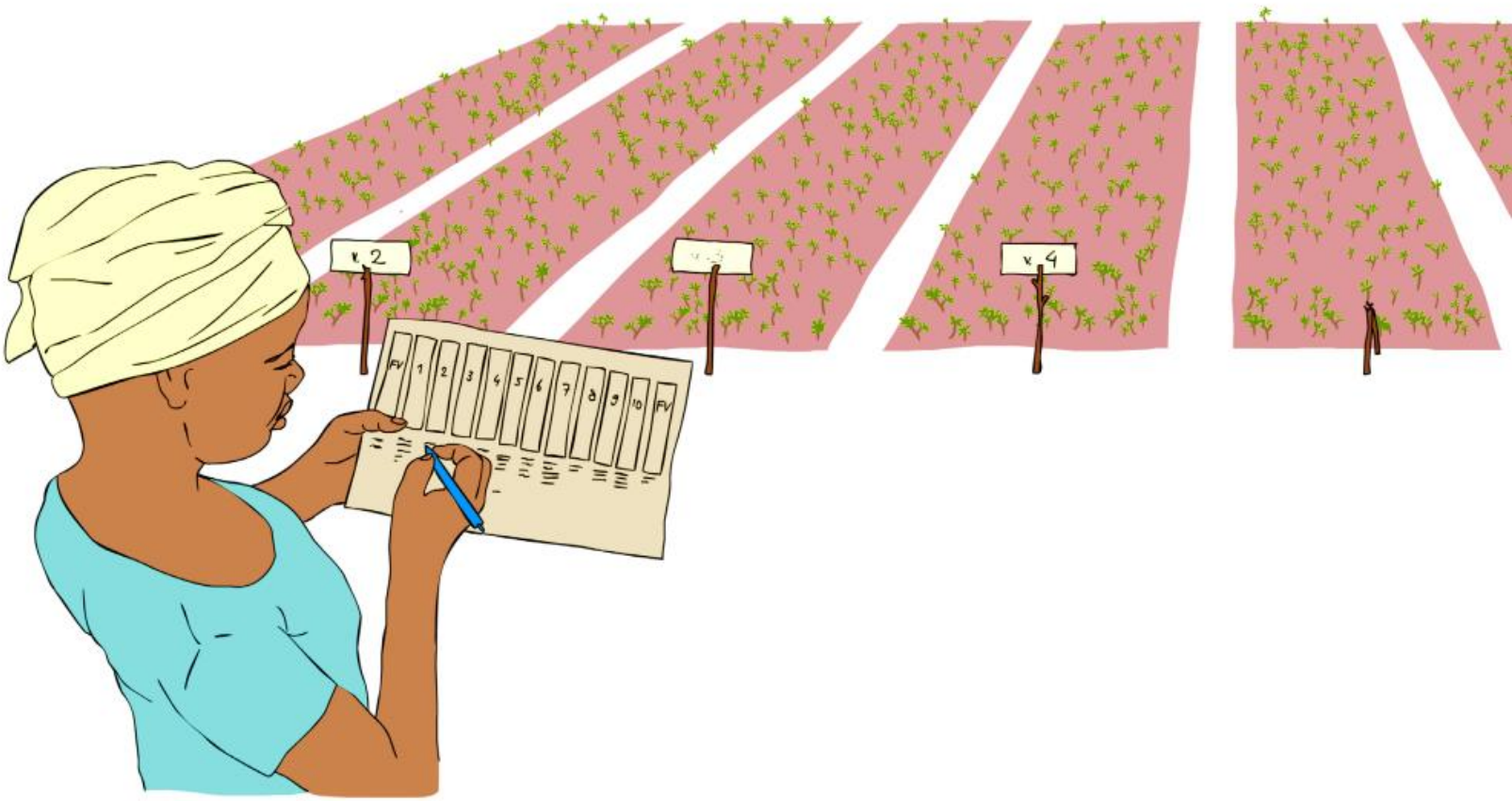
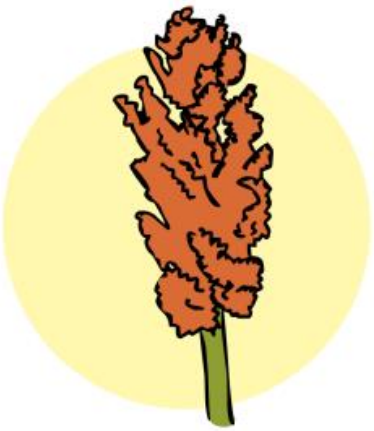
ZIMBABWE BRIEFING NOTES

PARTICIPATORY PLANT BREEDING IN FARMER FIELD SCHOOLS





Introduction

The Sowing Diversity = Harvesting Security program aims at improving farmers' access and use of crop diversity, strengthening farmers' seed systems, and supporting healthy nutrition in the community. The Farmer Field School forms its central approach. One of the main activities carried out in the FFS is Participatory Plant Breeding (PPB): with the support of scientists and local extension staff, farmers learn breeding and selection methods, and in the process, they test new varieties, or select and improve existing and develop new ones for key traits of interest.

This briefing note highlights the process and the most relevant results of the PPB efforts, which were conducted over the 2019-2023 period in the FFS in Zimbabwe. Focusing on pearl millet, we describe farmers' evaluation/adaptation of newly introduced diversity (**PVS** - participatory variety selection); in sorghum, we discuss the selection they undertook on existing local varieties (**PVE** – participatory variety enhancement)[1]. For all crops and methods, we describe baseline information regarding the challenges communities face, the seed sources they depend on, the perceived changes in the use of crop diversity; we then examine the priority traits and breeding objectives set by FFS participants at the start of the breeding process; finally, we evaluate the main results in each crop in terms of achievement of breeding objectives, yield improvements and performance against the control, and highlight the potential of a FFS/PPB approach as complementary to conventional breeding. Finally, we describe the country's policy context and the initiatives which are under-way, or which could be established, to create an enabling environment for participatory plant breeding and the rapid adoption of its products.

Study sites and observed changes in diversity

Fifty-two FFS across four districts in the drier areas of the country undertook PVS for two consecutive seasons, to evaluate newly introduced stable pearl millet lines from national breeding and conservation institutes. Another thirteen FFS in the same four districts worked with local sorghum varieties for four seasons, in an effort to improve some key traits and thus enhance their use (PVE).

All FFS fell into the drier agroecosystems of the country (natural regions IV and V), characterized by low and increasingly erratic rainfall (450 – 650mm per annum), even during what used to be a somewhat predictable rainy season. Overall, participants observed increased market influence driving the choice of crops and traits. New crops are being added to the farming systems, but the diversity of local crops was reported to still be maintained. However, seed sources are changing, with the share of seeds being purchased on the market on the rise for some crops.

PPB in FFS - methods

Plot design, planting density and variety identification within the plot followed the guidelines contained in the Facilitator's Field Guide for Farmer Field Schools on Participatory Plant Breeding[2]. Weekly meetings of each FFS were dedicated to making observations and taking measurements during the entire cropping

[1] For a definition of these PPB approaches, please consult the relevant manuals available here: Knowledge Base - SD=HS | SD=HS (sdhsprogram.org)

[2] Facilitator's Field Guide for Farmer Field Schools on Participatory Plant Breeding - SD=HS | SD=HS (sdhsprogram.org)

cycle[3]. The final evaluation of the lines was undertaken at maturity: for PVS, farmers evaluated the extent to which the lines responded to their breeding objectives or desired traits, the lines' yield, and their performance against the local control. For PVE, at maturity farmers evaluated the extent to which the varieties had improved after two or three years[4] of selection, any yield advantage they had acquired, which positive traits had been maintained and which negative traits remained to be worked upon. For expressing if the variety had improved, farmers could choose between the following responses: "the variety is no better", "the variety is slightly better", "the variety is better" and "the variety is much better". These options were assigned numeric values from 0 ("variety is no better") to 4 ("the variety is much better"), and the average result of this improvement score for each variety was calculated. For evaluating the changes in yield, the rate of increase between the initial and final yield was calculated.

Evaluating new diversity in pearl millet (PVS)

Current seed sources

Pearl millet seed is obtained from a variety of sources. Farmers' preferences were for informal ones, particularly seed fairs, on-farm sources, and community seed banks, because these guarantee the presence of desired traits, quality and reliability. Seed dealers and companies provide high quality seed, but their supply is less reliable and does not provide farmers with their preferred traits. Government supplied seed is poorly valued under all aspects. Table 1 summarizes these commonalities as well as the differences in the top preferred seed sources for pearl millet.

[3] On a weekly basis, each FFS performed an Agro-Eco-System Analysis AESA, which is a thorough study of the different components of the agricultural environment and its ecology. It facilitates proper decision-making by helping participants consider the complexity of their farms and the factors influencing the growth of crops. See Special Topic 10.4 in the Facilitator's Field Guide for Farmer Field Schools on Participatory Plant Breeding - SD=HS | SD=HS (sdhsprogram.org)

[4] Different FFS worked on these varieties for varying lengths of time, but the vast majority undertook at least two years of PVE on them.

Source	Presence of desired traits	Quality	Reliability
Agro-input dealers / Seed companies	+	+++	++
Community Seed Banks	+++	+++	++
Exchange with others in other communities	+++	++	+
Exchange with others in same community	++	++	+
Farm-saved / Own stock	+++	+++	++
Government	+	++	+
Local market	++	+++	+++
Seed fairs	++++	++++	++++

Table 1. Evaluation of the different seed sources which farmers use in pearl millet, in terms of presence of desired traits, quality of the seed and reliability of the supply.

Farmers' preferred traits

Understanding farmers' preferences is an important step for breeding programs that seek to develop acceptable varieties by farmers (Danial et al. 2007).

The top preferred traits which farmers reported to seek in pearl millet were related to yield (mostly importantly, grain and panicle size), followed by earliness, pest and disease resistance and drought tolerance. Narrowing down from the preferred traits to the actual breeding objectives (Table 2), significant differences emerged not only compared to the preferred traits but also among women and men. Women considered a much greater set of breeding objectives to be highly relevant, while men narrowed down their preference to four main traits (Table 2). Plant height and taste were ranked as the top priority objectives by both genders; the next most important objectives were drought tolerance for women and yield for men. Earliness and biotic/abiotic stress tolerance, which were important preferred traits, were ranked highly by women, and slightly less so among men.

Breeding objective	% WOMEN	% MEN
Plant height	100.00	100.00
Taste	100.00	100.00
Drought tolerance	97.18	63.16
Early maturity	95.66	61.80
Disease resistance/ tolerance	93.82	22.06
Germination	93.57	22.50
Yield	89.54	88.24
Pest resistance/tolerance	81.54	76.92

Table 2. Share of men and women who voted for each breeding objective.

Results of the post-season evaluation

Based on the breeding objectives and keeping in mind the other desirable traits, 100 PVS entries were evaluated across the FFS and the years, using one among six possible local varieties as a control.

The average number of breeding objectives or preferred traits met by the lines was 2.5. Over 40% of the lines responded to an above average number of breeding objectives and only one responded to the maximum of eight. The most frequently found key traits were drought tolerance and early maturity (each represented in over half the lines evaluated), followed by disease resistance. All these traits had been

chosen as important breeding objectives although not the top priorities. Improvements in plant height and taste, which both men and women had agreed on as being the most important objectives, were each found in only 10% of the lines.

In terms of productivity, just 24 lines were considered high yielders. Of these, only two met a high number of breeding objectives (seven), while the others responded to a number of breeding objectives which was closer to the overall average. Most, if not all, the top yielders carried the target traits of drought tolerance, and its closely related trait of early maturity. Many of them also did well under grain size aspects (Table 3).

Top yielding lines	N Obj	Disease tolerance	Drought tolerance	Early maturity	Pest tolerance	Plant height	Taste	Grain size	Panicle size
ICSR161	7	✓	✓	✓	✓		✓	✓	✓
IESV91070DL	7	✓	✓	✓		✓	✓	✓	✓
102IESH22022	4		✓	✓		✓		✓	
104IESH28002	4		✓	✓		✓		✓	
105IESH28020	4		✓	✓		✓		✓	
106IESH152011	4		✓	✓		✓		✓	
107P9504AXICSR172	4		✓	✓		✓		✓	
P9504AXICSR172	4	✓	✓	✓					✓
103IESH214015	3		✓	✓				✓	
ASARECA	3		✓	✓	✓				
ICSH152011	3		✓	✓					✓
IESV9906DL	3		✓	✓	✓				
KNE814	3	✓	✓	✓					
MAYERE	3	✓	✓	✓					
TCA_A137	3	✓	✓					✓	

Table 3. Pearl millet post-season evaluation results for the top yielding lines (average yield score = 3, as per the second column). The number and type of breeding objectives that these lines fulfilled are described in the subsequent columns.

Participatory Variety Selection - Main Highlights

1. Seed sources for pearl millet are mostly informal. Farmers prefer these sources because they are more reliable than commercial sources and because the seeds carry the traits they need. However, farmers appreciate the higher quality of seeds from the private sector. This calls for ensuring that the quality of the seed circulating in farmer managed systems is maintained high or enhanced.

2. Using a PVS approach with a diverse set of varieties in an FFS setting contributed to capturing a large set of farmer-valued traits and of differences between genders. Beyond seeking for yield-related and abiotic stress tolerance traits, farmers, especially women, sought for a broader range of additional characteristics such as taste and germination capacity.

3. The lines that responded to most breeding objectives were not necessarily the top yielders, although some of the top performers also did well under a relevant number of breeding objectives. This suggests that there is a trade-off between a line's productivity and its capacity to respond to other, multiple needs. It is therefore important for farmers to have access to a diversity of lines and varieties, which carry different suites of traits, some more narrowly

related to yield and others responding to farmers' multiple needs.

4. Most of the top yielders did well under drought tolerance and earliness and to a lesser extent disease resistance. On the contrary, some traits such as taste and germination capacity, were represented very marginally or not at all in these top performers. This could be due to the fact that the traits carried by breeding lines largely follow the priorities set by the national breeding programmes. While these traits are clearly of high relevance to farmers, the currently available breeding materials for PVS trials may fail to address other important features, especially those related to culinary quality and taste.

5. It is known that quality traits can indeed be a challenge for breeders to meaningfully assess unless there is a close collaboration with smallholders and social scientists, possibly using local materials which farmers appreciate under quality aspects, alongside the breeding lines.

Evaluating locally available diversity in sorghum (PVE)

Sorghum seed is obtained from a variety of both formal and informal sources. Commercial seed is appreciated for its quality but is not reliable enough (possibly because marginal farmers in remote areas are not an important target for seed dealers) nor does it guarantee the presence of desired traits. Farmers rate seeds sourced on the local market, at seed fairs and through community seed banks highly under all aspects (quality, presence of key traits and reliability). Table 4 summarizes the preferences farmers expressed about the different sources of seed under the above-mentioned aspects.

Source	Presence of desired traits	Quality	Reliability
Agro-input dealers / Seed companies	+	+++	+
Community Seed Banks	+++	+++	+++
Exchange with others in other communities	+	++	+
Exchange with others in same community	++	+	++
Farm-saved / Own stock	++	++	++
Government	+	++	++
Local market	+++	++++	+++
Seed fairs	+++	++++	+++

Table 4. Evaluation of the different seed sources which farmers use for sorghum, in terms of the presence of desired traits, quality of the seed and reliability of the supply.

Breeding objectives and the target PVE varieties

At the beginning of the PVE season, farmers prioritized their breeding objectives for sorghum (Table 5). There were no widespread differences between the preferences expressed by women and men, except for plant height which was deemed an important trait to be improved by women only, and threshability which was considerably more important among male respondents. Overall, the most important trait that farmers wished to improve was drought tolerance, followed by yield and specifically the yield-related traits of plant height (among women), grain and panicle size.

Breeding Objective	% WOMEN	% MEN
Drought tolerance	0.31	0.26
Yield	0.20	0.17
Plant height	0.08	0.00
Grain size	0.07	0.09
Head/panicle size	0.07	0.11
Threshability	0.06	0.12
Disease resistance/ tolerance	0.06	0.09
Other	0.16	0.17

Table 5. Breeding objectives listed for sorghum at the start of the PVE process, segregated by gender.

FFS participants chose to work on five local open-pollinated varieties: Chihumani, Chiredhi, Gokwe, Gokwe white and Matsoapede. When asked about the positive and negative reasons for choosing the above target varieties, surprisingly farmers stated that many of these already did well under some of their breeding targets, particularly drought tolerance. For other target traits, such as grain size and threshability, while some varieties were also positively assessed, data was missing for others (Table 6). A possible explanation for why farmers still chose to focus on drought tolerance even if the trait is already present in the target varieties, is that the changes in climates are pushing farmers to improve abiotic stress tolerance even further, including in an already hardy crop such as sorghum and its locally adapted landraces.

Initial traits	Chihumani	Chiredhi	Gokwe	Gokwe white	Matsoapede
Disease resistance/ tolerance			+	-	
Drought tolerance	++/-	+	+++	+	+
Grain size		+	+++		
Panicle size		-	+	-	
Plant height	+		-		
Threshability			++	-	+
Yield				+	+

Table 6. Summary evaluation of the positive (+ sign) or negative (- sign) performance of the five target varieties under the traits corresponding to the breeding objectives of the PVE activities. The presence of both signs indicates that there were both positive and negative votes for that trait in the given variety. Empty cells correspond to missing data.

Results of the post-season evaluation

Farmers considered all varieties to have improved. Most of them were considered to have become *slightly better*, with an average improvement score of 2.05. No variety ended up performing *much* better, although it cannot be excluded that with more cycles of PVE, greater improvements could be achieved. The variety for which there was the greatest perceived improvement was Matsoapede. All varieties also gained in yield, with the greatest yield gain being observed in Chiredhi and Gokwe (Table 7).

Variety	Improvement score	Average yield before PVE (T/ha)	Average yield after PVE (T/ha)	Yield Change
Matsoapede	2.40	2.00	3.50	x1.7
Gokwe	2.23	1.25	2.75	x2.2
Chihumani	2.02	1.75	2.75	x1.5
Gokwe white	2.00	0.80	0.95	x1.2
Chiredhi	1.59	1.00	2.33	x2.3

Table 7. Average improvement score, before and after yield estimates and yield change for each sorghum variety after PVE.

In terms of changes under the target traits, there was no data available for Gokwe White. Across the remaining varieties, the most widespread improvements were achieved in terms of drought tolerance, with three out of five varieties evaluated positively after the PVE activities (Chihumani, Gokwe and Matsoapede). Other traits were met in a patchier manner across the target varieties. The yield gains observed earlier (Table 7) are due to different traits in each variety: grain size increases in Gokwe and Matsoapede, panicle size and plant height improvements in Chiredhi, multiple yield related traits in Gokwe (no yield related trait was indicated for Chihumani) (Table 8).

The variety with the most positive traits corresponding to the breeding targets after enhancement was Gokwe (5 traits) while all others had only two improved traits, which differed across varieties.

Trait	Chihumani	Chiredhi	Gokwe	Matsoapede
Disease resistance/ tolerance			✓✓	
Drought tolerance	✓✓		✓✓✓	✓
Grain size			✓	✓
Grain weight			✓	
Head/panicle size		✓	✓	
Plant height		✓		
Threshability	✓			

Table 8. Positive traits which were maintained or improved in the five target varieties after PVE.

The relation between farmers' appreciation of overall improvements (highest in Matsoapede), the number of traits improved (highest in Gokwe), and the observed yield gain (most evident in Chiredhi) was not straightforward. It could be that Chiredhi's considerable yield gain is not perceived as significant since its initial yield was low and remains on the lower end even after the enhancement. Furthermore, Chiredhi does not seem to have improved other, non-yield-related traits. On the contrary, the high overall perception of improvements in Matsoapede may also be because this landrace was the highest initial yielder, hence even relatively smaller productivity gains become more relevant. Matsoapede's positive response in terms of drought tolerance improvements may further underline its higher improvement score. Gokwe was also ranked highly in terms of its improvement score: while its yield was almost as low as Chiredhi in the beginning, hence still quite inferior to Matsoapede's yield after PVE, the appreciation by farmers probably lies in the successful enhancement of multiple target traits.

Participatory Variety Enhancement - Main highlights

1. For sorghum, the seed source analyses indicate that local, informal seed sources are preferred by farmers under quality and reliability aspects, as well as in terms of finding their preferred traits. Since local varieties are the predominant material circulating within these sources, the importance of further enhancing their value through PVE emerges clearly.

2. Farmers chose to work with varieties which already did quite well under a number of breeding objectives, wishing to further enhance some key traits, most of which were related to their drought tolerance and yield. This points to local landraces' well-established adaptation to the local, harsh conditions and to the opportunity to use these successfully as starting materials for further improvements, especially in light of the increasing climate challenges.

3. After a few cycles of PVE, farmers observed at least a slight improvement in all varieties. Their overall positive evaluation did not depend directly on the yield gain nor on the number of traits which had improved, but likely on a combination of these aspects. It also appeared to be to some extent dependent on farmers' initial appreciation of their favourite varieties.

4. The above complexity once again suggests that while yield is an important determinant of farmers' overall appreciation, a variety's capacity to respond to breeding efforts under multiple traits is an important factor.

5. The results of the PVE efforts prove that relevant improvements of traits through PVE is feasible and allows farmers to keep appreciating their traditional landraces, furthering their adaptation to changing climates while keeping their preferred traits.

6. An integrated PPB approach which combines the introduction and evaluation of new diversity and the enhancement of locally available varieties may be the best way to serve the needs of small-scale farmers.

Initiatives to enable policy change

Registration of farmer varieties, including those deriving from PPB work, is critical as it allows these varieties and the efforts of the communities breeding and conserving them, to be better recognized. A framework for registration of farmer varieties was initiated thanks to and within the SDHS program. The process was kickstarted by showcasing the evidence deriving from the characterization and improvement of some prominent farmer varieties (Gokwe, Tsvimboyemupositori and Matsoapede for sorghum, and Nyati for pearl millet). Such evidence testified to how farmer varieties coming from PVE conducted in an FFS setting can perform as good as, or better than commercially bred varieties. Similar results were achieved within the PVS processes, thanks to which stable breeding lines were positively evaluated and adopted by farmers. This body of evidence, and the policy dialogues through which it was presented to decision makers, contributed to making variety registration authorities more receptive to the idea of developing a separate, slightly different framework for registering farmer-bred varieties, with possibly more relaxed DUS criteria. The work in this direction is ongoing and will continue beyond the SD=HS program.