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Participatory and conventional plant breeding for selection of soybean cultivars for smallholder agriculture in Mozambique

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Abstract: *The aim of this study was to select soybean cultivars adapted to Mozambican farming systems using participatory and conventional breeding and to assess the extent of agreement between these approaches. Experiments were conducted in the Zambézia and Tete provinces during the 2021/22 growing season in a randomized complete block design with 41 genotypes and three replications. In the participatory plant breeding approach, 165 farmers participated in the selection process. The top 35 cultivars for each method were identified and then compared using a coincidence index, which resulted in –29.41, confirming the divergence. The cultivar TGX 2002-3DM was ranked highest in the conventional method, whereas TGX 2014-16FM was selected by farmers. These findings indicate the need to incorporate farmers' preferred traits in selecting varieties in the breeding process to increase the likelihood of adoption of the varieties. These results support the hypotheses proposed in this study.*

Keywords: *Coincidence index,* Glycine max *(L) Merr., African continent, genotype × environment interaction*

INTRODUCTION

Soybean (*Glycine max* (L.) Merr.) production in Africa accounts for less than 2% of global soybean output (FAO 2023). However, soybean cultivation has expanded considerably on the continent. Over the past 23 years, soybean production in Mozambique has expanded at an average annual rate of 9.3%, increasing from around 950 thousand tons in 2000 to nearly 8 million tons currently. This growth has been driven primarily by increases in planted area rather than by gains in grain yield. Over this same period, planted area increased by 460%, whereas grain yield rose by only 39% (FAO 2023).

In Mozambique, expansion has been stimulated by demand from the poultry value chain and export markets. The national average grain yield remains low (1625 kg ha^{-1}; FAO 2023), constrained by a combination of biotic and abiotic factors, inefficient production systems, and public policy challenges (Tadele 2017).

New cultivars often exhibit low adoption rates among African farmers, as they are typically developed under edaphoclimatic and socioeconomic conditions

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differing from those of the target environments (Ceccarelli et al. 2000). Participatory plant breeding (PPB) has emerged as a key strategy for developing cultivars adapted to real conditions, particularly in smallholder agriculture systems and regions underserved by conventional breeding programs (Kumar et al. 2023).

Key to PPB is the recognition that crop performance is shaped by interactions among genotype, environment, and socioeconomic factors (G × E × S). Even genotypes that perform well under experimental conditions may fail to show their potential in low-input systems or under traditional farming practices (Merga 2017).

In the Mozambican context, socioeconomic conditions play a decisive role in cultivar adoption. Limited access to production technologies leads to marginal profitability in soybean cultivation, reflected in low and highly variable grain yields. These constraints arise from inadequate agronomic management, insufficient or improper use of inputs, low soil fertility, the use of varieties poorly adapted to local production environments, and irregular rainfall patterns (Van Vugt et al. 2017).

The objectives of PPB are broader than those of conventional breeding, as selection criteria and evaluation methods used by farmers often differ from those used by conventional breeders (Dereje et al. 2017). Comparing conventional and participatory breeding approaches for soybean in Mozambique is essential to assess their potential in delivering cultivars aligned with local realities. It has been reported that PPB is up to 80% more cost-effective than conventional methods, accelerates cultivar adoption, and improves farmers' access to genetic diversity (Greenberg 2018).

Although participatory plant breeding has been successfully applied to major African crops such as rice, maize, common bean, sorghum, barley, potato, wheat, and millet (Ceccarelli and Grando 2020), research on soybean remains limited. In Mozambique, no studies have applied PPB to soybean, and the degree of alignment between breeders' evaluations and farmers' preferences is unknown. Although soybean cultivation shows promise in Mozambique, it is still in the early stages of development and adoption of new technologies adapted to local edaphoclimatic conditions (Janeque et al. 2021).

Given these considerations, the aim of this study was to select soybean cultivars adapted to smallholder farming systems in Mozambique through both participatory and conventional breeding strategies. Hypotheses of this study are that cultivars selected through PPB will differ from those selected conventionally, due to farmer preference rankings; and PPB-selected cultivars will show comparable or superior agronomic performance under smallholder conditions. By addressing this knowledge gap, our study contributes to sustainable agricultural intensification, food security, and the development of climate-resilient cultivars in the region.

MATERIAL AND METHODS

Site and cultivar description

The 41 cultivars used were obtained from the Pan-African Soybean Variety Trials (PAT) database at the University of Illinois (Table S1). Cultivars were selected based on growth cycle duration, grain yield, and seed composition, specifically protein and oil content. They exhibit a medium growth cycle, grain yields ranging from one to nearly four tons per hectare, and an average seed composition of approximately 40% protein and 20% oil (DR&SS 2016).

The experiments were conducted in Mozambique at two locations: Zambézia Province (Gurué District) and Tete Province (Angónia District). In Gurué, the trial took place in Namarripe village (lat 15° 21′ 1.8″ S, long 36° 47′ 26.52″ E), with a *Cwb* climate according to the Köppen–Geiger classification.

During the field trial, the mean air temperature was 22.4 °C (11.8–30.1 °C), and total rainfall was 44.4 mm. In Angónia, the experiment was conducted in Ulongué village (lat 14° 44′ 50.28″ S, long 34° 22′ 5.16″ E), which has a *Cwa* climate. The mean air temperature during the trial was 20.8 °C (9.3–27.9 °C), and total rainfall was 51.9 mm. The results of soil chemical analysis of the experimental sites are shown in Table S2.

The experimental areas had previously been cultivated with maize. The soils in the experimental areas are classified as clayey, characterized by a heavy texture and high water-holding capacity.

Field trials conducted

The trials were sown in the first week of January 2022 in Angónia (Vila Ulongué) and in the second week of January in Gurué (Namarripe). The crops were harvested on 12 May in Vila Ulongué and on 10 May 2022 in Namarripe.

The experiments were established using a randomized complete block design (RCBD) with three replications. Seeds were sown manually, and each experimental plot consisted of four 5-meter-length rows spaced 0.5 meters apart. Plant population was adjusted to 320,000 plants ha^{-1}, grown under rainfed conditions. Phosphorus was supplied through basal application of 40 kg ha^{-1} of P_2O_5 in the form of triple superphosphate. Seeds were inoculated with the commercial inoculant Nodumax, containing the *Bradyrhizobium diazoefficiens* strain USDA 110, according to manufacturer's recommendations.

The inoculant was applied at a rate of 100 g per 50 kg of seed. To improve adhesion of the inoculant to the seed surface, gum arabic was used as an adhesive agent. The seeds of each cultivar were inoculated separately. After inoculant application, the seeds were kept in the shade for approximately 15 minutes before sowing.

Weed control was performed manually. Prior to the R1 phenological stage (beginning of flowering), a preventive fungicide was applied, consisting of 6.4 ml of hazoxystrobin (250 g L^{-1}) and difenoconazole (125 g L^{-1}) diluted in 16 liters of water.

In conventional breeding, the following traits were evaluated:

- Days to Flowering (DF): recorded when 50% of the plants in the plot reached the R1 phenological stage (beginning of flowering).
- Flower color and pubescence color: visually assessed at the R1 stage to identify variation among the genotypes.
- Days to physiological maturity (DPM): recorded when 90% of the plants in the plot reached the R8 phenological stage (physiological maturity).
- Biomass accumulation and Plant height (PH): random selection of five plants per plot at the R8 stage to determine biomass accumulation, expressed as grams per plant; plant height measured from the soil surface to the highest node on the main stem.
- Number of seeds per pod (NSP): collection of forty pods from ten randomly selected plants, recording the average number of seeds per pod.
- Grain Yield (GY): estimated from the harvest of the two central rows of each plot, adjusted to 13% moisture content, and converted to kg ha^{-1}.
- 100-Seed Weight (HSW): weighing 100 seeds to assess seed size and weight uniformity.

In PPB, a total of 165 farmers were involved. They have received annual training on participatory soybean selection, soybean growth stages and varietal traits, soybean agronomy, climate-smart agricultural practices, good agricultural practices, integrated pest and disease management, and post-harvest management. Farmers were selected based on recommendations from local cooperatives and farmers' associations as leaders in their communities. All farmers evaluated the same experimental plots in the trial conducted by the breeders.

The selected farmers were members of farmers' associations or cooperatives and had experience as soybean grain producers and community seed multipliers. They thereby had detailed knowledge of soybean growth and development, including the specific growth stages and key varietal traits of soybean. Their preferences are therefore representative not only of local farmers' choices but also of the demands of grain traders and processors who use soybean in poultry feed production.

The selection carried out by the farmers was based on visual assessment of the traits as follows. Plant architecture was scored on a scale from 1 (upright growth habit) to 3 (prostrate plants). Disease severity was assessed using a diagrammatic scale with five severity levels: 1 = 0%, 2 = 1–25%, 3 = 26–50%, 4 = 51–75%, and 5 = 76–100%. Seed quality was assessed based on seed size, hilum color, and oil and protein concentrations, which were determined through laboratory analyses through the University of Illinois. Grain yield was determined by harvesting all the plants from each plot, which were then threshed, and the grain was weighed to estimate yield in kg ha^{-1}.

The evaluation scale was developed to accommodate the different stakeholder groups involved in the assessment process, including breeders, farmers, development and purchasing companies, and non-governmental organizations (NGOs) operating in the sector. Grain quality/type was classified as excellent, very good, good, fair, or poor. Additionally, farmers completed a questionnaire.

Data analysis

Conventional breeding data analysis

The experiments at each location were analyzed separately using a mixed-model approach. Block effects was treated as random, while genotype effects were considered fixed. The normality of residuals was assessed based on the Shapiro-Wilk test (Shapiro and Wilk 1965), and homogeneity of variances was assessed using the maximum F-test (Hartley 1950). Experimental precision was evaluated through the estimation of accuracy and the coefficient of variation (Resende and Duarte 2007).

A joint analysis was performed across environments, modeling the residual variance-covariance matrix as $e_{ik} \sim N(0, j \oplus j = 1\ I\sigma_e^2)$ to better fit the model and improve the precision of the parameter estimates (Henderson et al. 1975). Genotype effects were treated as fixed, while environment effects, the genotype × environment interaction effects, and the block-within-environment effects were considered random.

Using the means of the best linear unbiased estimators (BLUEs), the selection index was estimated according to Mulamba and Mock (1978). For this index, economic weights of 1 were assigned to the variables GY, biomass accumulation, and days to maturity. Means were grouped using the Scott–Knott test ($p < 0.05$). All statistical analyses were performed using R software within the RStudio environment.

Participatory breeding data analysis

First, a descriptive analysis was conducted to characterize the profile of the farmers participating in the project in each region. The percentage of producers according to gender and ten-year intervals of age distribution was calculated. For cultivar acceptance and rejection, an independent quantification of producer responses was carried out, considering the evaluation sites jointly. Through this analysis, the cultivars were ranked based on the acceptance or rejection criteria established by the farmers.

Based on these results, the cultivars were classified into independent samples according to the number of times each cultivar was mentioned by the producers. Thus, the numerical count of producers who cited each cultivar *i*, whether for acceptance or rejection, was treated as an independent sample composed of *n* values.

The independent samples were analyzed using the Kruskal-Wallis test (Hollander et al. 2015) to observe significant differences among the medians of the evaluated groups. The Nemenyi test was performed to compare the groups that were formed in order to allow decision-making regarding individual differences between the median effect of each pair of independent samples.

Index of coincidence between breeding approaches

To identify coincidences between the cultivars selected using the conventional breeding approach and the PPB breeding approach, the top 35 cultivars identified under each strategy were considered. Spearman's correlation was estimated, and the significance of the correlation was determined by the t-test. The Hamblin and Zimmermann (1986) index was calculated. For this analysis, a selection intensity of 50% was applied to the group of cultivars defined by the analytical models, and the coincidence rate expected through chance was assumed to be equal to the intensity applied for selection.

RESULTS AND DISCUSSION

Conventional breeding strategy

The coefficient of variation ranged from a low 1.51% to a very high 35.32% (Resende and Duarte 2007). The experiments were conducted using an on-farm trial approach, which reflects real farmers' growing conditions and inherently involves environmental heterogeneity associated with producer profiles and production systems (Honsdorf et al. 2022). By applying mixed models, this variability was accounted for, ensuring that the coefficient of variation of 35.32% for grain yield (GY) reflects real environmental conditions and does not compromise the reliability of cultivar ranking.

For clarity, only the fifteen cultivars belonging to the highest-yielding group at each site are shown in Table 1. Disease severity was minimal, with most cultivars scoring 1, indicating very low infection levels (data not shown). In Angónia, the cultivar Lukanga led the highest grain yield (GY) group, whereas in Gurué, TGX 2002-35FM was the leader. Notably, Lukanga did not rank among the highest-yielding cultivars in Gurué, highlighting the influence of local environmental conditions on genotype performance.

In Angónia, all evaluated cultivars had higher values for DPM, by up to 30 days (data not shown); Lukanga exhibited a 26-day increase. Soybean phenology is strongly regulated by photoperiod, which is primarily determined by latitude. However, the relatively small latitudinal difference between Gurué and Angónia likely limited its direct effect on DPM. Under these circumstances, temperature becomes the dominant factor, modulating physiological processes such as photosynthesis, cell division, and stem elongation (Borém et al. 2022).

Table 1. Best linear unbiased estimators (BLUEs) of agronomic traits evaluated in the fifteen highest-yielding soybean cultivars at each site: days to flowering (DF), days to physiological maturity (DPM), plant height (PH), number of seeds per pod (NSP), 100-seed weight (HSW), biomass accumulation (Biom), and grain yield (GY)

Site	Cultivar	DF	DPM	PH	NSP	HSW	Biom	GY
Angónia	Lukanga	39.16c	111.91a	74.96a	2.16b	18.62c	6667.99a	3359.28a
Angónia	TGX 2014 33FM	43.07b	111.69a	75.08a	2.15b	18.68c	6322.18a	3334.68a
Angónia	Bimha	45.02b	112.13a	75.12a	2.27a	19.80b	6991.77a	3274.18a
Angónia	TGX 2002 35FM	43.07b	111.80a	77.72a	2.20b	18.66c	6170.49a	3193.59a
Angónia	SC Signal	42.09c	111.69a	74.83a	2.23a	19.55b	6459.74a	3117.31a
Angónia	TGX 2014 16FM	35.25d	112.91a	77.40a	2.15b	20.92b	6649.23a	3101.11a
Angónia	SC Saga	45.02b	111.80a	78.51a	2.20b	17.78c	6819.14a	3059.40a
Angónia	TGX 2002 3DM	48.28a	112.13a	79.66a	2.30a	18.56c	6490.46a	3056.85a
Angónia	SC SPIKE	44.05b	111.80a	74.40a	2.21b	19.19c	5658.85a	3033.53a
Angónia	S882	45.02b	112.47a	75.96a	2.16b	18.17c	6147.11a	3032.71a
Angónia	M667	45.35b	111.24a	74.97a	2.20b	18.86c	6309.95a	3010.16a
Angónia	TGX 2000 26FZ	47.63a	112.13a	72.48a	2.19b	17.38c	6287.11a	2998.76a
Angónia	TGX 2029 38F	46.33a	112.02a	74.05a	2.16b	18.05c	6664.18a	2998.73a
Angónia	TGX 2029 37F	45.67b	111.24a	76.41a	2.15a	23.87a	6395.04a	2998.53a
Angónia	SC SEMEKI	45.02b	111.91a	78.31a	2.27a	17.99c	6486.39a	2995.15a
Gurué	TGX 2002 35FM	41.59b	99.88a	48.01b	2.60a	13.76e	6721.10a	2935.70a
Gurué	TGX 2029 52F	49.40a	93.95a	69.64a	2.53a	14.16e	6375.12a	2822.40a
Gurué	TGX 2014 16FM	38.66d	87.68b	52.74b	2.44a	14.78e	3968.22a	2799.38a
Gurué	TGX 2029 38F	48.75a	100.21a	81.23a	2.74a	14.24e	5058.13a	2723.30a
Gurué	S1079/6/7	42.24b	92.96a	56.56b	2.57a	16.60d	4578.78a	2652.07a
Gurué	TGX 2029 37F	45.17a	99.22a	78.77a	2.57a	12.99e	4527.90a	2593.24a
Gurué	S1195/6/105	42.24b	88.34b	41.41b	2.48a	15.43d	5796.69a	2591.40a
Gurué	M667	45.82a	97.90a	47.11b	2.62a	13.87e	5794.55a	2587.51a
Gurué	TGX 2000 26FZ	46.15a	95.92a	47.75b	2.37a	14.21e	5762.41a	2579.83a
Gurué	TGX 2029 9F	46.15a	93.95a	74.69a	2.69a	14.01e	7042.45a	2552.79a
Gurué	SC SERENADE	40.29c	92.96a	51.77b	2.36a	22.95a	5028.67a	2486.40a
Gurué	TGX 2029 36F	48.10a	99.88a	68.99a	2.36a	13.41e	6035.56a	2483.34a
Gurué	TGx 1835 10E	40.61c	83.06b	67.50a	2.67a	14.23e	6539.00a	2441.03a
Gurué	MAKWACHA	40.94c	87.68b	50.15b	2.39a	16.01d	5419.64a	2423.25a
Gurué	SC SAFARI	38.99d	88.01b	60.90b	2.46a	17.05d	4859.96a	2422.39a

Means followed by the same letter in the columns do not differ according to the Scott–Knott test ($p < 0.05$). Angónia: SE_{DF}: 0.464; SE_{DPM}: 0.651; SE_{PH}: 3.550; SE_{NSP}: 0.464; SE_{HSW}: 0.464; SE_{GY}: 297.25; SE_{Biom}: 547.60. Gurué: SE_{DF}: 0.522; SE_{DPM}: 0.520; SE_{PH}: 2.237; SE_{NSP}: 0.123; SE_{HSW}: 0.0.562; SE_{GY}: 340.00; SE_{Biom}: 827.282.

Higher temperatures and lower altitude (704 m) in Gurué accelerated crop development, resulting in shorter crop cycles, whereas Angónia, with higher altitude (1258 m) and cooler temperatures, exhibited slower development and longer cycles. These environmental differences also affected plant height, biomass accumulation, and GY, illustrating a clear genotype × environment (G × E) interaction (Table 2). Temporal variation in rainfall, temperature, and soil fertility further contributed to differential cultivar performance, emphasizing that management recommendations must be site-specific.

Selecting genotypes with superior performance across multiple traits is essential for breeding programs, as it allows identification of cultivars that meet several agronomic criteria simultaneously (Kumar et al. 2025, Retore et al. 2026). Using the Mulamba and Mock (1978) index, TGX 2002-3DM, MAKWACHA, Mhembwe, SC Signal, and S882 were identified as the five most promising lines among the 20 evaluated (Figure 1). MAKWACHA has previously been highlighted for its tolerance to soybean rust, yield potential, and stability (Guwela et al. 2013). These findings suggest that breeders and farmers in similar agroecological zones may prioritize these lines for further evaluation and adoption.

SCS 1 exhibited the lowest selection index, indicating poorer performance in this study. However, Habtegebriel and Abebe (2023) reported broad stability for this cultivar across multiple Ethiopian locations, demonstrating that single-season trials may underestimate genotypic adaptability. Similarly, Lukanga displayed a high index in Angónia, but its yield appears to be sensitive to environmental conditions and plant density. Differences between plant density in this

Table 2. Cultivar mean squares (QML) and likelihood ratio tests for the genotype × environment interaction (LRT G × E Interaction) for the variables days to physiological maturity (DPM), grain yield (GY), and biomass accumulation (Biomass)

Variable	**QML** (Pr > *F*)	**LRT – G × E** (Pr > Chisq)	**CVe** (%)	***rgg***	Avg
DPM	3.07*	15.32*	1.51	0.85	102.13
GY	1193017.3*	211071.8*	35.32	0.72	2555.23
Biomass	3651979.0	1771343.65*	29.38	0.33	5627.58

* Significant at the 0.05 probability level for the Fisher-Snedecor F-test and the chi-square test (LRT – A × L). *rgg:* accuracy; Avg: average.

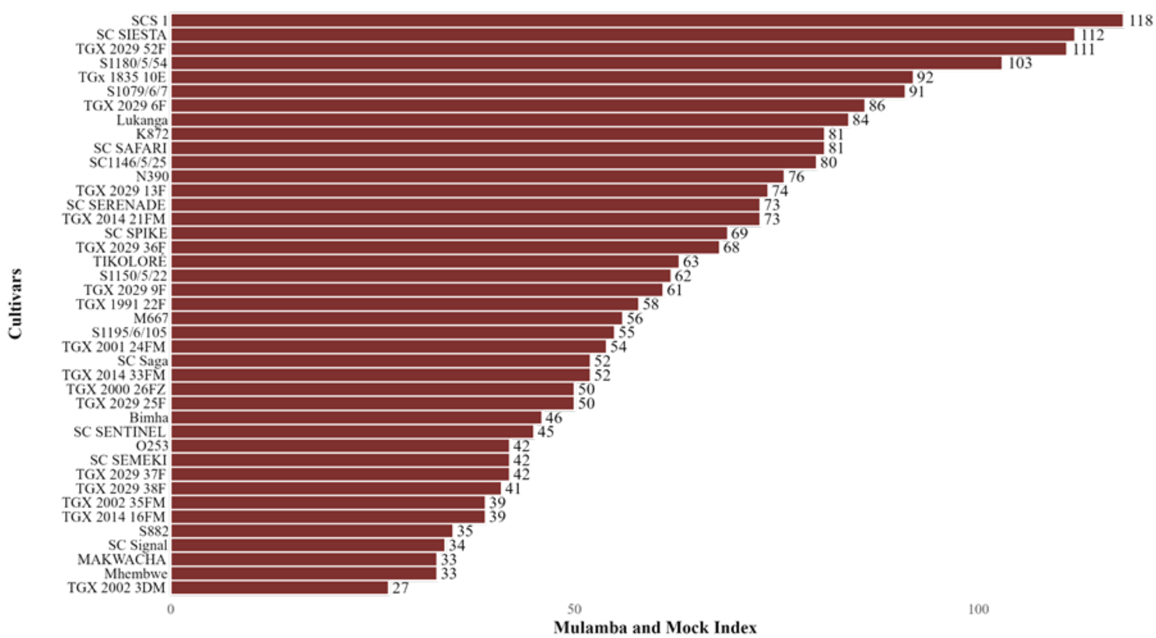

Figure 1. Ranking of soybean cultivars based on the Mulamba and Mock selection index for grain yield, biomass accumulation, and days to physiological maturity. Lower index values indicate superior overall performance across the evaluated traits.

study (320,000 plants ha^{-1}) and a previous study (400,000 plants ha^{-1}; Mwiinga et al. 2021) likely explain the observed discrepancies, highlighting the need for follow-up trials to evaluate density × environment interactions.

Overall, these results underscore the importance of conducting multi-environment trials and integrating physiological understanding when recommending cultivars. Future studies should include multi-year evaluations, genotype × management interactions, and broader environmental gradients to refine cultivar recommendations and improve yield stability for smallholder farmers in Mozambique.

Participatory breeding strategy

In this study, 67% of participating soybean farmers were male, predominantly between 30 and 50 years of age. Similar to the findings of Janeque et al. (2021), the present results indicate male leadership in soybean production in Mozambique. This predominance is likely related to the fact that the crop has been perceived as having higher economic return, which attracts greater male involvement in production decisions.

For women, seed size was the most decisive factor in cultivar choice, with a clear preference for larger seeds, likely due to their perceived association with oil content, ease of processing, and grain yield. In contrast, men tended to prioritize cultivars combining a high number of pods with large seeds, reflecting a stronger focus on field performance and market-oriented traits. These patterns are consistent with gender roles in local farming systems and have also been reported in other participatory breeding studies, which report that men tend to emphasize market-oriented traits, whereas women consider a broader set of criteria related to use and processing (Nchanji et al. 2021, Sanya et al. 2023).

Seed size is also a key determinant of soybean yield and quality, as seed size, oil content, and protein concentration are complex quantitative traits controlled by both genetic and environmental factors during seed development (Duan et al. 2023).

In Angónia, the cultivar with the lowest acceptance rate was 'Bimba'. Farmers reported that, although this cultivar produces large seeds, it has a low number of pods. In Gurué, it was the second least accepted cultivar, with 'Mhembwe' ranking lowest.

In both Angónia and Gurué, the cultivar with the highest acceptance rate was 'TGX 2014-16FM' (Figure 2). According to farmers, its most valued traits include large seed size combined with high number of pods and biomass production. Meyer et al. (2024) recommended this cultivar for breeders and producers in Zimbabwe due to its high and stable protein and oil contents.

The cultivar 'SC Saga' also achieved a significant acceptance rate among farmers. They affirm that its main strengths are high number of pods and large seed size. However, Meyer et al. (2024) characterized SC Saga as unstable, highlighting that its mean protein and oil contents were low or inconsistent compared to those of the other evaluated cultivars.

The cultivars 'TGX 2029 6F', 'TGX 2029 38F', 'TGX 2000 26FZ', 'SC1146/5/25', and 'S882' showed the lowest acceptance rates across both provinces (Figure 2). Farmers reported that TGX 2000 26FZ is prone to lodging, SC1146/5/25 has excessive plant height, and S882 produces fewer pods per plant.

The Nemenyi test revealed significant differences in acceptance levels among the evaluated cultivars (Figure S1). The traditional cultivars 'Bimha', 'K872', and 'Lukanga' showed low acceptance, with no significant differences among them. Cultivars such as 'TGX 2029-52F' and 'TGX 2001-24FM' had higher mean acceptance values and differed significantly from most of the other cultivars. However, no significant differences were observed between these TGX cultivars and Bimha, K872, Lukanga, or M667.

The cultivar Bimha is characterized by high yield potential and moderate tolerance to downy mildew, bacterial pustule, and frogeye leaf spot (*Cercospora sojina*). However, it performs best under medium- to high-input cultivation systems, which limits its suitability for smallholder agriculture (DR&SS 2016).

Index of coincidence between breeding approaches

The mean coincidence index was –29.41, indicating an inverse agreement between cultivar rankings obtained through conventional plant breeding and participatory plant breeding (PPB). Whereas conventional breeding aims to select

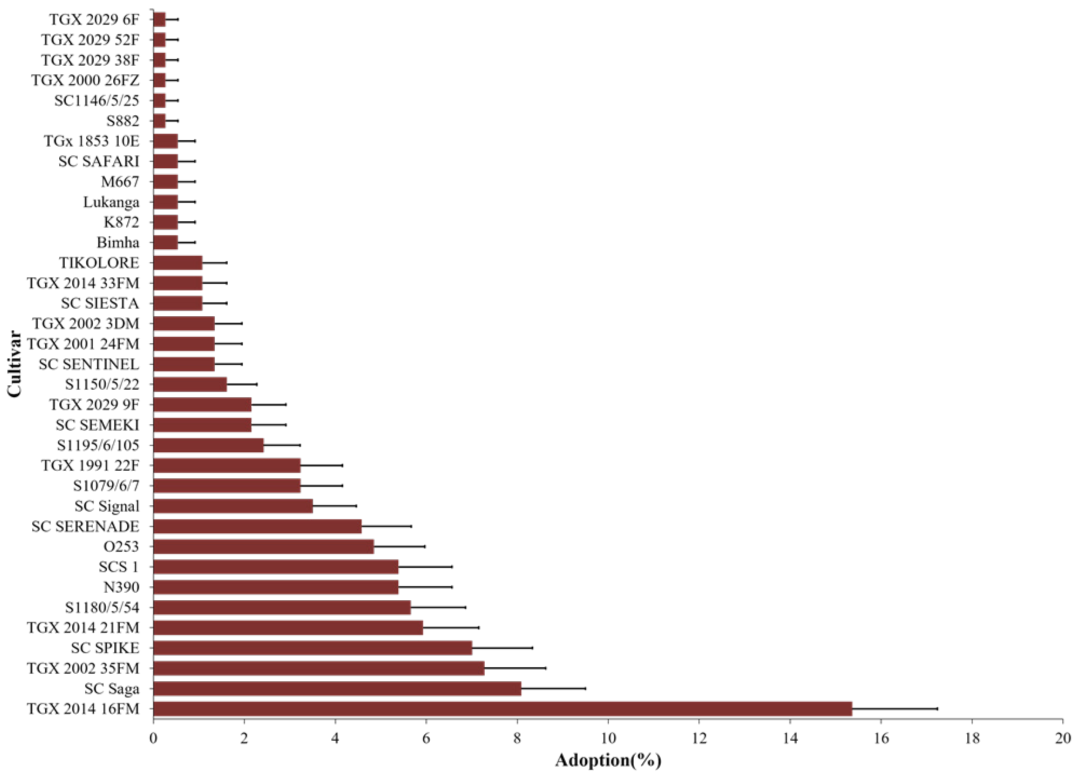

Figure 2. Adoption rate of soybean cultivars by farmers in participatory breeding trails across Angónia and Gurué.

genotypes with broad adaptability, PPB emphasizes the development of varieties specifically adapted to farmers' local conditions and available production technologies, integrating breeders' technical expertise with farmers' knowledge of environmental constraints and preferred traits (Casals et al. 2019).

Consistently, the highest-performing cultivar according to the Mulamba and Mock (1978) index (TGX 2002 3DM) was not among the ten most preferred by farmers, whereas the cultivar with the highest adoption rate was ranked within the top ten of the Mulamba and Mock index.

These results indicate that conventional selection criteria may not fully capture farmer preferences, and they reinforce the importance of integrating conventional breeding efficiency with participatory approaches in order to develop cultivars that are both agronomically superior and aligned with farmer priorities (Ceccarelli 2015, Dereje et al. 2017).

As Mozambique is an emerging soybean-producing country, studies of this nature should be expanded to additional locations, which may increase the range of cultivars available to farmers, enhance household income, contribute to the national economy, and reduce soybean imports.

CONCLUSIONS

The two breeding strategies (conventional and participatory) did not converge in identifying the best-performing cultivar under Mozambican conditions. Conventional breeding identified TGX 2002-3DM as the superior cultivar, whereas participatory breeding favored TGX 2014-16FM. These results reveal the need for long-term trials specifically designed to capture the full impact of genotype × environment interactions, which can significantly influence genotype performance and selection decisions.

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CREDIT STATEMENT

KB Viandro, AT Bruzi, S Kyei-Boahen and MF Santos conceived and designed the study. S Kyei-Boahen and MF Santos conducted data gathering. MR Piza, AT Bruzi and TTT Rocha performed statistical analyses. KB Viandro, AT Bruzi, TTT Rocha, JSP Santos and VAP Souza wrote the article.

DATA AVAILABILITY

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

REFERENCES

Borém A, Silva F, Sediyama T and Camara G (2022) **Soja: do plantio à colheita**. Oficina de Textos, Viçosa, 312p.

Casals J, Rull A, Segarra J, Schober P and Simó J (2019) Participatory plant breeding and the evolution of landraces: A case study in the organic farms of the Collserola Natural Park. **Agronomy 9**: 486.

Ceccarelli S (2015) Efficiency of plant breeding. **Crop Science 55**: 87-97.

Ceccarelli S and Grando S (2020) Participatory plant breeding: Who did it, who does it and where? **Experimental Agriculture 56**: 1-11.

Ceccarelli S, Grando S, Tutwiler R, Baha J, Martini AM, Salahieh H, Goodchild A and Michael M (2000) A methodological study on participatory barley breeding I. Selection phase. **Euphytica 111***:* 91-104.

Dereje G, Walelign B, Giddisa A, Hagos A, Dabi A, Dibaba R and Alemu D (2017) Participatory evaluation and determination of N and P fertiliser application rate on yield and yield components of Upland Rice (NERICA-4) at Bambasi District, Benishangul-Gumuz Regional State. **Advances in Crop Science and Technology 5**: 1-6.

DR&SS - Department of Research and Specialist Services (2016) Oil seeds. Available at https://www.drss.gov.zw/index.php/130-oil-seeds?start=1. Accessed on July 17, 2025.

Duan Z, Li Q, Wang H, He X and Zhang M (2023) Genetic regulatory networks of soybean seed size, oil and protein contents. **Frontiers in Plant Science 14**: 1160418.

FAO – Food and Agriculture Organization of the United Nations (2023) Soybean production in Africa. Available at https://www.fao.org/faostat/en/#data/QCL. Accessed on October 3, 2025.

Greenberg S (2018) **A review of participatory plant breeding and lessons for African seed and food sovereignty movements**. The African Centre for Biodiversity, Johannesburg, 71p.

Guwela VF, Bokosi J, Saka V and Tefera H (2013) Yield loss associated with soybean rust (*Phakopsora pachyhrizi* SYD.) in Malawi. **African Crop Science Conference Proceedings 11**: 279-284.

Habtegebriel MH and Abebe AT (2023) Grain yield stability of soybean (*Glycine max* (L.) Merrill) for different stability models across diverse environments of Ethiopia. **Agrosystems, Geosciences & Environment 6**: 20396.

Hamblin J and Zimmermann MJ (1986) Breeding common bean for yield in mixtures. **Plant Breeding Review 1**: 245-272.

Hartley HO (1950) The maximum F-ratio as a short-cut test for heterogeneity of variance. **Biometrika 37**: 308-312.

Henderson CR (1975) Best linear unbiased estimation and prediction under a selection model. **Biometrics 21**: 423-447.

Hollander M, Wolfe DA and Chicken E (2015) **Nonparametric statistical methods**. Wiley-Blackwell, Hoboken, 828p.

Honsdorf N, Van Loon J, Govaerts B and Verhulst N (2022) Crop management for breeding trials. In Reynolds MP and Braun HJ (eds) **Wheat improvement**. Springer, Cham, p. 257-274.

Janeque RA, Costa NL and Santana AC (2021) Cultivo de soja no continente africano: evidências contemporâneas baseadas em produtores moçambicanos. **Revista de Economia e Sociologia Rural 59**: e217894.

Kumar R, Kumar M, Gangwar LK, Kumar V, Singh S, Edhigalla P and Rahimi M (2025) Association and reliability analysis of multi-trait selection methods and selection of superior genotypes across the traits in Indian mustard. **Scientific Reports 15**: 23405.

Kumar R, Singhand J and Singh J (2023) Participatory plant breeding. **Just Agriculture 64**: 399-402.

Merga W (2017) Review on participatory plant breeding. **International Journal of Research Studies in Agricultural Science 3**: 7-13.

Meyer E, Prenger E, Mahmood A, Santos MF, Chigeza G, Song Q, Mwadzingeni L, Mukaro R, Chibanda M, Mabuyaye G, Diers B and Scaboo A (2024) Evaluating genetic diversity and seed composition stability within Pan-African Soybean Variety Trials. **Crop Science 64**: 3272-3292.

Mulamba NN and Mock JJ (1978) Improvement of yield potential of Elo Blanco maize (*Zea mays* L.) population by breeding for plant traits. **Journal of Genetics and Cytology 1**: 40-51.

Mwiinga B, Sibiya J, Kondwakwenda A, Musvosvi C and Chigeza G (2020) Genotype × environment interaction analysis of soybean (*Glycine max* (L.) Merrill) grain yield across production environments in Southern Africa. **Field Crops Research 256**: 107922.

Nchanji EB, Lutomia CK, Ageyo OC, Karanja D and Kamau E (2021) Gender-responsive participatory variety selection in Kenya: Implications for common bean (*Phaseolus vulgaris* L.) breeding in Kenya. **Sustainability 13**: 13164.

Resende MDV and Duarte J (2007) Precisão e controle de qualidade em experimentos de avaliação de cultivares. **Tropical Agricultural Research 37**: 182-194.

Retore YI, Fregonezi BF, Pavan JPS, Chigeza G, Leles EP, Santos MF, Goldsmith P, Diers B, Araújo MS and Pinheiro JB (2026) Boosting soybean adaptation in Africa through multi-trait selection in multi-environment trials. **Crop Breeding and Applied Biotechnology 26**: e54982618.

Sanya LN, Ssali RT, Namuddu MG, Kyotalimye M, Marimo P and Mayanja S (2023) Why gender matters in breeding: lessons from cooking bananas in Uganda. **Sustainability 15**: 7024.

Shapiro SS and Wilk MB (1965) An analysis of variance test for normality (complete samples). **Biometrika 52**: 591-611.

Tadele Z (2017) Raising crop productivity in Africa through intensification. **Agronomy 7**: 1-30.

Van Vugt D, Franke AC and Giller KE (2017) Participatory research to close the soybean yield gap on smallholder farms. **Experimental Agriculture 53**: 396-415.