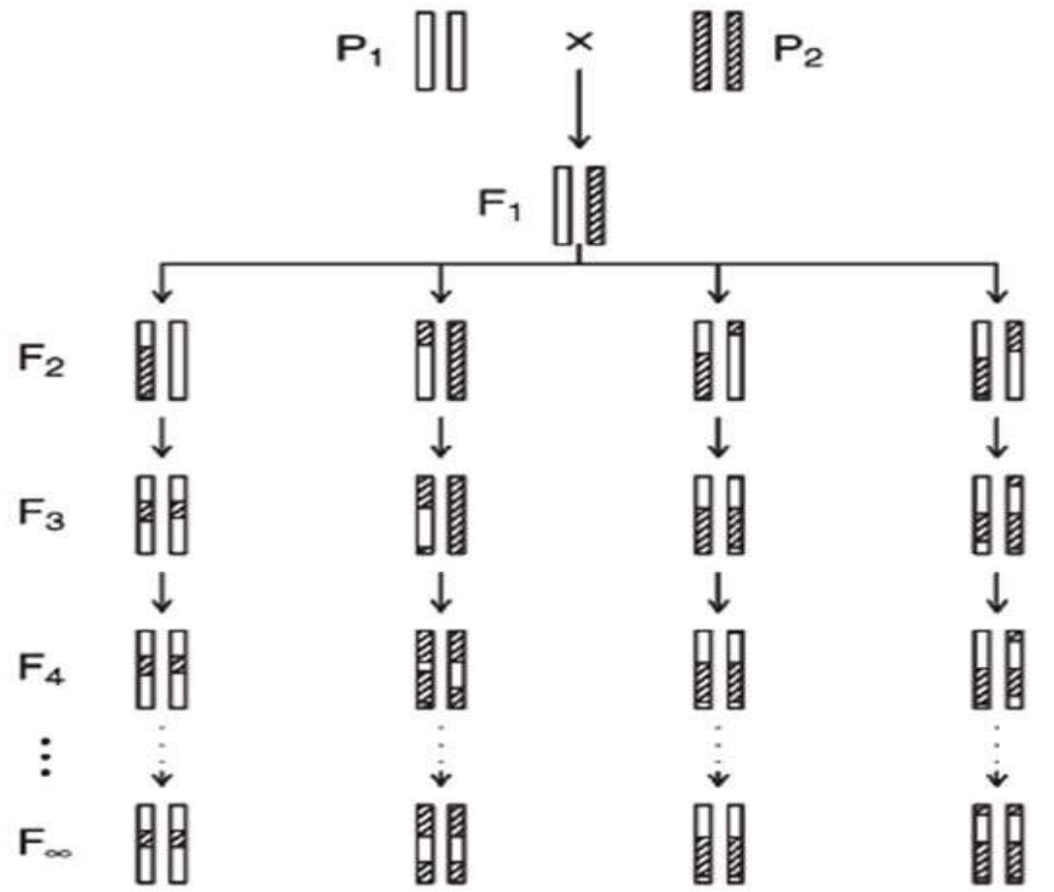
Backcross breeding in pearl millet

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 a ‘recurrent parent.’ It is particularly useful for:

- improvement of established cultivars,
- introgression of genes from wild relatives.

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.

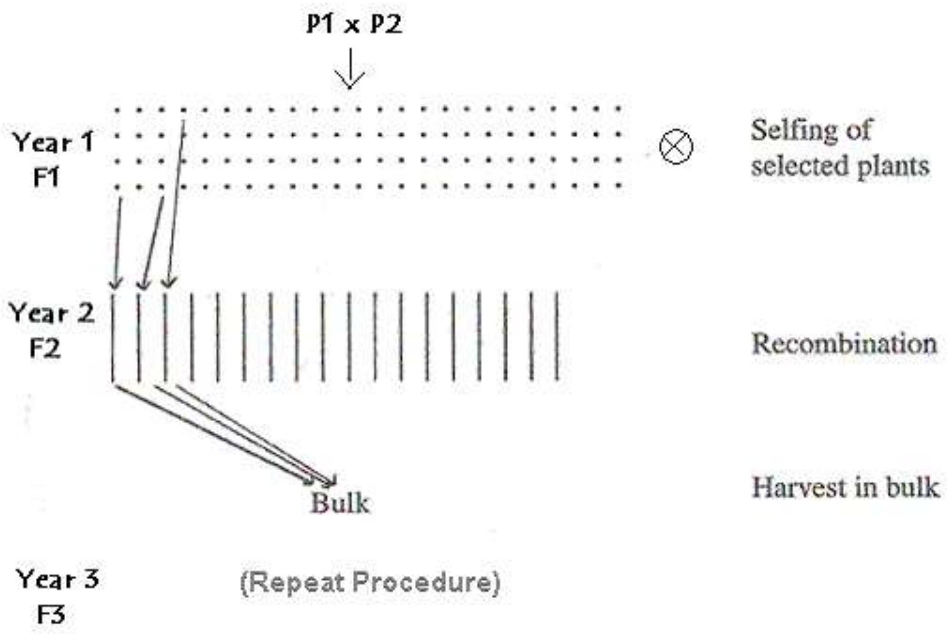
Figure 18: Steps in self-hybridization by pedigree selection. Source: Mero (2015b)



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 19** (next page).

Figure 19: 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 a cross-fertilized seed mixture of various parents (random mating in all combinations). Yield reduction in advanced generations is less when compared to a 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.

ANNEX 4: SORGHUM TOPICS

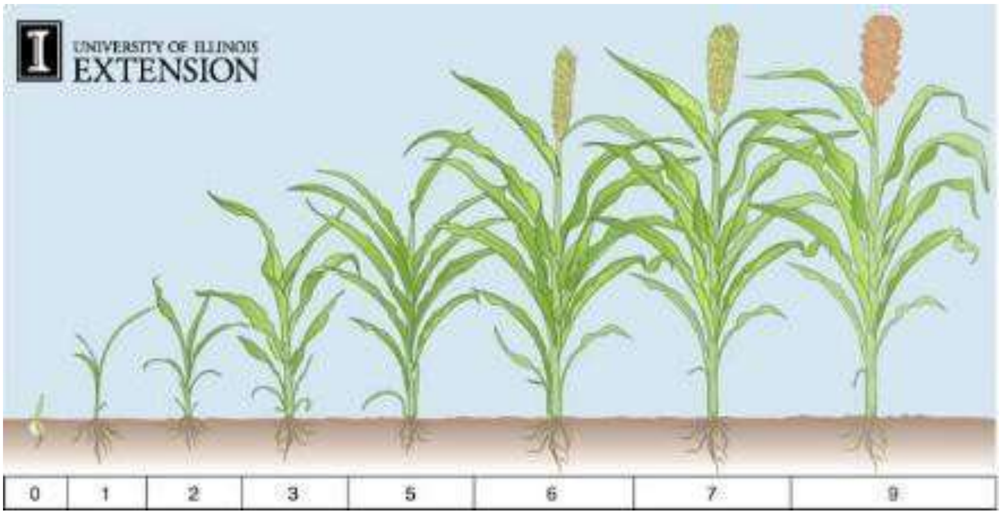
Sorghum (*Sorghum bicolor* (L.) Moench) is a self-pollinated diploid C4 grass with a high photosynthetic efficiency. Its small genome size, about 25 percent the size of maize or sugarcane, is fully sequenced. Sorghum is one among the few resilient crops that can adapt well to future climate change conditions, particularly frequent droughts, increasing soil salinity and high temperatures.[7]

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. It belongs to an elite handful of crops 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.

Growth Stages of Sorghum[8]

Figure 20: Growth stages of sorghum. Source: Vanderlip (2015)



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 vigour. Disease organisms occur more frequently under cool, wet conditions and such conditions would result in reduced stands. Therefore, planting

[7] ICRISAT. (2015). Sorghum (Sorghum bicolor (L.) Moench). http://www.icrisat.org/crop-sorghum.htm

[8] Vanderlip, R.L. (2015). How a Sorghum Plant Develop. Kansas State University, http://weedsoft.unl.edu/documents/growthstagesmodule/sorghum/sorg.htm.

should be timed so that germination and early plant growth occur during high day 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 then still small. Although sorghum does not recover as vigorously as corn, much of the leaf area can be removed since the growth 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 three 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 (Growth Point Differentiation). At this stage, the growth 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 at 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 favourable, 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 frost before the grain reaches physiological maturity will result in a light, chaffy grain.

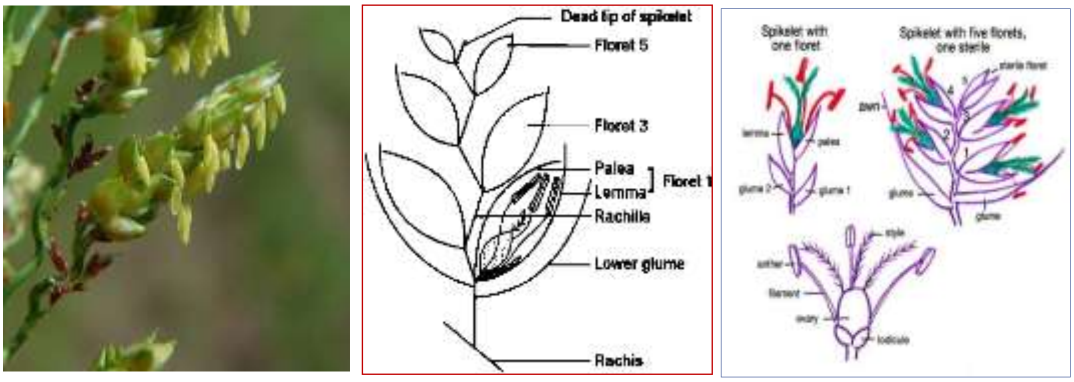
Stage 9 (Physiological Maturity). Maximum total dry weight of the plant has attained. This stage is determined by the dark spot seed on the opposite side of the kernel from the embryo. Grain moisture at physiological maturity depends on the crop type, with typical moisture ranging from 25 to 35 percent. Hybrid properties and weather conditions affect the time between maturity and the proper harvest time.

Hybridization in Sorghum

Important Characteristics of Sorghum

Sorghum is a highly self-pollinating crop. Outcrossing occurs at a level of about 5 percent but can be as high as 50 percent depending on genotype and conditions. 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. Anthesis occurs between 3 a.m. and 6 a.m. and completes in 7-10 days. Pollen grains are viable for a short period whereas the stigma remain receptive for 8-16 hours.

Figure 21: The inflorescence of sorghum.



Cross Pollination Method in Sorghum

Crossing in sorghum can be done 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 technique requires that a panicle suitable for emasculation is selected. 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. The procedure is as followed:

- clip away (with scissors) the tip and lower part of the panicle
- retain the part ready to flower within a day's time
- retain only a manageable number of florets
- insert the needle/tweezers in the middle of the floret
- move the needle gently across the glumes
- hold the panicle tactfully so as not to skip some florets
- rotate the needle at about 90 degrees
- take note of the following:
    - try not to damage the stigma; if damaged by mistake then remove the floret
    - make sure three anthers are lifted out
    - cover the emasculated panicle with a pollination bag
    - check the following day for skipped florets before crossing.

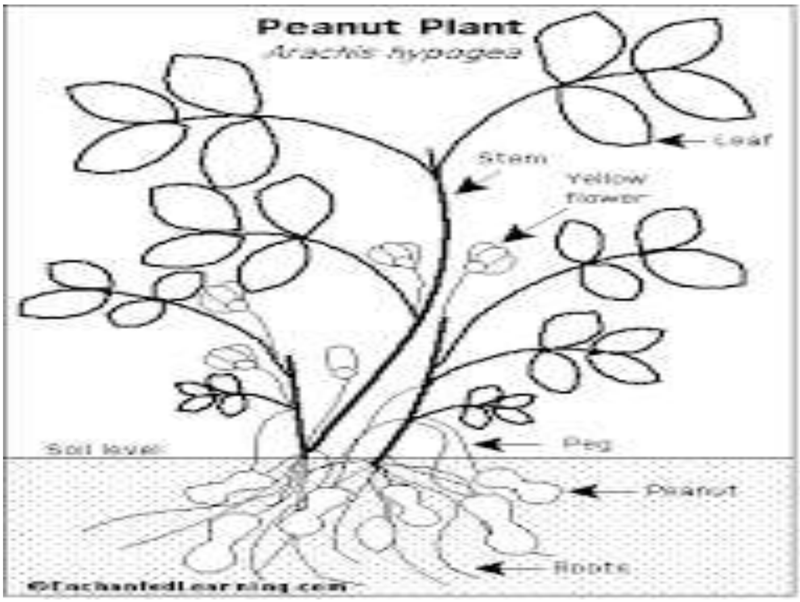
ANNEX 5: GROUNDNUT TOPICS

Groundnut is known botanically as *Arachis hypogaea* L. It belongs to the family of Fabaceae (legume) family. It is a native of South America. The primary centre of origin is situated in Brazil bordering Bolivia, Uruguay and Paraguay. Africa is considered as the secondary centre of diversity. The cultivated species *A. hypogaea* probably originated from a wild tetraploid, species *A. monticola*.[9]

Botany and floral biology

Groundnut is a herbaceous annual plant, basically interlineate in growth habit (**Figure 22**). 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 the soil. In the 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.

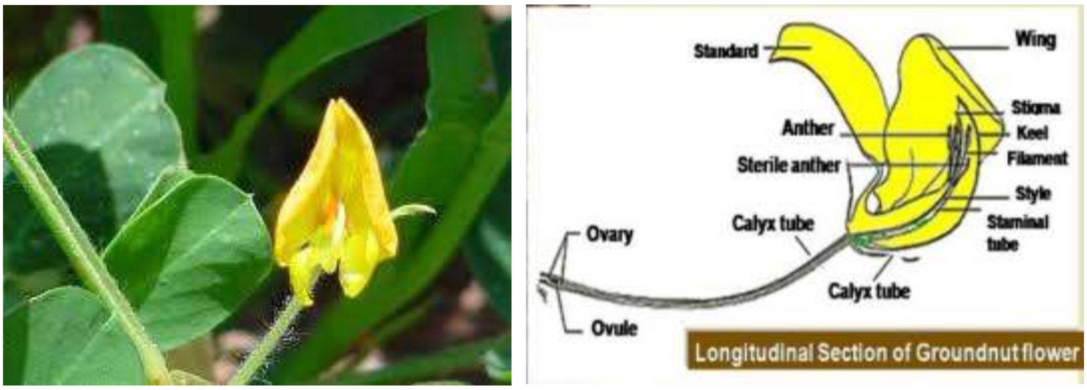
Figure 22: The groundnut (peanut) plant. Source: Mero (2015c)



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 whereas the fruits develop below the ground. The flowers are sessile, orange to yellow in colour, and complete and papilonaceous in nature. Each flower has five petals, i.e. a standard two wings and partially united two keels (**Figure 23**). 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.

[9] Mero, M. (2015c). Groundnut Biology Growth Stages and Hybridization. Presentation made during a 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, 16-31 July 2015

Figure 23: The groundnut flower. Source: Mero (2015c)



Groundnut Growth Stages

Seedling stage (Figure 24a): 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 24b): 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 24c): 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 24d): 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 24: Growth stages of groundnut. Source: Mero (2015c)

a. Seedling **b. Vegetative Stage** **c. Reproductive Stage** **d. Maturity Stage**

Reproduction characteristics and breeding methods

Groundnut is a self-pollinated crop, but outcrossing may occur in up to 2.5 percent. However, making crossings in groundnut is extremely difficult. 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.

Procedures governing production should conform to the national seed act. Farmers producing seed should meet standards as required by the regulatory authorities and/or Seed Services.

Seed production of sorghum and pearl millet

Site and field selection

Important factors to consider when selecting a field for seed production include:

- adequate isolation distance,
- the presence of birds, diseases, and insect pests
- a field that is relatively fertile, free from water logging, and with a pH not below 4.5.

Field preparation

Field preparation should be done in time. Sorghum and pearl millet seeds are small. Soil should have fine tilth. Ploughing should be done when the soil has adequate moisture. The field should be weed free at the time of planting.

Planting

Given that seeds are relatively bigger, the planting density is one seed 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.

Weeding

Seed plots are normally weeded 2-3 times using hoes, oxen, or tractor-drawn cultivators to keep fields weed-free at all times. In sorghum a combination of mechanical weeding and pre-emergence herbicide can be used to control weeds. Weeds compete with the seed crop for nutrients, sunlight, and soil moisture. They can also harbour pests and diseases that contaminate the crop at harvest.

Thinning

Thinning to the recommended spacing and plant population is required before tillers form. Gap filling is not recommended in a commercial seed crop.

Plant protection
Improved sorghum and pearl millet cultivars are tolerant of most prevailing diseases. Avoid growing seed in disease-endemic areas. Bird damage, potentially the most serious problem, can be minimized by careful selection of the site, growing larger areas, scaring, and planting varieties with some “resistance” to birds (for example, brown high-tannin sorghum and bristled types of pearl millet).

Inspection and rogueing
Rogueing is done to remove weak, diseased and off-type plants before they shed pollen, during flowering, and before harvest. Diseased plants should be destroyed by burning.

Harvesting, threshing and post-harvest handling
Harvesting should be done when the seed crop is fully mature but before lodging. Hand harvesting is the most common practice. Combine harvesting is possible for short varieties. Manually harvested panicles are sun dried for a few days and then threshed using suitable mechanical threshers, mortar and pestle, or sticks (beating). Care must be taken to avoid breaking or cracking the seed. Clean the threshing equipment before using it on a different variety or seed class. Clean the threshed seed by winnowing then treat with available chemicals and properly stored in well labelled bags.

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