Evolutionary Plant Breeding

Guide for farmer-facilitators

IFAD
Enabling poor rural people to overcome poverty

The International Treaty
ON PLANT GENETIC RESOURCES FOR FOOD AND AGRICULTURE

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Cenesta
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Introduction

While Participatory Plant Breeding (PPB) has made many gains over the past decades, some practitioners are concerned that with the growing control of the seed industry on both private and public research, farmers may need to start developing models of participatory breeding that allow them more autonomy from formal research systems (in which there breeders that are willing to work with farmers are unfortunately still in a minority). In addition, in some cases the demand for PPB is greater than the capacity of the handful of researchers to be able to respond. Nevertheless, the ideal model would be flexible enough to benefit from collaboration with breeders if such opportunities arise. The urgent necessity of bringing more genetic diversity back into farmers' fields as a response to climate change adds a further dimension to the issue.

Evolutionary Plant Breeding (EPB) promises to be a sound basis for responding to these realities and needs. The core features (of the evolutionary breeding method) are a broadly diversified germplasm and a prolonged subjection of the mass of the progeny to competitive natural selection in the area of contemplated use. Results showed that traits relating to reproductive capacity, such as higher seed yields,larger numbers of seeds/plant and greater spike weight, increase in populations due to natural selection over time. For example, a population of a mixture of nearly 1600 F2s of barley has been planted at 19 locations in five countries. It will be left evolving under the pressure of changing climate conditions with the expectation that the frequency of genotypes with adaptation to the conditions (climate, soil, agronomic practices and biotic stresses) of the locations where each year the population is grown.

The simplest and cheapest way of implementing evolutionary breeding is for the farmers to plant and harvest in the same location. However, it is also possible to plant samples in other locations affected by different stresses or different combinations of stresses by sharing the population with other farmers at an early stage. The breeder and the farmers can superimpose artificial selection with criteria that may change from location to location and with time. While the population is evolving, lines or sub-populations can be derived by collecting spikes, panicles, cuttings etc. depending on the crops. The lines or sub-populations can then be tested as pure lines (in the case of self-pollinated), clones (in the case of vegetatively propagated) or populations (in the case of cross pollinated) in the participatory breeding programmes, or can be used as multi lines, or a subsample of the population can be directly used for cultivation exploiting the advantages of genetic diversity described earlier. The key aspect of the method is that, while the lines are continuously extracted, the population is left evolving for an indefinite amount of time, thus becoming a unique source of continuously better-adapted genetic material directly in the hands of the farmers. In all the countries where the barley evolutionary population was grown in 2008/09, the farmers shared the excess seed with others so that the population is rapidly spreading. This guarantees that the improved material will be readily available to farmers without the bureaucratic and inefficient systems of variety release and formal seed production.

EPB allows farmers a lot more autonomy from gene banks, research stations and researchers because:

a. Farmers have access to greater genetic diversity than with PPB;

b. This genetic diversity is constantly evolving, changing and becoming better adapted to local conditions

c. Farmers can use the evolutionary population in a variety of ways, ranging from very simple to more sophisticated, therefore this method can be adapted to the level of interest and capacity of the farmers, and to the level of support available from researchers.

This guide is intended for training farmers to be facilitators who can guide other farmers in their community in working with and benefiting from evolutionary populations.

Selecting farmers to be facilitators

1. One criteria for selecting farmers where the evolutionary populations will be grown is that the farmers should have land with conditions that represent all the various stresses that the community is faced with (e.g. if salty soil is a problem for a number of farmers in that community, then at least one of the farmers in the EPB programme should have salty soil).

2. Farmers should be encouraged to see evolutionary breeding as a group process in which they can benefit from the research of other farmers.

3. *Other criteria for farmer selection will be identified through meetings to be held jointly in Garmsar with the farmers.*

4. Once the criteria are decided by the group of farmers, holding one or more workshops with a large number of farmers in order to see how the farmers interact with each other may be a good environment to select the farmers with the potential of being good facilitators.

A lesson in genetics

The facilitator should explain the purpose of the evolutionary population and some basic points about genetics and evolution so that farmers can have a basic appreciation for the underlying scientific principles and can make informed decisions about how to manage and use their evolutionary populations.

The following questions may help the facilitator to open a discussion on basic genetics:

Note: Not all of these questions will be addressed in one meeting. We have to think more carefully about which issues should be discussed with the farmers at which stage of the process.

1. What is a landrace? Ask the farmers to name some landraces they know. How do these landraces behave in the field in different years and under different stresses?

2. What is an improved variety? Ask the farmers to name some improved varieties they know. How do they behave in the field in different years and under different stresses?

3. What is a cross and how does the progeny of a cross change over generations?

4. The facilitator should ensure that the farmers have grasped the following key advantages of EPB:

    - Adaptation to climate change

- Living gene bank
- Farmer autonomy
- A large, genetically diverse mixture for finding locally adapted varieties
- Flexibility: a source of seeds for mixtures or single varieties

5. Is an evolutionary population more similar to a landrace or to an improved variety?
6. What is the difference between the base evolutionary population and the sub-population? What is the difference between natural selection and human selection? How many years does it take for the evolutionary population to be "adapted" to a particular environment? Does the population ever "stop" adapting?
7. Can evolutionary populations be shared with other farmers? When is the best year in the evolutionary process to share? Is there ever a point at which it is "too late" to share with other farmers? Can the seed be shared with other farmers in different environmental conditions? Again, is it ever "too late" to share with farmers who have different conditions?
8. What is the difference between a sub-population made of a mix of selected spikes vs. one made of spikes that have been selected and planted in a line and chosen line by line?
9. If we select the best spikes from within an evolutionary population do we risk "impoverishing" the base population? Is there a limit to how many spikes we should select in order to avoid impoverishment?
10. How can we make an evolutionary population? Can farmers make their own evolutionary populations? Is a mix of pure lines an evolutionary population? Is a mix of landraces evolutionary? How many different varieties are needed to make an evolutionary population? Which generation should be used to make an evolutionary population?
11. If farmers choose to make sub-populations, how many sub-populations should they aim to make? For example, one each year for one location? One sub-population each year divided into a number of locations?
12. The weakness of evolutionary breeding is that it is impossible to know which varieties are doing well and what is their pedigree. Farmers should understand why it is important to know this.

How the evolutionary populations can be used

1. The "base" evolutionary population

Planting in year 1

1. The entire population (the minimum amount of seed should be specified by the group that made that particular evolutionary population based on the number of lines it includes and a calculation of the probability that each line has an equal chance of being represented in a bag of seed of that amount) should be planted in one plot/field, in a location chosen by the farmer (which presents stresses that the farmer wants to find resistant varieties to) and cultivated

according to his/her chosen agronomic practices. If the objective of the first year is to produce enough seed to distribute to other farmers it is advisable to use conditions as "less selective" as possible.

2. The farmer/facilitator could pose the following questions to the farmers before planting, to help them decide what to plant, how much and where:

    a. Under which environmental conditions should the population be planted? By asking the relevant questions, the facilitator should seek to guide the farmers in understanding that they should plant the evolutionary population in conditions (including harsh conditions) for which they do not have access to suitable varieties: drought, salt, wind, organic agriculture, etc.

    b. According to which agronomic practices should the population be planted? Here the facilitator should ask questions that help the farmers to understand that they should adopt the agronomic practices that reflect their normal practice. If they are interested in trying new practices, then they can divide the population (if there is enough seed to have 4 kgs under each of the experimental conditions) and plant a portion of seed under each of the various agronomic practices.

    c. Why is there a minimum amount of seed that should be planted?

    d. What should be the seed rate?

    e. If the farmer wants or needs to harvest the EPB field with a tractor or combine harvester, how big does the field need to be in order to make this viable?

    f. Could the evolutionary population be used as the farmer's main crop?

Harvesting

1. The field is harvested as a whole.

2. Once the plot is harvested, the same minimum amount of seed has to be planted again the following year and 4 kg has to be kept in the fridge until the next year's crop has been harvested. The facilitator/farmer should ensure that farmers understand why 4 kg has to be kept in the fridge each year until the next year's harvest comes in. They should understand what they risk to lose if they do not do this. The facilitator could ask them what they think they can do with the 4 kg of last year which has been in the fridge after the harvest of this year comes in.

Planting in year 2

The process of year 1 is repeated.

2. Spike selection to create a new sub-population of the best spikes

Planting in year 1

1. In the first year, the evolutionary population can be planted in one field with no alleys.

2. During the spike selection (if applicable), farmers will be asked to consider the damage they are doing to the spikes by walking through the field, and it will be suggested that they might want to plant the field with space for walking corridors throughout the field at intervals.

3. In subsequent years, the base population should be planted with corridors leaving the main plots wide enough so that the farmer can easily reach any spike with the stretch of his arm while standing in the corridor.

4. Questions that the facilitator can ask the other farmers to consider:

    a) Do farmers have to do spike selection each year? Why?

    b) Do farmers still need to keep the base population after they have created a new sub-population? Why?

Harvesting

1. Questions to ask the farmers:

    a) What will happen if you select spikes only from the parts of the field where the spikes are visibly performing better? By posing this question, the facilitator will encourage the farmers to consider that they should select spikes from throughout the field in order to separate the environmental and genetic effects. Whether there are corridors or not, the farmer who wants to select spikes will be asked to imagine his field as a grid and to select the best spikes from each quadrant of the grid. This is because with the quadrant method, they can avoid selecting spikes simply from that part of the plot/field that has the best environmental conditions.

    b) Farmers will be asked to consider what size each quadrant should be. The size of each quadrant will depend on the variability of the soil and other environmental conditions of the plot of land, according to the farmers' knowledge: in a very variable plot, quadrants should be larger in order to avoid that the conditions of each quadrant are very different from each other.

    c) Farmers will be asked to consider how many spikes should be collected from each quadrant. The number of spikes to be collected from each quadrant depends on the size of the quadrant and the amount of seed that the farmer wants to have in order to start a new sub-population.

    d) The farmers who choose this method could discuss whether selecting a number of spikes by hand will mean that the base evolutionary population will be missing the best spikes? Could it be that too many spikes are collected and the base population becomes poor?

Planting in year 2

1. The chosen spikes will all be threshed together (How? Do farmers have access to a small thresher? Are they willing and able to thresh by hand?) and planted in one plot.

2. The sub-population can be planted under stressful conditions (e.g. fewer irrigations) in order to select for resistant varieties.

3. Spike selection for row planting

Planting in year 1

1. Spikes will be selected as outlined above in the section on spike selection for creating a new sub-population.

2. The selected spikes will not be planted as a mixture, rather they will be threshed individually (do farmers have the possibility of doing this?) and the seed of each spike will be planted separately in a row. Planting and harvesting in rows can be quite labour intensive. Farmers should consider the necessary investment. Would it be possible to select fewer spikes to keep the labour costs low?

3. The seed can be planted in rows under stressful conditions (e.g. less irrigation) in order to select for resistant varieties.

4. Farmers could consider why they think it could be useful to plant the seeds of each spike separately in a row. Do they expect each plant whose seed comes from the same spike to be like all the other plants from that spike (i.e. will all the plants in one row be exactly the same)?

5. They could consider: what is the advantage of this method over the method of spike selection and bulking?

Harvesting

1. Each row has to be harvested and threshed separately.

2. The farmers will decide which rows to keep to go into the new sub-population and which to discard. Selection could be based on diseases, height, maturity, uniformity, etc.

3. Can farmers keep only some plants from a certain row or do they have to treat the entire row as one? It depends if they want to have highly uniform varieties.

Planting in year 2

1. The selected rows will be mixed and planted all together as a new sub-population.

4. Spike selection for row planting to develop a new PPB trial

Planting in year 1

1. The selected spikes will be chosen and planted in lines as described above under the section on spike selection for row planting.

2. Farmers could be asked to consider: what would be a good number of lines to select to start a new PPB trial?

Harvesting

1. The best and more uniform rows will be selected to be used as the lines in a new cycle of a PPB trial.

Planting in year 2 (i.e. the first year of the new PPB trial)

1. Farmers should be aware of the requirements for conducting a PPB trial, such as time, special machinery, labour, statistical analysis, etc. They should consider what support they have to conduct the trials.

Comparing various populations and sub-populations

In order to assess whether the sub-populations really are better than the starting population, farmers can:

1. Multiply the populations that they have stored in the frig in order to have seed of the same source (i.e. produced in the same year and in the same place);

2. Organize an experiment which includes a) base population, b) year 1 populations from each farmers, c) year 2 populations from each farmer, and so on. PPB varieties and commercial varieties should be added;

3. The experiment should be planted in the field of each of the farmers who grew the population;

4. The experiment will allow to compare:

    a) Populations of various cycles (this will be a measure of the average improvement over time);

    b) Same as above but in each farmer field (this will measure if the improvement has been similar in all different environments);

    c) Populations versus PPB varieties (this will measure the advantage of EPB over PPB);

    d) Populations versus improved varieties (this will measure the advantage of EPB over CPB).

c) and d) can be combined in the comparison

Farmers should be asked:

1. Why they think it's important to go through the trouble of doing a scientific comparison between two varieties or populations (why not just do a rough estimate?)

2. What records do farmers need to keep in order doing proper comparisons? In order to keep track of their evolutionary populations and sub-populations?