



Farmers' participatory selection of lima bean (*Phaseolus lunatus* L.) landraces in northeastern Brazil

Edmilson Gomes de Oliveira · Maria Aldete Justiniano da Fonseca · Michelle dos Santos Nascimento · Maria Santa de Sousa Silva · Karla Anielle da Silva Bernardo · Verônica Brito da Silva · Ângela Célis de Almeida Lopes · Marcones Ferreira Costa  · Regina Lucia Ferreira Gomes

Received: 23 February 2026 / Accepted: 28 March 2026 / Published online: 9 April 2026
© The Author(s) 2026

Abstract The lima bean (*Phaseolus lunatus* L.) is a nutritionally important legume with significant cultural and socioeconomic value in Brazil, particularly for smallholder farmers in the northeastern region. Despite its potential, it remains underutilized. In this study, participatory plant breeding (PPB) to identify and select lima bean landraces with high adaptability and market potential in the Várzea Grande and Tianguá municipalities of Brazil. Thirty farmers participated in field trials and participatory selection workshops in which landraces were evaluated for agronomic traits, seed quality, and market-relevant characteristics. Semi-structured interviews provided

insights into traditional knowledge, cultivation practices, and the criteria used for cultivar selection. Farmers cultivated small plots, often under one hectare, maintaining up to three landraces for over 10 years, with Boca de Moça predominating in Várzea Grande and white-seeded cultivars in Tianguá. Prioritized traits included pest and disease resistance, productivity, and market acceptance. Analysis of the ranking matrix identified nine landraces as the most suitable, with BGP-UFPI 797, 1331, and 1242 performing the best across multiple traits. These results highlighted the role of farmers, especially women, in conserving genetic diversity and integrating traditional knowledge into breeding. PPB facilitates the selection of genotypes that combine productivity, resilience, and market appeal, supporting the conservation of agrobiodiversity and the sustainability of family farming. These findings demonstrate the potential of participatory approaches in enhancing underutilized crops, strengthening rural livelihoods, and promoting food security.

E. G. de Oliveira · M. dos Santos Nascimento ·
M. S. de Sousa Silva · K. A. da Silva Bernardo
Graduate Program in Agronomy, Federal University
of Piauí, Teresina, PI, Brazil

E. G. de Oliveira
Federal Institute of Piauí, Campus José de Freitas,
José de Freitas, PI, Brazil

M. A. J. da Fonseca
Embrapa Genetic Resources and Biotechnology, Brasília,
DF, Brazil

V. B. da Silva · Â. C. de Almeida Lopes · R. L. F. Gomes
Department of Crop Science, Federal University of Piauí,
Teresina, PI, Brazil

M. F. Costa (✉)
Federal University of Piauí, Amílcar Ferreira Sobral
Campus, Floriano PI, Brazil
e-mail: marconescosta@ufpi.edu.br

Keywords Leguminosae · Farmers preference ·
Food security · Participatory breeding

Introduction

Smallholder farmers often rely on landraces that have been selected and maintained for generations (Dias et al. 2024). However, these farmers

face increasing challenges such as resource scarcity, low adoption of technologies, and vulnerability to climate change, which compromise the productivity and stability of their agricultural systems (Calvet-Mir et al. 2025). In this context, research approaches that integrate scientific data with traditional knowledge are essential to understand the specific needs of these farmers and promote more sustainable and resilient agricultural systems.

Participatory plant breeding (PPB) is an effective and socially inclusive strategy as it directly involves farmers in the process of cultivar selection and evaluation (Colley et al. 2021). This approach strengthens the integration of scientific knowledge with local expertise and promotes the development of genotypes adapted to regional conditions and farmers' preferences (Letting et al. 2022). Moreover, PPB contributes to the conservation of landraces, valorization of indigenous knowledge, and reinforcement of family farming (Weltzien & Christinck 2017).

The lima bean (*Phaseolus lunatus* L.) is notable for its high nutritional value and cultural and socio-economic importance in various traditional and regional communities (Lustosa-Silva et al. 2023). However, this species remains underutilized and has not yet been fully integrated into structured production chains, which hinders its valorisation and limits the expansion of its cultivation (Adebo, 2023).

In Brazil, particularly in the northeastern region, there is considerable diversity in local lima bean landraces, which represent an important genetic resource for agroecology and family farming (Soares et al. 2022). However, despite advances in genetic improvement programs, there remains a scarcity of cultivars adapted to local conditions and the needs of farmers and other actors in the production chain, limiting the strengthening and valorization of this crop (Lopes et al. 2024; Lustosa-Silva et al. 2022). In this context, this study aimed to identify and select traditional lima bean cultivars with high adaptability and market potential through participatory selection involving family farmers in Northeast Brazil, thereby contributing to the improvement and valorization of this crop in the region.

Materials and methods

Participant mobilization and selection

Participatory selection of lima bean landraces was conducted in 2023 through two evaluation trials established on family farming properties in the municipalities of Várzea Grande, Piauí, and Tianguá, Ceará, Brazil.

The mobilization process began with meetings with the leaders of rural workers' unions in both municipalities, during which the objectives and procedures of the study were presented. Union leaders were responsible for disseminating information about the study, mobilizing farmers, and providing logistical support during field visits.

Participant selection followed specific criteria: (a) having experience in lima bean cultivation; (b) engaging in seed selection and conservation practices; (c) willingness to participate and share new experiences; and (d) ensuring gender and generational diversity, including women, youth, and the elderly, thereby valuing traditional knowledge and promoting intergenerational knowledge exchange.

Semi-structured interviews were conducted during farm visits to collect information on the cultivation practices, landraces used, length of seed stewardship, conservation methods, and selection criteria. These data informed the subsequent stages of the study, which involved planning the participatory selection workshops.

Participatory selection workshops

The participatory selection workshops were conducted in four stages. In the first stage, participants were registered by completing enrollment forms containing information on their identity and lima bean cultivation, and they received personalized name badges.

In the second stage, participants were welcomed and organized into a circle, introducing themselves and sharing the significance of lima beans in their cultivation and usage experiences. Each farmer deposited samples of their seeds in the center of the circle, which were properly labeled and incorporated into the *Phaseolus* Germplasm Collection at the Federal University of Piauí (BGP-UFPI).

The third stage involved identifying the traits of interest for participatory selection using a brainstorming methodology (Rickards 1999). Guiding questions were proposed, such as “Are all lima beans the same?” and “Which characteristics are observed when selecting a cultivar with market potential?” Individual responses were recorded on cards, presented to the group, grouped according to similarity, and discussed collectively. Through consensus, the final set of selection traits was defined and prioritized based on the frequency and importance ascribed to the participants. Each trait was assigned a color code and a scoring scale from 1 to 10 was established for subsequent evaluation.

In the fourth stage, the farmers conducted visual evaluations of the landraces in field experiments arranged in a randomized complete block design with two replications and 20 cultivars per block. Each plot consisted of two 5-m rows with ten planting holes per row, containing two lima bean plants and one maize plant used as a support. Evaluations were performed individually with the assistance of monitors, and scores (from 1 to 10) were recorded on color-coded sheets corresponding to the assessed traits. The sheets were then deposited in boxes placed in front of the plots for tabulation.

The 20 evaluated landraces are currently maintained in the BGP-UFPI, conserved under controlled conditions, and identified by specific alphanumeric codes that allow tracking and standardization of the information associated with each cultivar (Table 1).

Data analysis and ethical considerations

Following the field evaluations, a tabulation committee was formed to count the scores and create a ranking matrix, with the 20 cultivars as rows and the selected traits as columns. The matrix summarized mean scores per cultivar and per trait, enabling quantitative and qualitative comparisons among the landraces and highlighting the traits that most differentiated their performances. The results were discussed with the participants, fostering collective reflection on the performances of the cultivars and the importance of each trait.

Discussions were guided by prompting questions such as Which traits contributed most to the cultivars' scores? Which landraces performed best? Based on these analyses, which cultivars should be selected?

Table 1 List of landrace lima bean used in participatory selection in Várzea Grande—PI and Tianguá—CE

BGP-UFPI Code	Common name
BGP-UFPI 1320	—
BGP-UFPI 889	White lima bean
BGP-UFPI 1331	—
BGP-UFPI 1357	White lima bean
BGP-UFPI 1248	White lima bean
BGP-UFPI 1242	Large white lima bean
BGP-UFPI 1113	White lima bean
BGP-UFPI 1356	—
BGP-UFPI 934	White lima bean
BGP-UFPI 797	White lima bean
BGP-UFPI 1266	White lima bean
BGP-UFPI 882	White lima bean
BGP-UFPI 1371	—
BGP-UFPI 1366	Large white lima bean
BGP-UFPI 1268	White lima bean
BGP-UFPI 1249	Small white lima bean
BGP-UFPI 861	White lima bean
BGP-UFPI 1235	White lima bean
BGP-UFPI 883	White lima bean
BGP-UFPI 1228	White lima bean

and What is the significance of these results? Through these discussions and dialogues between farmers and researchers, cultivars with the highest production and commercial potential were selected, considering the adjusted averages and local preferences.

Data collected during the workshops and field experiments were subjected to descriptive analysis, including average values, standard deviations, and coefficients of variation (CV%), as well as frequency distributions, to identify the cultivars and traits most valued by smallholder farmers. This study was approved by the Research Ethics Committee (CAAE number 91040425.8.0000.5214). All participants participated voluntarily and signed the Free and Informed Consent Form (FICF), in accordance with the current ethical guidelines in Brazil for research involving human subjects.

Results

The information obtained through interviews with lima bean smallholder farmers and the Participatory Selection Workshops conducted in the municipalities of Várzea Grande and Tianguá allowed us to outline the farmers' socioeconomic profiles and understand the diversity of practices related to the conservation and selection of landrace seeds.

Thirty lima bean farmers participated in the study: 17 from Várzea Grande and 13 from Tianguá. The predominant age range was 40–60 years, comprising 50% of the participants from Várzea Grande and 46% from Tianguá. However, young farmers were also represented, accounting for 25% in Várzea Grande and 23% in Tianguá. In terms of sex, women represented 25% of the participants in Várzea Grande and 31% in Tianguá. In Várzea Grande, 17% of the women were aged 20–40 years, whereas in Tianguá, the predominant age group was 40–60 years (23%).

Regarding educational attainment, a higher proportion of farmers in Várzea Grande had completed secondary and higher education (53.8%), whereas in Tianguá, 61% had not completed primary education. Participation in representative organizations was also notable; in Tianguá, all farmers were union members, whereas in Várzea Grande, 80% belonged to unions.

Regarding land tenure, four categories of farmers were identified: landowners, agrarian reform settlers, tenants, and other forms of land use, the latter consisting mainly of children working on their parents' lands as dependents or heirs. Landowners constituted the predominant category, representing 53.8% of Várzea Grande and 61.5% of Tianguá. A significant proportion of agrarian reform settlers was also observed, accounting for 23% in both municipalities, in addition to the presence of tenancy arrangements, although with an incidence of below 10%.

Family farmers demonstrated extensive experience in lima bean cultivation, with 78% of farmers in Tianguá and 54% in Várzea Grande, where the species has been cultivated for over 20 years. This long-standing experience has contributed to a deeper understanding of crop behavior and the improvement of local agricultural practices.

In Tianguá, the period of seed stewardship among producers ranges from 4 to 31 years, with 57% maintaining their own seeds for more than 10 years. Thus, these farmers met the criteria established by

Ordinance N. 51 of October 3, 2007, of the Ministry of Agrarian Development (MDA), which in Article 3, item III, defines a minimum requirement of at least three years of varietal stewardship for the official registration of a cultivar.

Most of the family farmers interviewed cultivated their own seeds, which encompassed up to three distinct cultivars. The main landraces identified were Boca de Moça, Olho de Ovelha, Branca, Amarela, and Orelha de Onça.

In Várzea Grande, Boca de Moça stood out as the most widely cultivated landrace, as mentioned by 47% of the respondents. However, considering that some farmers refer to this cultivar as Olho de Ovelha (40%), its representation is even greater. The Branca cultivar was used the least frequently (28%). Among the producers in Tianguá, white-seeded cultivars predominated (71.4%), followed by Orelha de Onça and Amarela.

Regarding production indicators, the average cultivated area was similar between the two regions at approximately 1 ha, as was the productivity level. However, the average yield recorded during the study was lower than the municipal average of 79.3% and 75.6% in Tianguá and Várzea Grande, respectively.

The Participatory Selection Workshops involved 14 farmers in Várzea Grande and seven in Tianguá, representing 35.7% and 28.6% of the interviewed participants, respectively. Using the “Brainstorming” methodology, the main characteristics used to differentiate the cultivated landraces in both localities were identified. Eight characteristics were recorded in Várzea Grande, six of which were related to productivity, vegetative development, maturation cycle, plant health, seed traits, culinary quality, and adaptability to local farming systems (Table 2).

Regarding the selection criteria for the landraces, farmers in Várzea Grande mentioned six main traits, whereas those in Tianguá identified ten (Table 3). In Tianguá, farmers emphasized the same characteristics as those observed in Várzea Grande, adding a preference for heavier and white-colored seeds. They also highlighted traits associated with productivity, such as good plant development, longer inflorescences, a higher number of pods, larger pods, and the absence of diseases.

After defining the distinguishing and selection traits of lima bean landraces, the participants were

Table 2 List of traits used to differentiate landrace lima bean cultivars in Várzea Grande—PI and Tianguá—CE

Várzea Grande—PI	Tianguá—CE
1. Exhibit higher pod load and greater yield potential	1. Exhibit better vegetative development with increased vine growth
2. Display a wide range of seed coat colors, including variation among white seeds	2. Produce more pods and a higher number of grains
3. Present variability in seed size	3. Display a wide range of seed coat colors
4. Show increased tolerance to diseases	4. Present variability in seed size
5. Are late-maturing, with a longer production cycle	5. Require a longer germination period
6. Exhibit a higher degree of seed bitterness	6. Exhibit a higher degree of seed bitterness
7. Require a longer cooking time	
8. Show better adaptation to regional environmental conditions	

Table 3 List of traits used by farmers in the selection of landrace lima bean for cultivation and commercialization in Várzea Grande—PI and Tianguá—CE

Várzea Grande—PI	Tianguá—CE
1. Exhibit higher pod load and greater pod production	1. Vigorous plant growth with large leaves
2. Pods contain a higher number of seeds	2. Larger flower clusters (inflorescences)
3. Produce more pods and seeds	3. Clusters with a higher number of pods / higher pod load
4. Seeds are uniform in color, without color mixing	4. Larger pods
5. Seeds are larger and well-filled	5. Pods free from spots or disease symptoms
6. Seeds show no evidence of pest damage	6. Produce a greater number of seeds
	7. Heavier seeds
	8. Seeds free from spots or disease symptoms
	9. Clean, whole seeds without mixing or shriveling
	10. White seeds

invited to identify the attributes that characterize white-seeded cultivars with greater market acceptance, given the specific preferences of this segment. In Várzea Grande, farmers have identified the main selection criteria as plants with a higher productive capacity, expressed by the number of pods per plant; homogeneous seeds with no color mixtures; larger, well-filled seeds; and seeds free from pest or disease damage.

In Tianguá, participants defined the selection criteria as vigorous plant growth and development; productivity represented by the number and uniformity of pods; homogeneity; whole, well-filled, and undeformed seeds; and pods and seeds free from spots or disease symptoms. In addition, participants emphasized that, for the market, seed characteristics are the most decisive factors for product acceptance and valuation. Larger, heavier,

well-filled, clean, whole, uniform, and pest-free seeds are in high demand by buyers and achieve higher market prices.

Based on this information, a systematic analysis was conducted using the ranking matrix, incorporating scores from 1 to 10 assigned by farmers to the evaluated traits. Mean values, standard deviations, and coefficients of variation were calculated for each attribute. The results indicated good uniformity in the evaluations carried out in both localities, with coefficients of variation ranging from 6.2% (homogeneous seeds without color mixtures) to 21.2% (greater productive capacity) in Várzea Grande and from 5.9% (homogeneous, whole, well-filled, and undeformed seeds) to 20.1% (vegetative vigor) in Tianguá (Tables 4 and 5).

In Várzea Grande, farmers assigned mean scores below seven for all cultivars in the trait “greater

Table 4 Mean scores assigned to the traits

	Landraces	PL	LWFS	SFPDS	SUC	Y	Mean
In the participatory selection of landrace lima bean cultivars conducted in Várzea Grande—PI σ : standard deviation, CV: coefficient of variation, pod load (PL), larger and well-filled seeds (LWFS), seeds free from pest and disease symptoms (SFPDS), seeds with uniform color (SUC), and yield (Y)	BGP-UFPI 1228	3.417	5.104	4.625	7.125	3.22	4.698
	BGP-UFPI 1266	4.542	6.146	5.563	7.708	7.62	6.315
	BGP-UFPI 1235	6.250	8.271	8.354	7.875	5.99	7.349
	BGP-UFPI 1357	5.708	7.438	8.354	8.667	8.33	7.700
	BGP-UFPI 861	5.438	5.208	5.042	7.542	6.37	5.920
	BGP-UFPI 889	5.542	7.542	7.000	8.042	9.18	7.461
	BGP-UFPI 1356	5.333	7.000	7.067	6.833	8.15	6.877
	BGP-UFPI 1248	6.875	6.833	7.583	8.208	9.06	7.712
	BGP-UFPI 1268	5.333	7.125	8.000	7.917	6.29	6.933
	BGP-UFPI 934	4.938	6.792	5.417	7.583	8.21	6.588
	BGP-UFPI 882	5.583	5.458	5.792	7.292	7.03	6.232
	BGP-UFPI 883	5.271	7.167	6.521	7.667	5.76	6.478
	BGP-UFPI 1320	5.750	7.438	6.917	8.307	10.00	7.682
	BGP-UFPI 1113	5.875	6.542	6.292	7.583	8.33	6.925
	BGP-UFPI 1249	6.000	6.750	6.438	8.125	6.31	6.724
	BGP-UFPI 1371	5.083	8.021	7.229	8.125	6.49	6.990
	BGP-UFPI 797	5.563	7.125	6.625	7.583	8.14	7.008
	BGP-UFPI 1331	5.667	7.792	8.167	8.667	8.89	7.837
	BGP-UFPI 1366	5.250	6.604	6.708	8.208	6.50	6.655
	BGP-UFPI 1242	5.208	7.521	7.979	8.375	8.51	7.519
	Overall mean	5.431	6.894	6.784	7.872	7.420	6.880
	σ	0.6846	0.8729	1.1059	0.4862	1.5738	
	CV(%)	12.60%	12.66%	16.30%	6.18%	21.21%	

productive capacity.” Conversely, 70% of the cultivars received scores above seven for larger and well-filled seeds, 60% for productivity, 45% for seeds free from pest or disease damage, and 100% for homogeneous seeds without color mixtures.

Among the twenty landraces evaluated, BGP-UFPI 1357, BGP-UFPI 889, BGP-UFPI 1331, and BGP-UFPI 1242 stood out, achieving mean scores ≥ 7 for all assessed traits except productive capacity, highlighting their agronomic potential.

In Várzea Grande, BGP-UFPI 1248 exhibited the highest mean productive capacity; BGP-UFPI 1371, larger and well-filled seeds; BGP-UFPI 1235 and BGP-UFPI 1357, seeds free from pest or disease damage; BGP-UFPI 1357 and BGP-UFPI 1331, seed homogeneity; and BGP-UFPI 1320, productivity.

In Tianguá, all the evaluated landraces scored above seven for homogeneous, whole, well-filled, heavy, and spotless seeds, whereas 45% achieved scores above seven for productivity. BGP-UFPI 1268, BGP-UFPI 934, BGP-UFPI 883, BGP-UFPI 1371, BGP-UFPI 797, BGP-UFPI 1331, and BGP-UFPI

1366 performed well across all traits. Notably, BGP-UFPI 1356 exhibited seed homogeneity and filling; BGP-UFPI 883, pod health; BGP-UFPI 797, plant vigor; and BGP-UFPI 1268, productivity. Considering the overall mean performance and adopting a cut-off score ≥ 7.5 , five landraces were selected in Várzea Grande (BGP-UFPI 1357, BGP-UFPI 1248, BGP-UFPI 1320, BGP-UFPI 1331, and BGP-UFPI 1242) and four in Tianguá (BGP-UFPI 1268, BGP-UFPI 883, BGP-UFPI 1371, and BGP-UFPI 797) (Fig. 1).

In Várzea Grande, farmers assigned mean scores below seven for all cultivars in the trait “greater productive capacity.” Conversely, 70% of the cultivars received scores above seven for larger and well-filled seeds, 60% for productivity, 45% for seeds free from pest or disease damage, and 100% for homogeneous seeds without color mixtures.

Among the twenty landraces evaluated, BGP-UFPI 1357, BGP-UFPI 889, BGP-UFPI 1331, and BGP-UFPI 1242 stood out, achieving mean scores ≥ 7 for all assessed traits except productive capacity, highlighting their agronomic potential.

Table 5 Mean scores assigned to the traits

Landraces	CWFS	HS	SFD	PFD	PG	PL	Y	Mean
BGP-UFPI 1228	7.55	7.35	6.82	6.57	6.64	5.96	2.45	6.19
BGP-UFPI 1266	8.47	8.87	8.39	6.93	7.61	7.18	3.76	7.32
BGP-UFPI 1235	7.73	8.08	7.73	6.62	7.14	6.39	4.08	6.82
BGP-UFPI 1357	7.46	7.50	7.46	7.14	7.29	6.44	2.75	6.58
BGP-UFPI 861	8.53	8.60	7.63	6.93	7.61	7.18	5.23	7.39
BGP-UFPI 889	8.68	8.30	8.11	7.14	7.93	7.50	5.12	7.54
BGP-UFPI 1356	9.14	8.71	8.82	6.71	6.64	6.11	7.97	7.73
BGP-UFPI 1248	7.33	7.67	7.55	6.86	6.71	6.29	5.92	6.90
BGP-UFPI 1268	8.27	8.07	7.86	7.29	8.00	7.61	10.00	8.16
BGP-UFPI 934	8.00	8.14	7.40	7.40	7.54	7.11	7.46	7.58
BGP-UFPI 882	8.57	8.68	8.18	7.29	7.43	7.44	6.16	7.68
BGP-UFPI 883	8.39	8.25	8.36	8.47	8.89	8.86	7.98	8.46
BGP-UFPI 1320	8.68	8.81	8.29	6.79	7.11	6.43	5.56	7.38
BGP-UFPI 1113	8.57	8.64	8.51	6.48	5.39	5.19	2.87	6.52
BGP-UFPI 1249	8.18	8.21	7.79	7.54	7.50	7.64	5.24	7.44
BGP-UFPI 1371	8.68	8.64	8.25	8.21	8.68	8.57	7.69	8.39
BGP-UFPI 797	8.01	8.55	8.23	8.18	9.36	9.18	7.84	8.48
BGP-UFPI 1331	7.32	7.68	7.07	7.14	7.57	7.61	8.14	7.50
BGP-UFPI 1366	7.11	7.86	7.18	7.04	8.75	7.86	7.51	7.61
BGP-UFPI 1242	8.61	7.82	8.25	6.50	7.65	7.68	8.89	7.91
Overall mean	8.16	8.22	7.89	7.16	7.57	7.21	6.13	7.48
σ	0.5440	0.4402	0.5059	0.5427	0.8615	0.9595	2.0809	
CV (%)	12.04%	5.88%	15.51%	11.99%	20.17%	10.36%	33.94%	

In the participatory selection of landrace lima bean cultivars conducted in Tianguá—CE

σ : standard deviation, CV: coefficient of variation, clean and well-filled seeds (CWFS), heavier seeds (HS), seeds free from diseases (SFD), pods free from diseases (PFD), plant growth (PG), pod load (PL), and grain yield (Y)

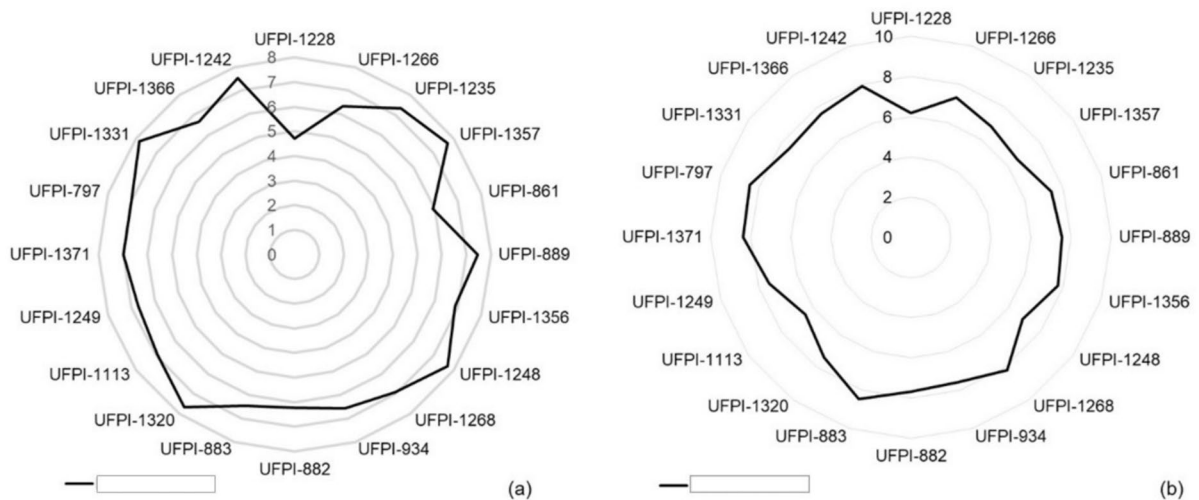


Fig. 1 Superior-performing landrace lima bean cultivars identified through participatory selection in Várzea Grande—PI (a) and Tianguá—CE (b)

In Várzea Grande, BGP-UFPI 1248 exhibited the highest mean productive capacity; BGP-UFPI 1371, larger and well-filled seeds; BGP-UFPI 1235 and BGP-UFPI 1357, seeds free from pest or disease damage; BGP-UFPI 1357 and BGP-UFPI 1331, seed homogeneity; and BGP-UFPI 1320, productivity.

In Tianguá, all the evaluated landraces scored above seven for homogeneous, whole, well-filled, heavy, and spotless seeds, whereas 45% achieved scores above seven for productivity. BGP-UFPI 1268, BGP-UFPI 934, BGP-UFPI 883, BGP-UFPI 1371, BGP-UFPI 797, BGP-UFPI 1331, and BGP-UFPI 1366 performed well across all traits. Notably, BGP-UFPI 1356 exhibited seed homogeneity and filling; BGP-UFPI 883, pod health; BGP-UFPI 797, plant vigor; and BGP-UFPI 1268, productivity.

Considering the overall mean performance and adopting a cutoff score ≥ 7.5 , five landraces were selected in Várzea Grande (BGP-UFPI 1357, BGP-UFPI 1248, BGP-UFPI 1320, BGP-UFPI 1331, and BGP-UFPI 1242) and four in Tianguá (BGP-UFPI 1268, BGP-UFPI 883, BGP-UFPI 1371, and BGP-UFPI 797) (Fig. 1).

Discussion

The production practices and trait preferences of lima bean farmers in the studied states provided valuable insights for guiding PPB strategies. This approach strengthens the integration of scientific knowledge with traditional agricultural practices and promotes the development of genotypes that are better adapted to local conditions and farmer preferences (Fadda et al. 2020).

It was observed that lima bean production in the study areas was predominantly carried out by men, reflecting their historically assigned role as the main decision-makers in the family, land, and production. However, women's participation in productive activities is significant, likely driven by the mobilization strategies employed and their crucial role in the selection and conservation of cultivated lima bean landraces.

This participation is particularly important, as women tend to value agronomic traits related to postharvest handling, processing, and food use, whereas men generally prioritize market-related attributes such as color, shape, size, and commercial

potential (Nchanji et al. 2021). Furthermore, research indicates that women possess detailed and essential knowledge to identify and select plants for agricultural cultivation (Sood et al. 2016), and that their increasing involvement in agriculture globally has contributed to strengthening their socio-economic role and enhancing farm productivity when labor is shared between husbands and wives (Islam et al. 2022).

Most farmers involved in lima bean production are over 40 years old, which may be associated with rural-to-urban migration among younger generations who often perceive agriculture and related activities as unprofitable (Wineman et al. 2020). This scenario underscores the evidence of an aging rural population and uncertainty surrounding the continuity of agricultural activities. Similar findings were reported in research with lima bean farmers in Piauí, which also identified a higher concentration of farmers within this age range (Lustosa-Silva et al. 2023; Soares et al. 2022).

This trend has fueled debate and initiatives aimed at strengthening family farming, which relies heavily on generational succession as a fundamental strategy for social reproduction (Spanevello et al. 2017). In this context, the presence of young people in agricultural activities, although still limited, may represent a promising movement toward the revitalization of lima bean cultivation, warranting greater attention and support for future initiatives and research focused on the sustainability of family farming.

The data from this study indicate a low level of formal education among lima bean farmers, a finding similar to that observed in the southern mesoregion of Ceará, Brazil (Oliveira 2019). Farmers' knowledge and education play crucial roles in increasing production, as higher levels of schooling are directly associated with greater adoption of new technologies and cultivars (Abed et al. 2020). Furthermore, practical experience in agricultural activities is a key determinant of productivity, influencing the farmers' ability to access, interpret, and apply technical information that can optimize crop management and yield.

Most of the farmers interviewed in both municipalities had over 20 years of experience in cultivating lima beans, reflecting a substantial accumulation of traditional and empirical knowledge about the crop.

These findings underscore the importance of integrating local knowledge into participatory breeding programs to value farmers' practical experiences in the development and selection of genotypes adapted to regional conditions.

Land tenure has also emerged as a determining factor that directly influences farmers' autonomy in decision-making, access to financial resources, and the adoption of sustainable technologies (Abab et al. 2023). Most farmers cultivated lima beans on small plots, typically up to 1.0 hectare, using up to three cultivars maintained for more than 10 years, with Boca de Moça predominating in Várzea Grande and white-seeded cultivars in Tianguá. These results indicate that lima beans are strongly associated with family farming and are maintained on small-scale farms using farmer-owned seeds.

However, smallholder farmers face difficulties in accessing credit and incentives because financial institutions often consider these enterprises to be high-risk (Suvi et al. 2021). The limited area devoted to lima bean cultivation also reflects its secondary status relative to other more commercially valuable crops, contributing to the persistent neglect of this legume in agricultural support and development programs.

In Várzea Grande, the cultivation of the Boca de Moça landrace was predominant. This preference can be explained by its adaptation to local cropping systems, its strong cultural identity in the region where it has been cultivated for generations, and the existence of an established market for its commercialization (Assunção-Filho et al. 2022). The cultural relevance of this cultivar has been widely documented in academic research, highlighting its symbolic and economic value to local farmers.

However, in Tianguá, the predominant use of white-seeded cultivars in cropping systems is associated with higher market acceptance and prices compared to other cultivars. The yellow-seeded cultivars also showed good acceptance in the regional market, albeit to a lesser extent. These findings reinforce the observation that smallholder lima bean farmers maintain and utilize diverse landraces in their production systems, which is essential for conserving agricultural biodiversity and enhancing the resilience of agroecosystems.

The genetic diversity of farmers is an important adaptive strategy in the face of climate change and

contributes significantly to food security (Babalola et al. 2025). In this context, lima bean producers can be regarded as the true guardians of genetic variability. By conserving and managing, over generations, a wide range of cultivars adapted to local conditions, these farmers play a crucial role in the knowledge, preservation, and utilization of this genetic heritage in breeding programs (Avila et al. 2025).

The number and type of traits used by farmers in the participatory selection process vary according to the objectives of the selection and the profile of the participants (Ishikawa et al. 2020). In the case of lima beans, the traits preferred by farmers when selecting landraces were pest and disease resistance, high productivity, and good market acceptance.

The incidence of pests and diseases, particularly anthracnose, is one of the main limitations to lima bean production worldwide (Brito et al. 2025). In this context, the development of cultivars resistant to this disease represents a promising strategy to increase crop productivity, reduce production costs, and consequently enhance economic benefits for smallholder farmers.

Productivity was highlighted by farmers as one of the most important criteria in cultivar selection because it is directly associated with increased income and improved living conditions for rural households. Market preference constitutes another determining factor in this process, as it directly influences the commercialization and added value of the product.

Thus, aligning farmers' preferences with market demand underscores the importance of participatory breeding programs that integrate agronomic and commercial criteria, promoting the development of lima bean cultivars that are more productive, disease-resistant, and better accepted by consumers.

Based on the ranking matrix constructed from the mean scores assigned by the farmers, nine accessions were selected as most suitable for cultivation: BGP-UFPI 1357, BGP-UFPI 1248, BGP-UFPI 1320, BGP-UFPI 1331, BGP-UFPI 1242, BGP-UFPI 1268, BGP-UFPI 883, BGP-UFPI 1371, and BGP-UFPI 797. Directing breeding programs and objectives for these farmer-selected accessions will facilitate the release and development of genotypes with traits aligned with their preferences and production needs, thereby strengthening the adoption and maximizing the impact of new cultivars in local farming systems.

This study highlights the importance of PPB as a strategy for aligning scientific research with the needs of smallholder farmers, thereby enabling the selection of lima bean landraces adapted to local conditions with market potential. Among the accessions evaluated, BGP-UFPI 797, BGP-UFPI 1331, and BGP-UFPI 1242 stood out for their superior performance according to the criteria defined by farmers. These results demonstrate the value of participatory selection in identifying genotypes that combine productivity, pest and disease resistance, market traits, and farmer preferences.

Valuing landraces and traditional knowledge contributes to the conservation of agrobiodiversity and development of more resilient farming systems in the face of climate change. Moreover, the inclusion of farmers in the decision-making processes strengthens rural community empowerment and food sovereignty.

Thus, integrating participatory methodologies with breeding programs is essential for the reinforcement of family farming and the promotion of socioeconomic and environmental sustainability, providing pathways for the expansion and valorization of underutilized species such as lima beans.

Conclusion

In this context, the present study demonstrates that participatory approaches to lima bean improvement enable an effective integration of scientific breeding strategies with farmers' traditional knowledge systems. This integration was fundamental to achieving the study objectives by identifying traditional cultivars with greater regional adaptability and market potential, ensuring that selection processes are closely aligned with local agroecological conditions and sociocultural demands in Northeast Brazil.

The incorporation of farmers' knowledge into the breeding process facilitated the identification of locally valued traits and supported the selection of genotypes better adapted to environmental conditions and on-farm management practices. Accordingly, this study highlights the importance of landraces not only as reservoirs of genetic diversity, but also as integral components of the cultural and productive heritage of rural communities.

Overall, these findings reinforce participatory plant breeding as a strategic pathway for the conservation and

sustainable use of lima bean genetic resources, enhancing their agronomic performance, socioeconomic relevance, and long-term contribution to family farming systems in Northeast Brazil.

Acknowledgements We would like to thank all the farmers who participated in this research for their time, collaboration, and valuable contributions throughout the study.

Author contributions E. G. de Oliveira, M. A. J. da Fonseca, V. B. Silva, A. C de A. Lopes, R. L. F. Gomes, M. F. Costa: Data curation; formal analysis; investigation; software; visualization; writing original draft. M. dos S. Nascimento, M. S. de S. Silva, K. A. da S. Bernardo: Formal analysis; investigation; visualization. E. G. de Oliveira, M. A. J. da Fonseca, A. C de A. Lopes, R. L. F. Gomes, M. dos S. Nascimento, M. S. de S. Silva, K. A. da S. Bernardo: Investigation; validation. A. C de A. Lopes, V. B. Silva, R. L. F. Gomes: Formal analysis; supervision. E. G. de Oliveira, R. L. F. Gomes: Project administration; resources. E. G. de Oliveira, M. F. Costa and R.L.F. Gomes: review and editing.

Funding The Article Processing Charge (APC) for the publication of this research was funded by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) (ROR identifier: 00x0ma614). This study had the financial support from Fundação de Amparo a Pesquisa do Piauí (FAPEPI), Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES)—Finance Code 001, and Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq).

Data availability The datasets generated during and analysed in the current study are available from the corresponding author.

Declarations

Conflict of interest The authors declare no competing interests.

Ethics approval All procedures performed in the study involving human participants were in accordance with the ethical standards of the National Research Ethics Commission (CONEP Resolution N°. 466/2012, Brazil/ (CAAE number 91040425.8.0000.5214). Informed consent was obtained from all individual participants included in the study.

Consent for publication Informed consent was obtained from all individual participants included in the study.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your

intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>.

References

- Abab SA, Senbeta F, Negash TT (2023) The effect of land tenure institutional factors on small landholders' sustainable land management investment: evidence from the highlands of Ethiopia. *Sustain* 15(12):9150. <https://doi.org/10.3390/su15129150>
- Abed R, Sseguya H, Flock J, Mruma S, Mwango H (2020) An evolving agricultural extension model for lasting impact: how willing are Tanzanian farmers to pay for extension services? *Sustain* 12(20):8473. <https://doi.org/10.3390/su12208473>
- Assunção-Filho JRD, Costa MF, Pinheiro JB, Carvalho LCB, Ferreira-Gomes RL, Lopes ÁCDA (2022) Selection of superior genotypes of lima bean landraces by multivariate approach. *Rev Caatinga* 35(01):87–95. <https://doi.org/10.1590/1983-21252022v35n109rc>
- Avila JET, Coelho FC, Sardo PML, Haddade IR, Moonen AC (2025) In situ conservation of agrobiodiversity carried out by traditional family farmers in a mountainous region of Brazil. *Agroecol Sustain Food Syst* 49(6):797–820. <https://doi.org/10.1080/21683565.2024.2445729>
- Babalola KO, Monacelli N, Gozzi M, Ceccarelli S, Folloni S, Galaverna G (2025) Genetic diversity and climate change adaptation in wheat: a systematic review of landraces, composite cross populations, and evolutionary populations. *Front Sustain Food Syst* 9:1504922. <https://doi.org/10.3389/fsufs.2025.1504922>
- Brito MV, Torres KKB, Sousa JVM, França GB, Costa MF, da Costa GAL, Ferreira GNC, Silva VB, Sá GH, Lopes ACA, Melo MP, Gomes RLF (2025) Inheritance of genetic resistance to anthracnose in lima beans: analysis and implications for breeding. *J Phytopathol* 173(1):e70036. <https://doi.org/10.1111/jph.70036>
- Calvet-Mir L, Benyei P, Porcuna-Ferrer A, Aceituno-Mata L, Braga Junqueira A, Mattalia G, Miñarro S, Reyes-García V, Schlingmann A, Ávila JVC, Labeyrie V (2025) Landraces and climate change: global trends through the lens of political agroecology. *Agric Hum Values*. <https://doi.org/10.1007/s10460-025-10721-4>
- Colley MR, Dawson JC, McCluskey C, Myers JR, Tracy WF, Van Bueren EL (2021) Exploring the emergence of participatory plant breeding in countries of the Global North—a review. *J Agric Sci* 159(5–6):320–338
- Dias WKNS, Anuruddi HIGK, Fonseka DLCK (2024) Development of improved landraces in agriculture for rural development. *Plant Mutagenesis: Sustainable Agriculture and Rural Landscapes*. Springer Nature Switzerland, Cham, pp 207–217. https://doi.org/10.1007/978-3-031-50729-8_16
- Fadda C, Mengistu DK, Kidane YG, Dell'Acqua M, Pè ME, Van Etten J (2020) Integrating conventional and participatory crop improvement for smallholder agriculture using the seeds for needs approach: a review. *Front Plant Sci* 11:559515. <https://doi.org/10.3389/fpls.2020.559515>
- Ishikawa H, Drabo I, Joseph BB, Muranaka S, Fatokun C, Boukar O (2020) Characteristics of farmers selection criteria for cowpea (*Vigna unguiculata*) varieties differ between north and south regions of Burkina Faso. *Exp Agric* 56(1):94–103
- Islam MS, Islam S, Fatema K, Khanum R (2022) Rural women participation in farm and off-farm activities and household income in Bangladesh. *Heliyon*. <https://doi.org/10.1016/j.heliyon.2022.e10618>
- Letting FK, Venkataramana PB, Ndakidemi PA (2022) Farmers' participatory plant selection of lablab (*Lablab purpureus* (L.) sweet) in Tanzania. *Front Plant Sci* 13:784032. <https://doi.org/10.3389/fpls.2022.784032>
- Lopes ACL, Araujo ASF, Júnior JEAB, Torres KKB, Medeiros LDSA, Vale LM, Costa MF, Silva VB, Gomes RLF (2024) Vinte anos de pesquisas com o feijão-fava (*Phaseolus lunatus* L.) na Universidade Federal do Piauí. *Revista RG News* 10:1
- Lustosa-Silva JD, Ferreira-Gomes RL, Martínez-Castillo J, Carvalho LCB, de Oliveira LF, Ortiz-García MM, Sánchez-Sosa AG, Silva GR, Costa MF, Silva VB, Lopes ACA (2022) Genetic diversity and erosion in lima bean (*Phaseolus lunatus* L.) in Northeast Brazil. *Genet Resour Crop Evol* 69(8):2819–2832
- Lustosa-Silva JD, Oliveira EG, Costa Soares LA, Ferreira-Gomes RL, Costa AF, Barros RFM, Almeida RC, Silva VB, Costa MF, Lopes ACA (2023) Traditional varieties of lima beans (*Phaseolus Lunatus* L.) in northeastern Brazilian farms: conservation and sustainability. *Genet Resour Crop Evol* 70(7):2021–2032
- Nchanji EB, Lutomia CK, Ageyo OC, Karanja D, Kamau E (2021) Gender-responsive participatory variety selection in Kenya: implications for common bean (*Phaseolus vulgaris* L.) breeding in Kenya. *Sustain* 13(23):13164. <https://doi.org/10.3390/su132313164>
- Oliveira EG. Cropping systems and evaluation of lima bean landraces in the southern mesoregion of Ceará. 2019. 117 p. Master's thesis, Federal University of Piauí, Graduate Program in Agronomy, Teresina, 2019.
- Rickards T (1999) Brainstorming revisited: a question of context. *Int J Manag Rev* 1(1):91–110
- Soares LADC, Lustosa-Silva JD, Silva VB, Ferreira CS, Batista de Sousa AMDC, Costa MF, Lopes AC, Ferreira-Gomes RL (2022) On-farm conservation in *Phaseolus lunatus* L.: an alternative for agricultural biodiversity. *Agroecol Sustain Food Syst* 46(3):392–409. <https://doi.org/10.1080/21683565.2021.2016545>
- Sood M, Gupta V, Jan A (2016) Role of women in conserving plant genetic resources and related traditional knowledge for food security. *Plant genetic resources and traditional knowledge for food security*. Springer Singapore, Singapore, pp 237–253. https://doi.org/10.1007/978-981-10-0060-7_14
- Spanevello RM, Matte A, Andreatta T, Lago A (2017) A problemática do envelhecimento no meio rural sob a ótica dos agricultores familiares sem sucessores. *Desenvolv Questão* 15(40):348–372
- Suvi WT, Shimelis H, Laing M (2021) Farmers' perceptions, production constraints and variety preferences of rice in Tanzania. *J Crop Improv* 35(1):51–68. <https://doi.org/10.1080/15427528.2020.1795771>
- Weltzien E, Christinck A (2017) Participatory breeding: developing improved and relevant crop varieties with farmers.

In *Agricultural Systems* (pp. 259–301). Academic Press.
<https://doi.org/10.1016/B978-0-12-802070-8.00008-6>.

Wineman A, Jayne TS, Isinika Modamba E, Kray H (2020) The changing face of agriculture in Tanzania: indicators of transformation. *Dev Policy Rev* 38(6):685–709. <https://doi.org/10.1111/dpr.12491>

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.