International Journal of Agronomy and Agricultural Research
ISSN: 2223-7054 (Print); 2225-3610 (Online) | IJAAR |
Website: https://www.innspub.net
Email: info@innspub.net

RESEARCH PAPER
Vol. 27, Issue: 5, 2025

OPEN ACCESS

Farmers perception of the genetic diversity of peppers (*Capsicum annuum*) in Niger: Between tradition and innovation

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DOI: https://dx.doi.org/10.12692/ijaar/27.5.12-22

ARTICLE INFORMATION

RESEARCH PAPER

Vol. 27, Issue: 5, p. 12-22, 2025

Int. J. Agron. Agri. Res.

Maiga *et al.*

ACCEPTED: 06 November, **2025**

PUBLISHED: 12 November, **2025**

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ABSTRACT

Genetic diversity plays a crucial role in crop development on farms facing the growing challenges posed by climate change. Rural bell pepper growers in Niger are heavily dependent on this biodiversity, for which they are constantly seeking a balance to ensure sustainable production. Studying farmers' perceptions of bell pepper genetic diversity in Niger is a necessity to explore the relationship between traditional farming practices and innovative approaches to crop diversity management. The aim of this study is to understand how farmers in Niger perceive and use bell pepper genetic diversity. To this end, a survey was carried out in the country's main pepper-growing regions. The results showed the existence of a great diversity of accessions, the use of rich and varied farmer descriptors and the coexistence of 3 systems: traditional, improved and a combination of the two. In addition, the study showed that several factors influence farmers' choices and preferences in the selection of bell pepper accessions, as well as the seed system used.

Key words: Pepper, *Capsicum annuum*, Genetic diversity, Farmers' perception, Niger

INTRODUCTION

Pepper (*Capsicum annuum* L.), a member of the Solanaceae family, originates from Mexico, with Guatemala identified as its secondary center of origin (Bukasov, 1930). The most widely cultivated species, *C. annuum* (2n = 2x = 24), possesses a genome size of 3.48 GB (Kim *et al.*, 2014). It is a predominantly self-pollinated crop, although the cross-pollination rate can reach up to 10% (Rai *et al.*, 2013). Pepper is a major horticultural crop with substantial commercial importance and medicinal value. Globally, approximately 36 million tons of peppers are produced on about 2 million hectares. China is the leading producer, accounting for 46% of global production, followed by Mexico, Indonesia, and Turkey (FAO, 2021). Genetic diversity plays a pivotal role in the development of climate-resilient crops, particularly in the context of the increasing challenges posed by climate change. Within the broader framework of agricultural adaptation, the conservation and utilization of genetic diversity represent key strategies to enhance agricultural resilience (Mohamed *et al.*, 2025). Moreover, genetic diversity is fundamental to both natural evolutionary processes and breeding programs. Through genetic variation, crop species are able to survive and adapt to diverse and changing environmental conditions (Salgotra and Chauhan, 2023).

In Niger, pepper (*Capsicum annuum* L.) is a key crop, highly valued for its economic importance as well as its cultural significance. However, increasing environmental pressures, the evolution of agricultural systems, and shifting market demands have compelled farmers to continuously adapt their cultivation strategies. Understanding farmers' perceptions of genetic diversity in pepper has therefore become crucial for exploring the complex relationship between traditional agricultural practices and innovative approaches to crop diversity management. Such an investigation provides insight into how local knowledge systems evolve and integrate with modern agricultural innovations in response to changing socio-economic and environmental conditions. The present study aims to analyze how Nigerien farmers perceive, maintain, and utilize the genetic diversity of pepper. It seeks to identify the balance between time-tested traditional knowledge and the potential offered by improved and emerging agricultural practices, contributing to the sustainable management and enhancement of pepper genetic resources in Niger.

MATERIALS AND METHODS

An agroecological zoning approach was employed to identify regions with a potential diversity of pepper (*Capsicum annuum* L.). Based on this zoning, a field survey was conducted in six major regions of Niger: Diffa, Zinder, Maradi, Tahoua, Dosso, and Tillabéri (Fig. 1).

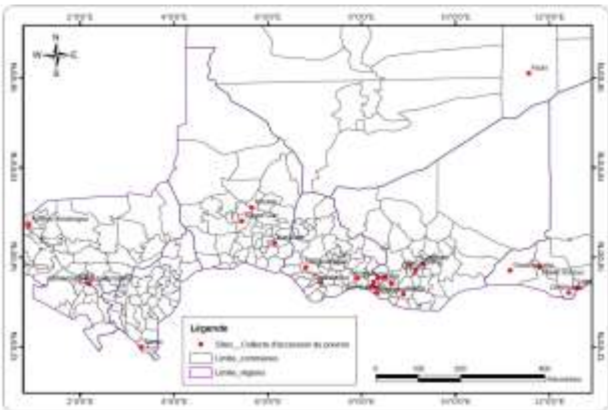

Fig. 1. Surveyed commune and pepper accessions collected in Niger

Within each region, department, and commune, preliminary interviews were held with regional, departmental, and communal agricultural officers to identify key pepper-producing sites. A systematic sampling (SS) method was then used to determine the number of villages and the number of producers per village to be included in the survey. The procedure began with the random selection of a starting point (village or production site), followed by the selection of every k-th village or site according to a predefined sampling interval. The sampling interval (k) was calculated as $k = N/n$, where N represents the population size (total number of producers or villages per commune) and n the sample size. A random number (r) between 1 and k was first chosen, and the sample sequence was defined as $\{r, r + k, r + 2k, ..., r + nk\}$. For field data collection, ethnobotanical surveys were carried out to document traditional knowledge and perceptions related to pepper varieties. A total of 338 producers were individually interviewed using a structured questionnaire, and 23 focus group discussions were organized across the study regions. Data were collected using the KoboToolbox platform to ensure accuracy and consistency. All data analyses were performed using R software (version 4.4.1), following standard statistical procedures for survey-based research.

RESULTS

Local names of pepper accessions and their meanings

Varietal diversity

In the Diffa region, eight pepper accessions are known and cultivated (Table 1). These include Kangadi Nglaro (bearing long and large fruits), Massa Kallé (long but thin fruits), Mawor (short, large, and round fruits), Bongo (short, large, and round fruits; small-sized plant), Mangala (long and large fruits; reddish-brown seeds), Koriaram (large and round fruits; yellow seeds), Tattassé Koura (large and round fruits), and Champo (long and slender fruits).

Among these, Kangadi Nglaro is by far the most widely cultivated accession in the region, found in the communes of Diffa, Chétimari, Mainé Soroa, and Goudoumaria. Massa Kallé is cultivated exclusively in the commune of Diffa. Mawor and Bongo are respectively grown in Chétimari and Mainé Soroa, while Mangala and Koriaram are cultivated in Toumour. Tattassé Koura and Champo are found in Goudoumaria. The commune with the highest number of pepper accessions is Goudoumaria (three ecotypes), followed by the other communes, each with two accessions.

In the Zinder region, 11 local pepper accessions are cultivated. These include Tattassé (long and large red fruits; long leaves), Kangadi Nglaro, Mango (long, slender, pointed fruits; high yield), Lardou (large, round fruits; less pungent), Dan Izala (long, thin fruits), Dan Damso (large, round fruits; high yield; large leaves), Kahon Barewa (long, slender fruits resembling a gazelle horn), Mai Yado (highly productive; round but smaller fruits), Hantchin Sania (large, round fruits with a cow-nose-shaped tip), Dan Tcharantchi (long, slender fruits; high yield; multiple harvests), and Gamji (large, round fruits; high yield).

Table 1. Accessions de poivron de Diffa et Zinder et leurs caractéristiques

Commune	Accessions number	Local name	Accessions traits
Diffa			
Diffa	2	Kangadi Nglaro	Long and large fruit
		Massa Kallé	Long but small/thin fruit
Chétimari	2	Kangadi Nglaro	
		Mawor	Short, large, and round fruit
Mainé Soroa	2	Kangadi Nglaro	
		Bongo	Short, large, and round fruit; small-sized plant
Toumour	2	Mangala	Long and large fruit; reddish-brown seeds
		Koriaram	Large and round fruit; yellow seeds
Goudoumaria	3	Kangadi Nglaro	
		Tattassé Koura	Large and round fruit
		Champo	Long and slender fruit
Zinder			
Mirriah	1	Tattassé	Long and large red fruit; long leaves
Zermou	3	Kangadi Nglaro	
		Mango	Long and slender fruit with pointed tip; high yield
		Lardou	Large and round fruit; less pungent
Bandé	2	Dan Izala	Long and slender fruit
		Dan Damso	Large and round fruit; high yield; plant with large leaves
Dan Bartho	3	Kahon Barewa	Long and slender fruit resembling a gazelle horn
		Mai Yado	More productive; round but smaller fruit
		Hantchin Sania	Large and round fruit with cow-nose-shaped tip
Ichirnaoua	4	Dan Tcharantchi	Long and slender fruit; high yield; multiple harvests
		Dan Damso	Large and round fruit; high yield
		Hantchin Sania	Large and round fruit; less productive than others
		Poivron doux	Large and round fruit; non-pungent (low capsaicin)
Kantché	2	Hantchin Sania	Large and long fruit; broad and long leaves
		Kahon Barewa	Long and slender fruit with pointed tip ("gazelle horn"); high yield
Doungou	3	Dan Tcharantchi	Long and large fruit; high yield; multiple harvests; early-maturing
		Dan Damso	Large and round fruit; high yield
		Gamji	Large and round fruit; high yield; early-maturing; thick and firm pericarp

Among all accessions, Kangadi Nglaro shows the widest ecological distribution, being found in both Diffa and Zinder regions. In Mirriah commune, only one accession, Tattassé, is cultivated. In Zermou, three accessions are produced: Kangadi Nglaro, Mango, and Lardou. Dan Damso is cultivated in three communes of Zinder Bandé, Ichirnaoua, and Doungou, while Hantchin Sania occurs in Dan Barto, Ichirnaoua, and Kantché. Kahon Barewa is found in Kantché and Ichirnaoua communes. The Ichirnaoua commune exhibits the highest level of pepper biodiversity, with four ecotypes, followed by Zermou, Dan Barto, and Doungou, each with three accessions.

Table 2. Accessions de poivron de Tahoua, Maradi, Dosso et Tillaberi et leurs caractéristiques

Commune	Accessions number	Local name	Accessions traits
Maradi			
Hawandawaki	3	Hantchin Sa	Large, long fruit, broad leaves, tall habit, high yield
		Dourgou	Broad leaves, short habit, large, round fruit, high yield
		Kahon Barewa	Long, thin fruit with a pointed tip resembling a stag's horn, high yield
Korgom	4	Hantchi Sa	Large, long fruit, broad leaves, tall habit, high yield
		Dourgou	Large and small leaves, short habit, large, round fruit, high yield
		Kahon Barewa	Long, thin fruit, high yield, tall habit
		Bakin Iri	Tall habit, long fruit of medium size, dark-colored seeds
Gazaoua	3	Kahon Barewa	Long, thin fruit with a pointed tip and bright red color, high yield, tall habit
		Dourgou	Large and small leaves, short habit, large, round fruit, high yield, early-maturing
		Bakin Iri	Tall habit, long fruit of medium size with a dark red color, high yield
Jirataoua	2	Tougandé ou Tattassé	Tall habit, large, long fruit, high yield, small leaves, early-maturing
		Poivron	Large, round fruit, tall habit, early-maturing, high yield
Tahoua			
Keita/ Boussaragué	1	Tougandé	Medium-height habit, large, long fruit, high yield
Tabalak/ Fachi	1	Tougandé ou Tattassé	Tall habit, large, long fruit, high yield
Karofane	3	Maybiro	Long, thin fruit, large size, high yield, pointed tip
		Gadjéré	Medium, round fruit, medium size, high yield
		Dan Dangolé	Short habit, large, round fruit, high yield
Dosso and Tillabéri			
Tanda	1	Tattassé /Tonko Béro	Long, large, and pungent-tasting fruit, tall plant, long leaves
Ayérou/ Koutougou	1	Sayhillo	Long and large fruit, tall plant, long leaves
Liboré	3	Simbad	Broad, dark green leaves, medium-sized plant, large, round fruit
		Chinois	Small leaves, large plant, large, long fruit
		Yellow wonder	Broad leaves, tall habit, round and large fruit

Pepper biodiversity in the Maradi and Tillabéri regions

In the Maradi region, pepper biodiversity is represented by four accessions (Table 2). The accession Hantchin Sa (large and long fruits, broad leaves, tall growth habit, high yield) is cultivated in the communes of Hawandawaki and Korgom. The ecotype Dourgou (broad leaves, short growth habit, large and round fruits, high yield) has a wider ecological distribution, being present in three communes: Hawandawaki, Korgom, and Gazaoua. The ecological range of Kahon Barewa in this region spans the communes of Hawandawaki, Korgom, and Gazaoua; this accession is characterized by long, slender, pointed fruits resembling a doe's horn and a high yield. Bakin Iri (long growth habit, long fruits of medium size, dark red color, high yield, and dark-colored seeds) is cultivated in Korgom and Gazaoua.

Overall, five accessions are cultivated in Maradi. These include Tougandé or Tattassé (medium height, large and long fruits, high yield), “Poivron” (large and round fruits, high yield, tall growth habit, early-maturing), Maybiro (long and slender fruits, large size, high yield), Gadjéré (medium-sized round fruits, high yield), and Dan Dangolé (small plant, large and round fruits, high yield). Among these, Tougandé is the most widespread, found in the communes of Jirataoua, Keita/Boussaragué, and Tabalak/Fachi.

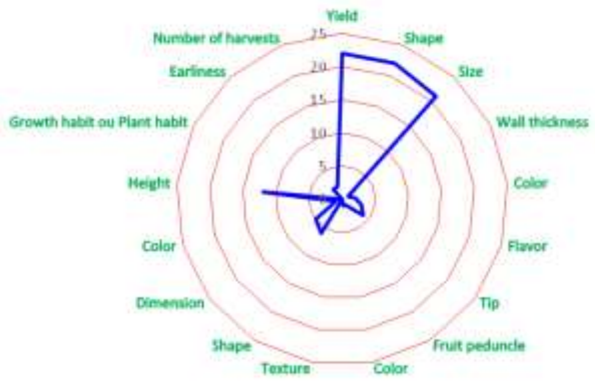

Fig. 2. Farmers preferred traits used to describe local pepper ecotypes

In the Tillabéri region, four pepper ecotypes are produced: Sayhillo (long and large fruits, tall plants, long leaves), Simbad (broad, dark green leaves, medium height, large and round fruits), Chinois (small leaves, tall plants, large and long fruits), and Yellow Wonder (broad leaves, tall plants, large and round fruits).

The high yield is the most frequently mentioned trait, appearing for every single accession (Fig. 2). This underscores that high productivity is a paramount selection and conservation criterion for local farmers. In addition, plant growth habit (height) is a clear distinction between tall and short varieties, offering choices for different cropping systems. Concerning the fruitmorphology, the primary distinction is between ''long and slender'' fruits and ''large and round" ones. This is a fundamental classification by farmers. The long/slender types are often associated with high yield and multiple harvests. Some have very specific shapes. The large/round types are also often high-yielding.

Peasant descriptors

Farmers have often played a key role in naming varieties, ecotypes, and accessions. They rely on observable and meaningful criteria (descriptors) for this purpose. These descriptors have been listed and can be classified into different categories. The Table 3 presents the results of farmer's responses, when they were asked to describe specific characteristics (descriptors) of a plant. The data is organized by plant organ and shows how frequently each descriptor was mentioned across different communes.

Table 3. Descripteurs paysans

Plant organ	Peasant descriptors	Communes	Frequences (%)
Fruit	Yield	22	100
	Shape	22	100
	Size	21	95,5
	Wall thickness	1	4,5
	Color	2	9,1
	Flavor	3	13,6
	Tip	4	18,2
	Fruit peduncle	1	4,5
Seed	Color	1	4,5
	Texture	0	0
Leaf	Shape	6	27,3
	Dimension	5	22,7
	Color	1	4,5
Stem	Height	12	54,5
	Growth habit ou Plant habit	0	0
Duration	Earliness	2	9,1
Number of harvests		2	9,1

The fruit is the most extensively described organ, indicating that it is the primary focus for the farmers. The yield and the fruit shape were mentioned in all 22 communes (100% frequency).

The fruit size was also very important, as it was mentioned in 21 communes (95.5%). The fruit tip" (18.2%), flavor (13.6%), and color (9.1%) ere with moderate importance, these characters were mentioned by a smaller but notable number of communes. The characters with low importance were, wall thickness and fruit peduncle (both 4.5%) were rarely mentioned. Seed characteristics were largely ignored. Only color was mentioned in one (1) commune (4.5%). The stem height was a significant characteristic, mentioned in over half of the communes (54.5%).

The varieties duration (Earliness) and number of harvests were both mentioned by only 2 communes (9.1% each), suggesting they are minor considerations for this particular group of farmers.

The farmers' primary concerns are directly related to marketable yield and visual appearance. The top three descriptors yield, shape, and size are crucial for productivity, marketability, and potentially for meeting specific consumer preferences or standards. A fruit's yield and uniform shape/size are often directly linked to its economic value.

Table 4. Diversity of pepper use in rural areas in Niger

	Nomber	Farmers number	Proportion (%)
Known varieties	5	13	3,9
	4	26	7,7
	3	109	32,3
	2	138	40,9
	1	51	15,1
Utilisation	Spices	337	100,0
	Vegetables	335	99,4
	Medicine	17	5,0
	Industrial	1	0,3
	Other (trade)	337	100,
Variety extinction	Yes	13	3,9
	No	311	92,3

The peasants secondary importance of sensory and plant architecture traits, like flavor, stem height, and leaf shape are considered but are not universal priorities. Flavor might be important for local consumption, while stem height could relate to cultivation practices (e.g., ease of harvesting).

The neglect of specific and agronomic traits was mentioned. Hence, descriptors like seed texture, growth habit, wall thickness, and earliness were largely or completely ignored.

Some descriptors are used according to geographical or cultural origin. These descriptors refer to a certain tradition linked to the variety, such as its supposed origin or the names of production sites, such as Dan Talabé. There are also analogical descriptors with other elements. For example, there are animal comparisons such as Kangadi N'Glaro (sheep's horn), Mouri Koro (donkey dung), Kahon Barewa (deer horn), Hantchi tsa or nono tsa (cow's nose or udder), Sayhillo (snake) (the shape of certain animals' horns). There are also references to certain religious practices such as Dan Izala, Mowor (name of the Kanouri ethnic group), Mangala (basket), Bongo (hut); or comparisons with objects: Poivron Mango (reminiscent of the shape of a mango).

The Table 4 shows dominance of few varieties: hence, the vast majority of farmers (73.2%) know only 1, 2, or 3 varieties (15.1%, 40.9%, and 32.3% respectively). This indicates that while the plant is widely cultivated, the depth of varietal knowledge is concentrated on a small set.

Additionally, only a small minority (11.6%) know 4 or 5 varieties. This suggests that extensive knowledge of the plant's genetic diversity is held by a few farmers. This concentration is a potential risk for agricultural resilience. If a disease or pest affects the most common varieties, the entire farming community could be vulnerable.

Concerning the utilization of the plant the dual purpose as spice and vegetable is almost universally usage. Thus, the usage as both a spice (100%) and a vegetable (99.4%) was noticed. This indicates it is a fundamental and versatile crop in the local diet and agriculture. Other uses are negligible in comparison, these are medicinal use (5.0%) and industrial use (0.3%) is virtually nonexistent. The "Other (trade)" category at 100% is critically important. It shows that every single farmer grows this plant for commercial sale, not just for personal consumption. This crop is a key cash crop and a vital source of income for the community.

An overwhelming 92.3% of farmers report not having observed any variety extinction (`No`). This suggests that, from their perspective, the genetic diversity of the plant has been relatively stable. However, A very small fraction (3.9%) has observed extinction (`Yes`). This could be due to localized events, the loss of very rare varieties, or the replacement of traditional varieties with modern ones that some farmers perceive as extinction.

The acquisition and conservation of accessions rely on several interconnected systems, involving farmers, research institutes, and formal and informal distribution channels (Table 5). The traditional system for acquiring pepper varieties coexists harmoniously with an improved system, albeit with a certain predominance (over 76%) of the latter.

Introduction of improved varieties: between challenge and opportunity

As agriculture evolves, new varieties are being introduced into the production system. This represents up to 18% of producers (Table 5). Traditional varieties are overwhelmingly dominant.

Table 5. Variety status: acquisition, exchange, and conservation of accessions

Varietal status	Number of farmers	F (%)	Source	Number of farmers	F (%)
Traditional variety	258	76	Own	200	78
			Local market	39	15
			Neighbor	2	1
			Research	2	1
			Others	15	6
Improved variety	62	18	Own	20	32
			Local market	14	23
			Neighbor	0	0
			Research	23	37
			Others	5	8
Coexistence of both	18	5	Own	9	50
			Local market	3	17
			Neighbor	0	0
			Research	1	6
			Others	5	28

At 76%, the vast majority of farmers rely on traditional varieties. This indicates a strong preference for, or dependence on, locally adapted, farmer-developed seeds. This system promotes agrobiodiversity and resilience but may be perceived as having lower yields than improved types. Improved varieties are a minority choice: Only 18% of farmers use improved varieties (likely higher-yielding or disease-resistant varieties developed by formal research institutions). This suggests limited penetration of formal seed systems, which could be due to lack of access, high cost, or farmer preference for traditional varieties' traits (e.g., taste, culinary qualities, reliability). A very small group (5%) uses both types. These farmers are likely more experimental or have diversified their risk and production strategies.

Two distinct seed systems is revealed. The source of seeds differs dramatically between the two main groups, highlighting two parallel agricultural economies.

For Traditional Variety Farmers (76% of total): A massive (78%) use their own saved seeds. This is the cornerstone of traditional agriculture. It indicates a high degree of self-sufficiency and the preservation of knowledge around seed selection and saving.

The local market (15%) is the second most important source, functioning as a key node in the informal seed exchange network. Acquiring from neighbors (1%) is surprisingly low, suggesting that the local market is the primary venue for this exchange rather than direct barter.

The research system (1%) is virtually irrelevant as a source for traditional seeds, underscoring the separation between formal and informal seed systems. The primary source for improved varieties is research institutions (37%). This is the only group where "own" saved seed is not the top source, indicating a reliance on external, formal channels for seed supply. While reliant on research, these farmers also source significantly from their own saved seed (32%) and the local market (23%).

However, we are moving towards a complementary relationship between tradition and innovation. Rather than being opposed, the traditional system and innovations resulting from the improved system can be complementary. An integrative approach is emerging, with some farmers (5%) combining traditional and improved varieties.

Factors influencing farmers' choices and preferences in selecting pepper accessions

The criteria for preference and selection of accessions in farming communities are as numerous as they are diverse. Pepper biodiversity is based on criteria for selection, production, conservation, and perpetuation of pepper accessions in order to ensure sustainable production that is adapted to local conditions and meets market needs. The farmer preference criteria, shown in Table 6, are as follows: pest resistance (85.2%), drought tolerance (84.0%), earliness (78.6%), market value (85.2%), fruit color, fruit flavor (53.7%), fruit yield, fruit size, elongated shape, intermediate fruit shape, etc. These criteria can be classified into different categories. First, there are agronomic criteria, which include production potential (yield), vegetative cycle (early or late varieties), resistance to pests (diseases and pests), adaptability to climatic conditions (drought resistance), vigor, and plant habit. Second, farmers use fruit quality criteria, including shape and size depending on use, color when ripe, pericarp thickness, taste, and capsaicin content. Finally, there are socio-economic and commercial criteria, in particular market value, which is regulated by market demand (consumer preferences).

Table 6. Preference and selection criteria for accessions

Preferred variety traits	Number of farmers	Frequencies (%)
Resistance to pests	287	85,2
Drought tolerance	283	84,0
Early ripening	265	78,6
Market value	287	85,2
Fruit color	220	65,3
Fruit flavor	181	53,7
Fruit yield	319	94,7
Large fruit	228	67,7
Medium-sized fruit	10	3,0
Elongated shape	324	96,1
Intermediate shape	3	0,9
Round fruit	8	2,4

Varietal status of peppers according to level of education

The varietal status of peppers according to the level of education of producers can be analyzed through access to information, the adoption of varieties, and cultivation practices. Thus, the level of education influences farmers' ability to adopt innovations and high-performance varieties and/or accessions. In the traditional variety acquisition system, 5% have no education, 47% have only Koranic education, 16% have both Koranic education and primary or secondary education, 3% have primary education, 4% have secondary education, and none have higher education (Table 7). In the improved system, 3% have no education, 6% have only Koranic education, 5% have Koranic education combined with primary or secondary education, 2% have primary education, 2% have secondary education, and 1% have higher education.

Principal component analysis (Fig. 3) shows that the use of traditional varieties is more influenced by Koranic education alone. However, the combination of the two systems is practiced by producers who have Koranic education coupled with primary or secondary education.

Table 7. Variety status of peppers according to level of education

Level of education	Varietal status								
	Traditional			Improved			Both		
	Nber	F (%)	RF (%)	Nber	F (%)	RF (%)	Nber	F (%)	RF (%)
None	18	5	64	10	3	36	0	0	0
Quranic	156	47	85	21	6	11	7	2	4
Quranic + Primary/Secondary	54	16	70	16	5	21	7	2	9
Primary	10	3	59	5	2	29	2	1	12
Secondary	14	4	67	6	2	29	1	0	5
Higher	0	0	0	2	1	100	0	0	0
Total	252			60			17		

RF= Relative Frequencies, F= Frequencies

Table 8. Diversity in pepper seed acquisition according to education level

Level of education	Seed source														
	Own			Local market			Research			Neighbor			Others		
	Nber	F (%)	RF (%)	Nbre	F (%)	RF (%)	Nbre	F (%)	RF (%)	Nbre	F (%)	F (%)	Nbre	F (%)	RF (%)
None	17	5	61	2	1	7	9	3	32	0	0	0	0	0	0
Quranic	132	40	72	31	9	17	4	1	2	1	0	1	15	5	0
Quranic + Primary Secondary	46	14	60	19	6	25	3	1	4	1	0	1	8	2	0
Primary	9	3	53	2	1	12	5	2	29	0	0	0	1	0	0
Secondary	18	5	82	1	0	5	3	1	14	0	0	0	0	0	0
Higher	0	0	0	0	0	0	2	1	100	0	0	0	0	0	0
Total	222	67	67	55	17	17	26	8	8	2	1	1	24	7	0

RF= Relative Frequencies, F= Frequencies

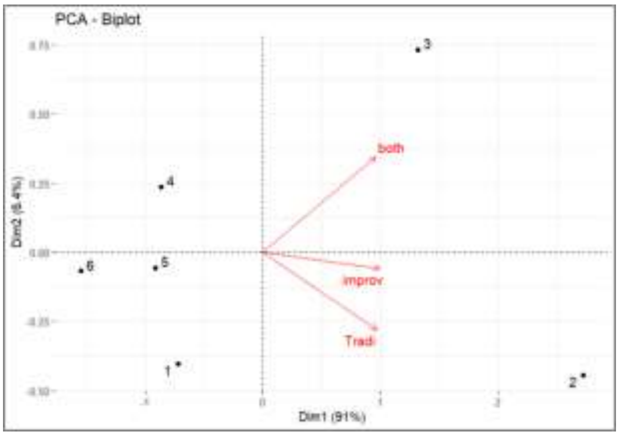

Fig. 3. Principal component analysis of varietal status and educational attainment

No education=1, Quranic =2, Quranic + Primary + Secondary =3, Primary =4, Secondary =5, Higher =6

Diversity in pepper seed acquisition based on education level

The method of acquiring pepper seeds in Niger is influenced by education level. Thus, 72% of producers who have only received Koranic education (40% of the population) use their own seeds each year, compared to 61% of farmers who have received no education (5% of the population) who also use their own seeds (Table 8). Among producers who have received higher education, 100% use seeds derived from research.

DISCUSSION

The results showed a wide diversity of varieties or ecotypes cultivated by farmers. It is widely recognized that the varietal diversity maintained by farmers is a key component of agrobiodiversity and plays a major role in the sustainability of agricultural systems (Tendro *et al.*, 2013; Altieri *et al.*, 2011; Jackson *et al.*, 2010). However, strategies still need to be developed to preserve this diversity while improving agricultural productivity (Brush, 2000; Adams *et al.*, 2004). Rural populations often rely on the biodiversity of natural resources and the broad range of ecosystem services essential to their well-being (Raphaël *et al.*, 2012). Biodiversity plays a crucial role in food supply by maintaining access to a diversity of local products. This helps sustain a balanced and satisfactory diet while enhancing the adaptability and resilience of crops to future risks and environmental changes (O'Farrell *et al.*, 2007).

The results also showed that farmers use several types of descriptors to name varieties or ecotypes (stem height, shape, size and color of leaves, shape, size, color, peduncle, and tip of the fruit, etc.). The use of farmers' descriptors to name pepper varieties could have agronomic, cultural, and economic implications.

In participatory or adaptive varietal selection, local names help identify varieties adapted to specific conditions such as climate, soil type, and disease resistance. The use of local descriptors also plays an important role in the transmission of traditional knowledge. By preserving these local names, farmers share practical knowledge about varietal characteristics such as growth cycle and taste.

Farmers' descriptors may also contribute to genetic diversity, as this nomenclature helps promote the conservation of traditional varieties. Moreover, they have cultural and social implications: these local names root the accessions in a particular terroir, tradition, and history, thus becoming part of local heritage and identity. In addition, the practice of naming varieties is part of the farming traditions passed down from generation to generation.

Farmers' descriptors are much more than simple names—they carry history, collective memory, and valuable agronomic knowledge. Recognizing and preserving these naming criteria is important for maintaining crop diversity and farmers' autonomy. The results revealed great diversity in the status of the varieties used, as well as in the methods of acquisition, exchange, and conservation of accessions. The varietal status, mode of acquisition, exchange practices, and conservation methods of accessions are crucial factors in maintaining genetic diversity. Thus, alongside the traditional system predominantly practiced by farmers, an improved system and a combination of the two are emerging harmoniously. The introduction of new pepper varieties (improved varieties developed through research) adapted to local conditions will not only increase yields but also improve the quality and competitiveness of products, as they meet current market and consumer demands. This will also contribute to enriching the genetic pool of peppers (Karakadzhiev *et al.*, 2025).

Mintewab *et al.* (2025) demonstrated that the adoption of improved seed technologies increases overall crop income compared to the adoption of traditional seeds in Ethiopia. Moreover, these authors showed that when both types of seeds are adopted by farmers, the overall agricultural income derived from the technologies increases for both improved and traditional seeds. This suggests a complementarity in the use of the two seed sources at the farm level.

The study showed that farmers' choices and preferences in selecting accessions are influenced by several factors, which may be agronomic, economic, sensory, environmental, or sociocultural.

Farmers generally make their strategic choices not randomly, but by combining these factors in order to maximize production and ensure the profitability and sustainability of their crops.

CONCLUSION

The substantial observed diversity was not random but is a strategic adaptation to local environments and markets, representing an invaluable resource for food security, nutrition, and future crop breeding programs in the face of climate change. The stark difference noted in terms varietal names throughout different regions strongly suggests local adaptation and divergent selection. Farmers in each region have selected, over generations, for varieties that perform best in their specific local conditions (soil, climate, pests) and meet their cultural and culinary preferences. The study showed that for these peasants, the economic and physical attributes of the fruit itself are the central criteria for evaluating and describing this plant. The study successfully captures local knowledge and farmer preferences, which would be invaluable for plant breeding programs, conservation efforts, or agricultural development projects aimed at meeting the actual needs of these farming communities. The plant in question is likely a fruit-bearing crop where the visual and quantitative fruit characteristics are the main determinants of its value. Additionally, the plant was showed as central to the local economy, with 100% of farmers using it as a spice and trading it. Its role as a vegetable also makes it a dietary staple. In essence, the crop is a successful and vital commercial commodity, but this very success might be linked to a risk of narrowing of the genetic diversity being cultivated, which could pose a long-term risk to its sustainability. Further research would be needed to understand why knowledge of varieties is so concentrated and to verify the status of lesser-known varieties that may be at risk of disappearing.

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