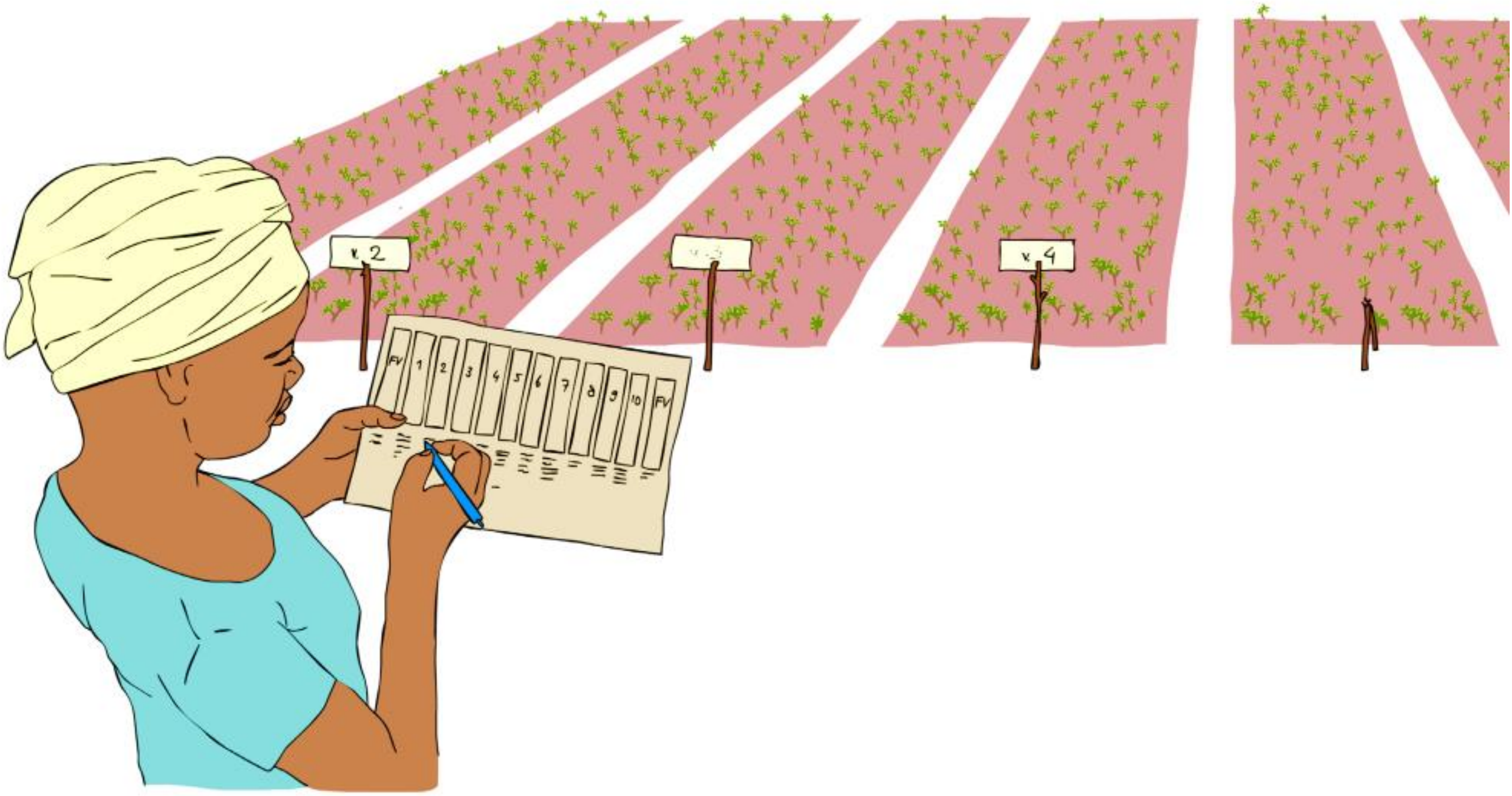
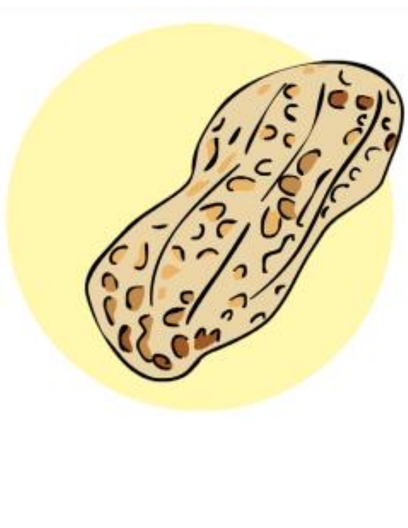
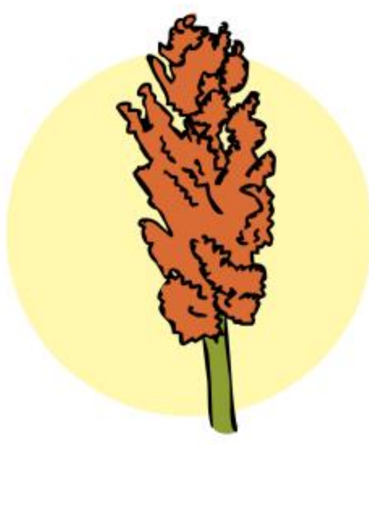
ZAMBIA BRIEFING NOTES

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 (FFS) 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, select, and improve existing ones or develop new lines.

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 Zambia. Focusing on sorghum and groundnut, we describe farmers' evaluation/adaptation of newly introduced diversity (PVS - participatory variety selection); in maize, we discuss the selection they undertook on existing local varieties (PVE – participatory variety evaluation)[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 terms of achievement of breeding objectives, yield improvements and performance, 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 PPB and the rapid adoption of its products.

Study sites and observed changes in diversity

Fourteen FFS across four districts in the drier areas of the country undertook PVS with newly introduced stable sorghum lines, while seven FFS across three districts worked with groundnut lines (all from the national genebank or breeding programmes). Ten FFS worked with local maize varieties, in an effort to improve some key traits and thus enhance their use (PVE).

All FFS fell into the drier agroecosystems of the country (agroecological zones I and II), characterized by low (800-100 mm/year) and increasingly erratic rainfall, even during what used to be a somewhat predictable rainy season. FFS participants described the diversity of the crops and varieties to be changing. In general, increased market influence is driving the choice of crops and traits. Cash crops are gaining importance, local crops tend to become neglected, seed sources are changing.

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 cycle[3].

[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)

[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

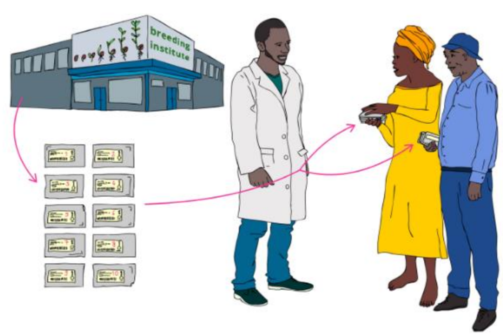
The final evaluation of the lines was undertaken at maturity: for **PVS**, farmers evaluated the extent to which the lines responded to their breeding objectives or desired traits, the lines' yield, and their performance against the local control. For **PVE**, farmers evaluated the extent to which the 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.

Throughout the implementation of FFS on PPB, farmer field days were organized, to showcase the plots and the lines being evaluated.

Evaluating new diversity in sorghum and groundnut (PVS)

Current seed sources

Before embarking on the actual PVS work, a seed system analysis was carried out, to understand farmers' current seed sources and the strengths/weaknesses of each. Sorghum seed is obtained almost exclusively through informal channels, including farmers' own stock, local markets, exchanges in and beyond the community and community seed banks; groundnut seed is sourced informally, but also from seed companies or agro-dealers. In both sorghum and groundnut, seed from community seed banks or from farmers' own stocks (plus those from the local market in groundnut) is considered the best in terms of presence of desired traits, but less so in terms of quality. Community seed bank sourcing of seed is considered highly reliable. Table 1 summarizes the commonalities and differences in the top preferred seed sources for sorghum and groundnut.



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	
	Groundnut	Sorghum	Groundnut	Sorghum	Groundnut	Sorghum
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 sorghum and groundnut, in terms of presence of desired traits, quality of the seed and reliability of the supply.

Farmers' preferred traits

Understanding farmers' preferences (across different agroecological conditions and growing seasons) is an important step for breeding programs that seek to develop acceptable varieties for farmers. In sorghum, yield-related traits were of the utmost importance, followed by abiotic stress tolerance (mostly related to drought); market-related traits such as grain colour and cooking quality were also relevant, reflecting the poor market potential of local varieties. In groundnut, traits related to processing quality (specifically, ease of shelling) and taste were the most important, again reflecting the need to improve the marketability of existing varieties. Biotic, rather than abiotic stress tolerance traits were also a priority in groundnut.

Based on the list of desired traits described above, farmers came up with their top breeding objectives for their PVS activities. In both crops, drought tolerance-related traits received the top priority, while market or quality-related traits were prioritized much less frequently compared to the importance they had been awarded when farmers reflected on their preferred traits. This may be due to the fact that during the definition of breeding objectives the FFS was invited to narrow down their preferred traits, also keeping in mind the features of the breeding lines available from the national research institute, many of which are likely focused on a narrower set of traits.

There was no gender-based difference in the ranking of breeding objectives. Table 2 summarizes the share of votes which women and men gave to each breeding objective.

	Sorghum		Groundnut	
Breeding Objective	**% WOMEN**	**% MEN**	**% WOMEN**	**% MEN**
Early maturity	0.98	0.92	0.53	0.58
Drought tolerance	0.74	0.67	0.70	0.83
Grain size	0.73	0.58	-	-
Pest resistance/tolerance	0.43	0.46	0.53	0.38
Taste	0.36	0.42	0.22	0.14
Ease of shelling	-	-	0.70	0.67
Disease resistance/ tolerance	-	-	0.53	0.54
No. of pods/plant	-	-	0.52	0.33
Yield	-	-	0.22	0.14
Seed colour	-	-	0.17	0.14

Table 2. Share of men and women who voted for each breeding objective, in decreasing order of importance. Highlighted cells indicate the top two breeding objectives in each crop.

Results of the post-season evaluation

Sorghum

Based on the breeding objectives and keeping in mind additional desired traits, the FFS evaluated 13 PVS advanced stable lines from the breeding programme of the Zambian Agriculture Research Institution (ZARI). One among four possible local varieties was used as a control, and the experiment ran for three consecutive seasons. Based on farmers' evaluations, the average number of breeding objectives met by the lines was just above four. Six out of the 13 PVS lines responded to an above average number of breeding objectives or preferred traits (between five and seven, see white rows in Table 3). The top priority objectives of early maturity and drought tolerance were met by all these lines, and particularly by the first three.

The top two lines performed well also under grain size (related to yield) and one of them was appreciated for its grain color, a more qualitative trait. However, in terms of yield, these six multi-trait varieties were not the top performers: their average yield was considered medium. The yield advantage of the two top yielding lines (red sorghum and ZVS 165, highlighted rows at the bottom of Table 3) seems to reside in increased grain size, improved head/panicle size and increased number of productive tillers (data not shown). However, these top performers did not carry as many (or none) of the objectives or traits desired by farmers. In sorghum, there seems to be a trade-off between the lines' capacity to fulfill multiple breeding objectives and their productivity.

Variety	N breeding objectives or preferred traits	Breeeding objectives					Preferred traits					Average Yield Score (1 to 3)	Performance score (-1 to +1)
		Drought tolerance	Early maturity	Grain size	Pest resistance	Taste	Cooking quality	Disease resistance	Early plant vigour	Grain colour	Grain weight		
Sima	**7.00**	✓✓	✓	✓	✓		✓		✓	✓		2.29	0.57
ZSV 15	**5.00**	✓	✓				✓	✓	✓			2.00	1.00
ZSV 16	**5.00**	✓	✓				✓	✓	✓			2.00	1.00
ZSV 17	**5.00**	✓✓	✓✓				✓	✓✓	✓✓			2.00	1.00
GV 36R	**5.00**	✓	✓	✓					✓		✓	2.00	1.00
Kuyuma	**5.00**	✓✓✓✓	✓✓✓✓✓					✓✓✓	✓	✓✓		2.00	0.27
ZSV 165	**4.00**	✓	✓	✓				✓				3.00	1.00
Red sorghum	**0.00**											3.00	1.00

Table 3. Sorghum post-season evaluation results. The highlighted rows describe the evaluation of the top yielding lines (those which scored highest in terms of yield and performance against the local control – last two columns). The ticks in the central columns describe the level of farmers' appreciation of each line, under the priority objectives and preferred traits.

Groundnut

Based on the breeding objectives and the most desirable traits, the FFS evaluated 15 PVS lines, which were either breeding lines from ZARI or released varieties (Wamusanga) introduced into the FFS from other communities. One popular local variety was used as a control, and the experiment was conducted over three seasons.

The results of the FFS' evaluations are presented in Table 4. The lines in the experiment fulfilled an average of five breeding objectives/preferred traits. Five out of the 15 PVS lines responded to an average or above average number of priorities (Table 4, white lines), particularly the top priority breeding objective of drought and disease tolerance, with only one exception. Ease of shelling, a highly ranked breeding objective, was met by most of these lines, but only one excelled. Cooking quality or taste were satisfactory – but not excellent – in a smaller subset. As observed in sorghum, the top performer in terms of productivity (Table 4, highlighted line) was not among the lines which carried most of the preferred traits, again suggesting that "multifunctionality" does not necessarily go hand in hand with maximum yield. Quality traits, such as ease of shelling and cooking quality, which had been ranked highly by farmers, were not represented as much as traits related to drought tolerance and yield, in the tested lines. The best performing entry under quality aspects was the Wamusanga variety, which also did quite well in terms of disease and drought tolerance, albeit not being the top performer.

		Breeding objectives						Preferred traits			
Variety	**N breeding objectives or preferred traits**	Disease resistance/ tolerance	Drought tolerance	Early maturity	Ease of shelling	Pest resistance /tolerance	Taste	Cooking quality	Ease of processing	**Average Yield Score (1 to 3)**	**Performance score (-1 to +1)**
PVT-SP-E-4-P-203	**6**	✓✓	✓✓	✓	✓	✓			✓	2	1
PVT-SP-E-7-P-201	**5**	✓✓✓	✓✓✓	✓✓	✓✓✓			✓		2	1
Wamusanga	**5**	✓✓	✓✓	✓✓				✓✓	✓✓	2.5	0.5
MGV 8	**5**	✓	✓✓	✓	✓				✓	2	1
MGV 5	**5**	✓	✓	✓	✓			✓		2	1
PYT-SP-E-1	**4**	✓	✓	✓			✓			3	1

Table 4. Groundnut post-season evaluation results. The highlighted row indicates the top yielding line (the one which scored highest in terms of yield and performance against the local control – last two columns).

Learning and spreading

FFS participants expressed high satisfaction with the learning they achieved on plant breeding during the FFS and reported a spreading interest in PVS activities and the lines therein among their own and neighboring communities. This has led to some seed being exchanged beyond the PVS experiment and making its way into farmers' fields. Farmer field days were considered the most effective tool for sparking an interest among other farmers.

Participatory Variety Selection - Main highlights

1. Seed sources are mostly informal for both crops, but groundnut is increasingly being sourced from agro-dealers as well, possibly because saving quality seed at household level under sub-optimal storage conditions is more difficult in groundnut. However, informal sources seem to still be preferred especially in terms of presence of desired traits and reliability. This points to the importance of maintaining and enhancing the diversity of seed circulating in informal systems, which serve small-holders in marginal areas better than the formal system.

2. Using a PVS approach with a diverse set of varieties in a FFS setting contributed to capturing a large set of farmer-valued traits. Farmers were interested in a broad range of different traits and did not necessarily place a narrow focus on yield. However, when choosing their actual target objectives, especially in groundnut, the FFS' focus was narrowed down to fewer traits, most importantly those related to abiotic stress tolerance and yield. This more or less evident divergence between the wider range of preferred traits and the actual breeding objectives may at least partially be explained by the fact that farmers were informed of which traits were more readily available in the stable lines produced by the national breeding programmes. Both the sorghum and groundnut programmes focus mostly on improving yield, disease resistance, climate adaptation traits (mostly related to drought tolerance) and wide adaptation. Therefore, the features reflected in the materials available for PVS may have driven, to some extent, farmers' narrowed-down choice of their breeding targets.

3. Despite the above-described influence, the prominence of drought tolerance and early maturity as breeding targets also testifies to farmers' perceived impact of a changing climate even on a hardy and traditionally drought tolerant crop as sorghum.

4. In groundnut, while many of the tested lines performed well in terms of improved shelling, other quality traits such as cooking and processing quality were positively evaluated in a patchier manner across entries, possibly because they are not the main priority of the current breeding programmes and are hence not well represented in their materials. Participatory approaches may be a very powerful way forward to integrating these traits into a breeding programme for the future.
5. In both sorghum and groundnut, the lines that responded best to the set objectives were not necessarily the top yielders. Indeed, small-holder farmers' preferences tend to be multi-variate: hence, the availability of varieties which carry different suites of traits, and not necessarily yield advantages alone, may best allow them to satisfy their multiple needs.

Evaluating locally available diversity in maize (PVE)

Current seed sources

Maize seed is obtained from a variety of both formal and informal sources. Whereas hybrid seed can only be purchased on formal markets, seed of open-pollinated varieties is regularly obtained from informal sources. Compared to sorghum and groundnut, the appreciation of commercial seed appears to be higher in terms of quality and presence of desired traits, although not in terms of reliability. Farmers highly value their own seed stock too, in terms of the presence of desired traits and reliability, but not so much in terms of quality. Table 5 summarizes the above preferences that farmers expressed for each source.

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 5. Evaluation of the different seed sources which farmers use for maize, 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 maize (Table 6). The most important traits they wished to improve were related to abiotic (drought tolerance and early maturity) and biotic (disease resistance) stresses, followed by yield-related traits, particularly the number of cobs per plant and grain size. No major difference was observed between women's and men's preferences.

Breeding Objective	% WOMEN	% MEN
Early maturity	0.23	0.25
Drought tolerance	0.20	0.20
Disease resistance/ tolerance	0.16	0.17
n. of cobs/plant	0.14	0.14
Grain size	0.08	0.06
Cob size	0.05	0.05
Plant height	0.03	0.05
Yield	0.03	0.04
Pest resistance/tolerance	0.02	0.02

Table 6. Breeding objectives listed for maize at the start of the PVE process, segregated by gender.

FFS participants chose to work on five local open-pollinated maize varieties: Gankata, Kafwamba, Kajakete, Kapyawangu and Lwano. Farmers' evaluation of the positive and negative traits of each of these varieties at the start of the process (Table 7) showed that the most recurrent negative trait was late maturity, affecting all but one variety (Lwano). Indeed, improving this feature was among the most important breeding objectives and is very likely linked to improving these varieties' adaptation to climate change. Unsatisfactory cob size was reported in two varieties while plant height and yield shortcomings were mentioned for one variety each. The most widespread positive trait by which the local varieties are appreciated was grain size, but it was considered fully satisfactory in only three out of the five target varieties.

Variety	Gankata	Kafwamba	Kajakete	Kapyawangu	Lwano
Cob size		-		-	+
Disease resistance/ tolerance	+/-	+/-	+	++/-	+/-
Drought tolerance	+	+/-	+	++/-	+/-
Early maturity	-	+/-	-	+/-	-
Grain size	+/-	+		+	+
n. of cobs/plant				+	+
Pest resistance/tolerance		+			+
Plant height				-	
Yield		-			

Table 7. Summary evaluation of the positive (+ sign) or negative (- sign) performance of the five target varieties under each breeding objective. The presence of both signs indicates that there was an equal number of 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 2.4. No variety ended up performing *much* better, although it cannot be excluded that with more cycles of PVE, greater improvements could be achieved. Just one variety (Lwano) was rated by *all* farmers as consistently *better* (average improvement score of 3). All varieties gained in yield, with a few spectacular changes (Kafwamba increased its productivity by five times and both Lwano and Gankata doubled it) (Table 8).

Variety	Improvement score	Average yield before PVE (T/ha)	Average yield after PVE (T/ha)	Yield Change
Lwano	3.00	1.00	2.00	x2
Gankata	2.75	1.75	3.00	x1,7
Kapyawangu	2.19	1.13	2.25	x2
Kafwamba	2.00	0.25	1.25	x5
Kajekete	2.00	NA	NA	NA

Table 8. Average improvement score, before and after yield estimates and yield change for each maize PVE variety.

The most important breeding objectives were met across several varieties: in particular, early maturity and disease resistance improvements were widespread: these traits were considered positive in all varieties at the end of the PVE process. Another consistently achieved objective was drought tolerance, with only one variety (Kajakete) not carrying this positive trait at the end of the improvement cycle (Table 9).

The varieties with the most positive traits after the enhancement were Kafwamba (7 traits) and Gankata (6 traits). The initial most negative traits in Kafwamba were cob size and yield: cob size is not listed as a positive post-improvement trait for this variety, while the impressive yield increase has been described above. Gankata also improved the size of its cobs (initially deemed as poor) as well as in terms of grain size, but despite these successes, its yield did not improve as dramatically. The other three varieties also did well in terms of improving the negative traits highlighted at the start of the process.

Variety	Gankata	Kafwamba	Kajekete	Kapyawangu	Lwano
Cob size	✓	✓		✓	
Disease resistance/ tolerance	✓	✓	✓	✓	✓
Drought tolerance	✓	✓		✓	✓
Early maturity	✓	✓	✓	✓	✓
Grain size	✓				✓
No. of cobs/plant		✓		✓	
Pest resistance/tolerance	✓	✓			
Plant height		✓			

Table 9. Positive traits which were maintained or improved in the five PVE target varieties.

The relation between farmers' appreciation of overall improvements, the number of traits improved, and the observed yield gain was not straightforward: the variety which most improved its yield was Kafwamba, and it also had the highest number of final positive traits. However, its *overall* improvement score was on the lower end, i.e. it was considered only slightly improved. Indeed, its yield gain was impressive; however, it was initially considerably less productive than its counterparts, and its final yield remains lower than all others. Furthermore, while it did achieve many breeding objectives, its pre-season evaluation had also shown that several farmers considered it to already carry, at least to some extent, quite a few positive traits, with the only exception of yield-related ones. The two varieties which both doubled their yield (Lwano and Kapyawangu), however responded to a slightly different set of objectives, and hence were appreciated differently in terms of their overall improvement. Additional data (not shown) indicated that Lwano was also appreciated for its grain size and weight and the number of grains per ear/panicle/head. These traits had not been listed among the priority breeding objectives but are strongly related to yield, possibly contributing to farmers' perception of an overall improved performance.

Participatory Variety Enhancement - Main highlights

1. While farmers source maize seed both from formal and informal sources, they appreciate commercial seed for its capacity to guarantee high quality and the presence of desired traits but prefer their own seed stock in terms of reliability of the supply. The greater reliability of the local, farmer managed seed system makes it crucial to enhance and widen the diversity and quality of the materials circulating therein, even for a crop with a large commercial seed market such as maize.
2. Farmers expressed a good level of appreciation about the target local varieties, but wished to improve some key traits, most of which were related to their capacity to escape drought (by improving their tolerance or by increasing their earliness) and resist diseases. Yield improvements followed in importance.

3. After two or three years of PVE, farmers observed at least a slight improvement in all varieties. Their overall positive evaluation did not depend exclusively on the yield advantage acquired (even if very consistent) nor on the number of traits which had improved, but likely on a combination of these aspects as well as, of course, the enhancement of the target traits. Farmers' initial appreciation of (or traditional attachment to) each variety may also play a role.

4. The results of the PVE efforts also prove that substantial improvement of traits through PVE is well feasible, even on a short-term basis.

Initiatives to enable policy change

In Zambia, the seed development and commercialization processes follow laws and regulations that are enshrined in the Plant Variety and Seeds Act of 1998 (Seed Act) and the Plant Breeders' Act of 2007 (PBR Act). The Seed Control and Certificate Institute is the regulatory body that oversees the governance of the seed sector. For varieties to be listed and considered for seed production and marketing, it is mandatory by law that varieties meet the criteria of being distinct, uniform and stable (DUS). In addition, the act considers variety registration of lower classes of seed through the Quality Declared Seed (QDS) system. Nevertheless, the QDS system still requires that for seed to be registered it must meet the DUS criteria.

This kind of system limits the traits and diversity that farmers can chose from as well as limits their access to seed which tends to be highly priced. In order to increase diversity and increase the contribution of farmer varieties in the seed value chain, CTDT in Zambia is developing a parallel National Variety Register that will list farmer varieties which can be considered for seed production and marketing, in the control and ownership of the farmers. This will strengthen and promote local seed systems, thus increase seed availability, affordability, access and support the realization of Farmers' Rights.