Ethnobotanical significance of *Citrullus* landraces and wild relatives in Sesheke, Kaoma, and Mumbwa Districts of Zambia

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Research

Abstract

Background: Watermelon, cultivated globally, is an important genetic resource in traditional agricultural systems. Their ethnobotanical significance in such systems, however, remains underexplored, including within the Zambian context. This study explores the ethnobotanical significance of watermelon (*Citrullus lanatus* (Thunb.) Matsum. & Nakai, Cucurbitaceae) landraces, related species (*C. amarus* Schrad.) and their wild relatives in Sesheke, Kaoma, and Mumbwa Districts of Zambia.

Methods: Utilizing a qualitative and quantitative approach through questionnaires and semi-structured interviews, data were collected and organized using Microsoft Excel and analyzed using the ethnobotanyR version 0.1.9 package in R version 4.4.2 (2024-10-31 ucrt) to calculate quantitative indices.

Results: The study identified seven traditional cultivars: four *C. amarus* landraces (**matanga, vikululu** and **sikululu)**, including **kanyang'ombe*,*** a wild form of *C. amarus* and three *C. lanatus* landraces (**namunywa, mahapu,** and **makabe)**. Four categories of use were documented: food and nutrition, medicinal, fishing and fodder. Among these, the landrace **sikululu** in Sesheke recorded the highest ethnobotanical values (UR = 69, CI = 2.4, CVe = 0.9) within the Lozi-speaking community. Other landraces such as **mahapu** and **kanyang'ombe** were found to be more localized, likely influenced by cultural practices and environmental suitability, particularly in the semi-arid, sandy soil regions of Western Province.

Conclusions: Landrace diversity and ethnobotanical values were highest in Sesheke and Kaoma compared to Mumbwa, reflecting both ecological and cultural influences. The observed differences in landrace characteristics and their uses underscore the importance of local knowledge in plant selection and conservation. These findings highlight the critical need for targeted conservation strategies to preserve both the genetic diversity and cultural relevance of traditional watermelon landraces in Zambia's rural communities.

*Keywords***:** *Citrullus amarus; C. lanatus*; landraces; wild relatives; diversity; Ethnobotany; Ethnobotanical indices

Background

The family Cucurbitaceae is a large and diverse group, containing approximately 980 species across 101 genera distributed globally (Christenhusz & Byng 2016, POWO 2025). Within this family, the genus *Citrullus* stands out as a valuable and culturally significant taxon, notably through the iconic watermelon (*Citrullus lanatus* (Thunb.) Matsum. & Nakai). *Citrullus lanatus* landraces are locally adapted, cultivated varieties selected and maintained by local farmers over generations and these have emerged through this rich history of cultivation and adapted to local environments and preferences (Mujaju & Fatih 2011). The landraces often exhibit substantial genetic and morphological diversity resulting in a diverse array of shapes, sizes, rind patterns, flesh colors, and flavor profiles adapted to local growing conditions compared to commercially bred watermelon varieties.

Alongside the cultivated landraces, the wild relatives of *C. lanatus*, such as *C. amarus* Schrad, *C. ecirrhosus* Cogn. *and C. rehmii* De Winter*,* are native to southern Africa (Chomicki & Renner 2015). These wild *Citrullus* species share genetic ties with the domesticated watermelon and have retained traits like bitterness or high seed content (Jarret *et al.* 2017), but with valuable attributes like drought-tolerance and disease-resistance (Nantoumé *et al.* 2013). The wild relatives represent an untapped reservoir of genetic diversity with potential applications in crop improvement and food security strategies.
For centuries, various *Citrullus* species, particularly watermelon (*C. lanatus*), have played significant roles in traditional agricultural practices and cultural traditions across Southern Africa and have been studied by different scholars around the globe (Chomicki & Renner 2015, Fajinmi *et al*. 2022b, Mujaju 2009, Olarewaju *et al*. 2021).

The ethnobotanical knowledge surrounding *Citrullus* landraces encompasses a wide range of aspects, including their culinary uses, medicinal properties, and cultural significance (Martirosyan *et al*. 2025, Nantoumé *et al*. 2013, Olarewaju *et al*. 2021). *Citrullus* has long been a staple food, with diverse parts of the plant utilized in various ways. The fruit is consumed fresh or cooked, while the seeds are often roasted and eaten as a snack (Mujaju 2009), or used to extract oil (Meena *et al*. 2014, Olarewaju *et al*. 2021).

In West Africa, the seeds of **egusi**-melon (*C. mucosospermus* Fursa) have been reported to be an important source of dietary protein and are used in various traditional dishes. Among certain African communities, watermelon rind is reported to be dried and used as a vegetable during lean periods and the leaves and vines are also consumed as leafy vegetables (Maggs-Kölling *et al*. 2000). Traditional uses of *C.* landraces extend beyond food consumption to include animal feed and medicinal purposes, as documented in various regions of Africa (Fajinmi *et al*. 2022b, Meena *et al.* 2014, Van Wyk 2011). Medicinal uses include treating digestive issues, infections, skin conditions (Bieski 2012, Van Wyk 2011), diabetes and hypertension (Olarewaju *et al*. 2021).

The field of ethnobotanical research on *Citrullus*, particularly *C. lanatus* (watermelon), has been dominated by qualitative studies. While these studies have provided valuable insights into traditional uses and cultural significance, they have also revealed a critical gap in quantitative data. This gap is not unique to *Citrullus* landraces and their wild relatives but extends to several other crops and wild plants of ethnobotanical importance across Southern Africa (Fajinmi *et al.*2022a, Mujaju & Nybom 2011).

Quantitative ethnobotanical indices, such as those proposed by Prance (1987) and later refined by Phillips (1996), can provide more robust and comparable data. These methods offer a deeper understanding of the cultural significance and use patterns of landraces, allowing for statistical analyses and cross-cultural comparisons (Mwambo & Chuba 2024, Tardío *et al.* 2006).

We sought to contribute to the understanding of the potential of *Citrullus* landraces and wild relatives as a vital component of food security strategies and to analyse the biodiversity and cultural heritage associated with these crops in Zambia. We undertook a pilot ethnobotanical study of the crop and its wild relatives to show that significant diversity in morphological characteristics and ethnobotanical uses of *Citrullus* landraces exists among domesticated and wild relatives in Sesheke, Kaoma and Mumbwa Districts of Zambia.

Materials and Methods

Study area

This study was conducted in Sesheke, Kaoma and Mumbwa Districts of Zambia. These districts were selected as study areas because they represent a clear ecological gradient, from the sandy and arid soils of Sesheke, through the moderately arid conditions of Kaoma, to the clay-rich soils of Mumbwa allowing for comparative analysis of how environmental variation influences the distribution and traditional knowledge of *Citrullus* species (El-Absy 2022, Mujaju and Fatih 2011) (Fig. 1).

Sesheke District is located in the Western Province of Zambia, bordering the Zambezi River and sharing borders with Namibia and Zimbabwe. The district has a total land area of 21,896 square kilometres and a population of around 110,000 people (Zamstats 2022). The soils are predominantly sandy with low water retention capacity and poor fertility status (Martinsen 2014). The soils are characterized by low organic matter content and are highly susceptible to erosion during the rainy season (Chongo 2010).

Kaoma District is situated in the Western Province of Zambia, approximately 500 kilometres west of the capital city, Lusaka. The district covers an area of 42,194 square kilometres and has a population of approximately 240,000 people (Zamstats 2022). Kaoma District features sandy or loamy sand soils with moderate fertility and good drainage properties (ZARI 2020). These soils contain a mixture of sand, silt, and clay particles, making them suitable for various crop production systems.

Mumbwa District is located in the Central Province of Zambia, approximately 150 kilometres west of Lusaka. The district covers an area of around 19,700 square kilometres and has a population of approximately 260,000 people (Zamstats 2022). This district has predominantly red clay loam soils with high water retention capacity and good fertility levels. These soils are rich in minerals and organic matter, providing excellent conditions for agricultural activities throughout the growing season (ZARI 2020).
Agriculture is a primary economic activity in Sesheke, Kaoma and Mumbwa Districts, with the cultivation of crops like maize, millet, sorghum, and watermelons (*C. lanatus*) being common (Mwila *et al*. 2008).

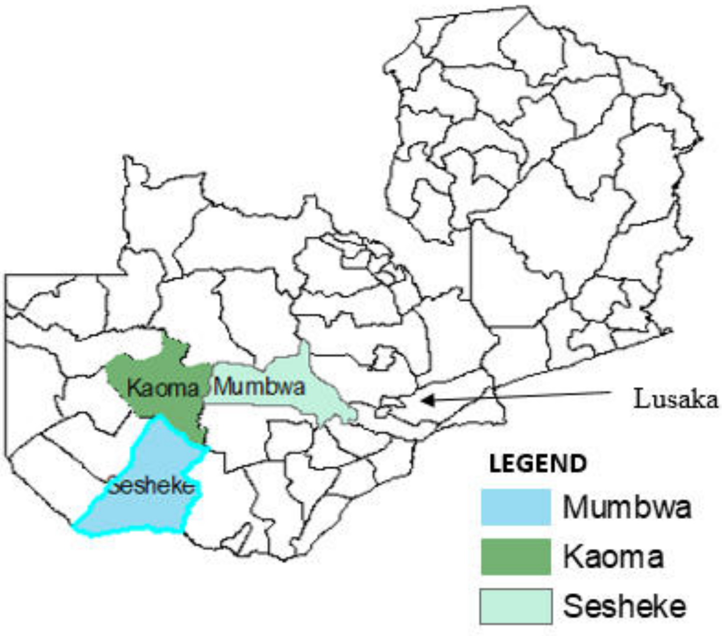

Figure 1. Map of Zambia, showing the study area.

Data collection
The ethnobotanical study of *Citrullus* landraces employed a mixed-methods approach, combining qualitative and quantitative techniques (Albuquerque 2014). Snowball sampling was applied to identify knowledgeable informants (Naderifar *et al*. 2017), particularly farmers who cultivate *Citrullus* species and maintain them in their fields, as this method facilitated access to reliable information on landraces and their uses. Data collecting involved the use of questionnaires and semi-structured interviews, with agricultural extension officers providing translation into local languages to ensure that desirable data were collected.

A total of 29 local farmers cultivating *Citrullus* landraces were interviewed across the study area; 16 from Sesheke, eight from Kaoma, and five from Mumbwa Districts. The study specifically had to target only farmers that had cultivated water melons to obtain the required data and that's why snowball sampling was the best method and it yielded different numbers of farmers in each district.

The selection criteria encompassed several key demographic factors: occupation (farmers, entrepreneurs and civil servants), educational background (illiterate, primary, secondary and tertiary), age group (below 25 years, 26 - 35 years, 36 - 45 years, and above 45 years), and gender. This approach aimed to capture a wide range of perspectives and knowledge bases, reflecting the diverse socio-economic and demographic composition of the local communities.

To ensure the authenticity and region-specificity of the collected data, only native local farmers from each district were included as informants. This focus on native farmers aimed to tap into deep-rooted, locally-specific knowledge about *Citrullus* uses, which has been passed down through generations (Albuquerque 2014, Ali *et al*. 2025, Luh *et al*. 2025, Mujaju 2012, Shah *et al.* 2024). The inclusion of various occupations, educational backgrounds, and age groups facilitated the collection of both traditional knowledge from older generations and potentially newer practices from younger farmers, providing a broad view of local *Citrullus* species diversity and associated agricultural practices.

Alongside the ethnobotanical data collection, plant voucher specimens of *Citrullus* species were collected from the farmers. These specimens were dried using a plant press and subsequently identified at the University of Zambia (UNZA) Herbarium. The identified specimens were mounted on acid-free mounting sheets (Shivas *et al.* 2005) and deposited in the UNZA Herbarium.

Data Analysis

The data were organized and prepared in Microsoft Office Excel sheets and analyzed using the ethnobotanyR version 0.1.9 package (Whitney 2019) in R version 4.4.2 (2024-10-31 ucrt) programming language.

Use Report (UR) index per species

Use report (UR) indices were calculated to determine the diversity of uses and the extent of use for each taxon (Phillip 1996). The URs index that represents the total number of use reports or citations for a particular taxon was determined.

$$\mathrm{URs} = \sum_{\mu=\mu_1}^{\mu_{NC}} \sum_{i=i_1}^{i_N} UR_{\mu i}$$

Where:
UR is the use reports by informants
N is the total number of informants
NC is number of use-categories

URs calculates the total uses for the species by all informants (from i_1 to i_N) within each use category for that species (*s*). It is a count of the number of informants who mention each use category *NC* for the species and the sum of all uses in each use-category (from μ_1 to μ_{NC}).
A higher UR value indicates that the plant species (landrace) is more widely used and has a greater diversity of uses within the community.

Cultural Importance (CI) index

The CI index provides a quantitative measure of the cultural significance of plant species to local communities (Prance 1987, Tardío *et al.* 2006). It combines the Use Report (UR) and the number of use categories or applications for a species.

$$\mathrm{CIs} = \sum_{\mu=\mu_1}^{\mu_{NC}} \sum_{i=i_1}^{i_N} {UR_{\mu i}}/{N}$$

Where:
NC is number of use-categories
UR is the use reports by informants
N is the total number of informants
Higher CI values indicate that a plant species is more culturally important and has a greater diversity of uses within the community. Plants with high CI values are often prioritized for conservation and further ethnobotanical studies.

Cultural Value (CVe) index

The CVe index was calculated to assess the cultural value of plant species by quantifying the importance of each species based on the number of informants who mentioned its use, the frequency, and the variety of its uses (Prance 1987, Tardío *et al.* 2006).

$$CVe = \left[\frac{NUs}{NC}\right] \times \left[\frac{FCs}{N}\right] \times \left[\sum_{\mu=\mu_1}^{\mu_{NC}} \sum_{i=i_1}^{i_N} UR_{\mu i}/N\right]$$

Where:
NU_s is number of different uses
NC is number of use-categories
FC_s is the frequency of citations
N is the total number of informants
UR is the use reports by informants

A higher CVe indicates greater cultural importance. Plants with higher CVe are generally used for multiple purposes, mentioned frequently by informants and are used in culturally significant ways. Plants with high CVe may be prioritized for conservation efforts, as their loss could have a greater cultural impact.

Results

Identified landraces

The study identified seven landraces, including four of *C. amarus* (**matanga, vikululu, sikululu,** and **kanyang'ombe**, the latter recognized as wild *C. amarus)* and three of *C. lanatus* (**namunywa, mahapu,** and **makabe**) (Fig**.** 2).

The landraces **matanga, vikululu,** and **sikululu** are referred to as cooking melons. **Matanga** displays light green fruit with dark green stripes, accompanied by ovate, lobed leaves. **Vikululu** has uniformly light green fruit without striping, paired with lobed leaves. **Sikululu** is notable for its blotched light and dark green patched fruit. Its leaves are distinctively large with minimal lobing, and some plants display unlobed leaves with whole dark green fruit (Fig. 2). The fruit of these landraces are cooked due to the hard inner flesh, which is tasteless when uncooked. This unique characteristic distinguishes them from other landraces.

Wild *C. amarus,* **kanyang'ombe** (Fig**.** 2) was also identified, primarily used for cooking during lean periods, is characterized by small fruit with blotched light and dark green patches. It is distinctive for its unlobed leaves, setting it apart from the cultivated landraces. Interestingly, it is dispersed through cattle, which eat the fruit and deposit the seeds in their dung, allowing for the spread of this taxon and hence its name **kanyang'ombe**, which means 'pooed by the cattle' in the local Lozi language.

In contrast, the landraces **namunywa, mahapu,** and **makabe** have fruit that are consumed raw. **Namunywa** has fruit with faintly light and dark green stripes. Its leaves are characterized by ovate, wavy margins with deep lobes. **Mahapu** exhibits distinct light and dark green striped fruit, complemented by deeply lobed leaves with ovate, wavy margins. **Makabe** is distinguished by its solid dark green fruit and large, ovate leaves with wavy margins and less secondary incision (Fig**.** 2). These fruit are locally known for their sweetness and juiciness, making them ideal for fresh consumption.

The above traits are characteristic of typical cultivated watermelons (*C. lanatus*).

Ethnobotanical uses

The ethnobotanical survey of *Citrullus* revealed diverse traditional uses across different landraces, demonstrating their important role in local communities. Five uses were identified from the farmers' responses that included livestock feed, Human food (cooked with corn meal, eaten raw, cooked as vegetables, dried and seasoned with dry fish, dry bush meat or cooking oil as well as ground nuts), medium for earthworm production, making jam and as an aphrodisiac (Table 1). The uses were further categorized into four use categories: food and nutrition (human food and jam-making); medicinal (aphrodisiac); fishing bait (medium for earthworm production); and fodder (livestock feed). Several landraces of *C. amarus*, **matanga, vikululu, sikululu,** and its wild form, **kanyang'ombe**, were documented alongside *C. lanatus* local varieties, **namunywa, mahapu,** and **makabe**. These landraces showed remarkable diversity in their applications, with different plant parts (leaves fruit and seeds) being utilized for various purposes (Table 1).

The results revealed that *C. amarus* landraces are utilized in local communities for both livestock feeding and human consumption, demonstrating their dual-purpose significance. For livestock, including pigs, goats, and cattle, the fruit is typically cut into medium-sized pieces to facilitate ease of feeding. In terms of human use, several distinct preparation methods were documented across different communities. One common method involves boiling the fruit with minimal water, followed by mashing and mixing with cornmeal or sour milk to create a porridge-like meal.

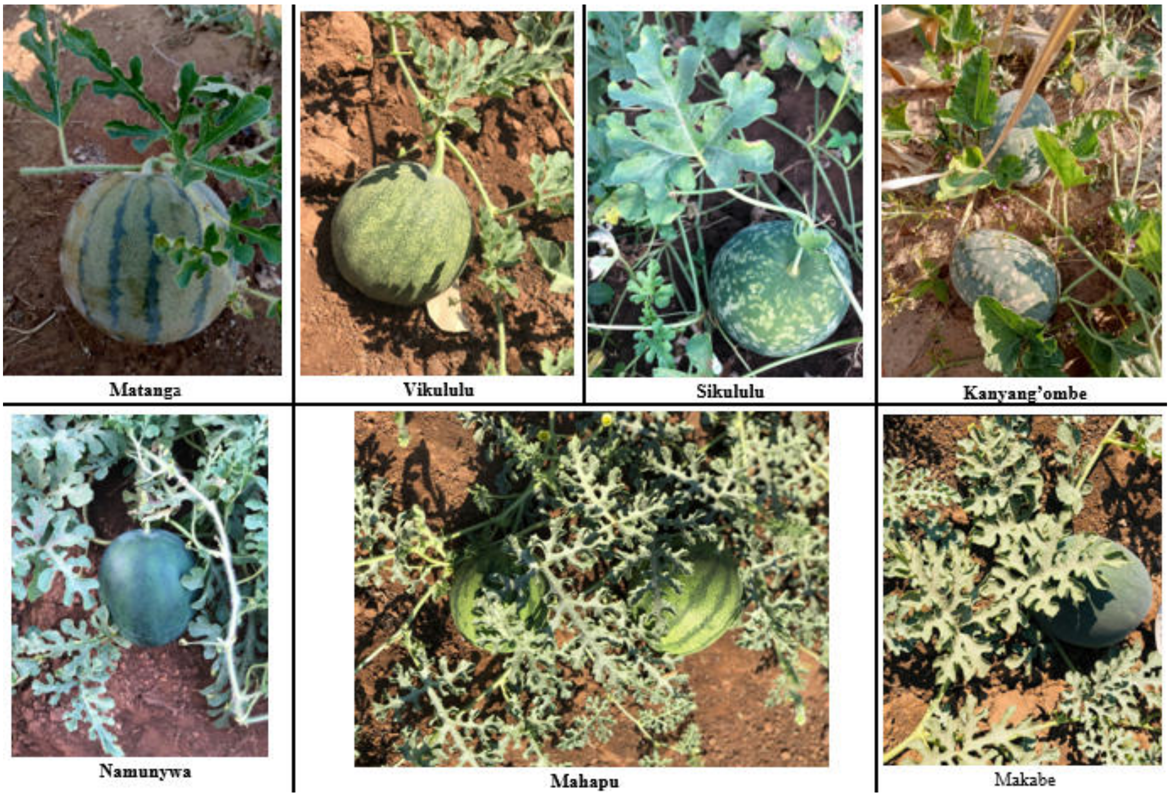

Figure 2. *Citrullus amarus* landraces; **matanga**, **vikululu** and **sikululu** (referred to as cooking melons), and **kanyang'ombe** the wild relative of *C. amarus* and *C. lanatus* landraces; **namunywa**, **mahapu,** and **makabe** (fruit are eaten raw).

Furthermore, it was noted that many communities enhance the flavor and nutritional appeal of these dishes by adding sugar or honey. Additional practices include slicing the fruit into small pieces, drying them, and cooking them with dried fish, bush meat, cooking oil, or groundnuts (Table 1).

The leaves of *C. lanatus*, specifically from the **mahapu** landrace, and the leaves of *C. amarus*, represent a substantial vegetable food source in local diets. Traditional preparation methods involve harvesting fresh, tender leaves, which are then finely chopped and prepared in two distinct ways. Sometimes people prefer cooking the leaves with groundnuts, while other times they prepare them with cooking oil, both methods resulting in nutritious vegetable dishes that form part of the local culinary tradition.

An innovative fishing bait application was documented for certain *C. amarus* varieties, particularly the **sikululu** landrace and the wild form, **kanyang'ombe**. The fruit is utilized to create a medium for earthworm production through a specific process in which the melon is cut into small pieces, mixed with soil in a container, and maintained with periodic watering (Table 1). All local varieties of *C. lanatus* are particularly valued for both fresh consumption and food processing applications. Fresh consumption involves a simple preparation method of thoroughly washing the outer rind and cutting the fruit into preferred shapes, with the option of seed removal. More elaborate processing includes jam production, where the fruit flesh is prepared by removing the rind, cutting it into small pieces, and cooking it with sugar and lemon juice for 30-40 minutes until it reaches the desired consistency. The resulting jam is then preserved in clean bottles for future use (Table 1).

Traditional medicine and wellness applications form another significant aspect of *C. lanatus* utilization. **Namunywa, mahapu,** and **makabe** landraces are recognized for their potential aphrodisiac properties, with both the fruit flesh (particularly the pink flesh near the rind) and seeds being utilized. Local practitioners recommend either direct consumption of the raw fruit and seeds or the preparation of a juice by blending fruit chunks, including some white rind (Table 1).

Table 1. Uses of *Citrullus amarus*, *C. lanatus* landraces and wild relative.

Scientific Name	Landrace	Plant part	Uses	Description of uses
Citrullus amarus	**Kanyang'ombe** **Matanga** **Sikululu** **Vikululu**	Fruits	Livestock feed and Human food	Fruits cut into medium sized pieces for pigs, goats and cattle. Fruits dried and cooked with dry fish, dry bush meat and groundnuts or mashed, and mixed with corn meal or milk.
Citrullus lanatus	**Mahapu**	Leaves	Human food (vegetable food)	Chopped leaves cooked with groundnuts or oil
Citrullus amarus	**Kanyang'ombe** **Matanga** **Sikululu** **Vikululu**	Leaves	Human food (vegetable food)	Chopped leaves cooked with groundnuts or oil dry fish, bush meat, or groundnuts
Citrullus amarus	**Kanyang'ombe** **Sikululu**	Fruits	Medium for earthworm	Melon pieces mixed with soil, water added periodically.
Citrullus lanatus	**Mahapu** **Namunywa** **Makabe**	Fruits	Human food (Eaten raw, Jam making)	Fruits eaten raw, seeds removed if preferred. Fruits cooked with sugar to make jam and stored in bottles.
Citrullus lanatus	**Mahapu** **Namunywa** **Makabe**	Fruits and/ together with seeds	Aphrodisiac	Fruits and seeds eaten raw, or blended into juice.

Ethnobotanical indices

The quantitative ethnobotanical indices for *C. amarus*, *C. lanatus* and wild relative were calculated across three districts, Kaoma, Sesheke, and Mumbwa. The use report (UR) values ranged from 3 to 69, with the highest UR recorded for *C. amarus* in Sesheke District under the Lozi language group (**sikululu** landrace). The cultural importance (CI) index followed a similar pattern, ranging from 0.103 to 2.379, with **sikululu** again showing the highest value (Table 2).

Frequency of citation (FC) values varied from 1 to 18, with both **sikululu** and **mahapu** landraces from Sesheke District showing the highest frequencies. The number of uses (NU) ranged from 2 to 7 across all landraces, with **vikululu** from Kaoma District exhibiting the highest number of uses. The relative frequency of citation (RFC) values spanned from 0.034 to 0.621, with **sikululu** and **mahapu** from Sesheke District showing the highest values.

The cultural value (CVe) index demonstrated considerable variation across landraces, ranging from 0.001 to 0.923. **Sikululu** from Sesheke District showed higher cultural value (0.923) than all other landraces. The same landrace exhibited high values across multiple indices, suggesting its particular importance in the local context.

Table 2. Ethnobotanical indices of *Citrullus amarus*, *C. lanatus* landraces and wild relative for each district.

District	Language (Tribe)	Scientific Name	Landrace Local Name	URs*	CIs*	FCs*	NUs*	RFC*	CVe*
Kaoma	Tonga	*Citrullus lanatus*	**Namunywa**	17	0.586	6	3	0.207	0.045
Kaoma	Lozi/ Tonga	*Citrullus amarus*	**Vikululu**	8	0.276	3	4	0.103	0.014
Kaoma	Lozi	*Citrullus lanatus*	**Mahapu**	7	0.241	3	3	0.103	0.009
Kaoma	Tonga	*Citrullus amarus*	**Matanga**	3	0.103	1	3	0.034	0.001
Kaoma	Tonga	*Citrullus lanatus*	**Makabe**	3	0.103	2	2	0.069	0.002
Sesheke	Lozi	*Citrullus amarus*	**Sikululu**	69	2.379	18	5	0.621	0.923
Sesheke	Lozi	*Citrullus lanatus*	**Mahapu**	43	1.483	18	5	0.621	0.069
Sesheke	Lozi	*Citrullus amarus*	**Kanyang'ombe**	19	0.655	14	5	0.483	0.198
Sesheke	Tonga	*Citrullus lanatus*	**Namunywa**	4	0.138	1	4	0.034	0.002
Sesheke	Tonga	*Citrullus lanatus*	**Makabe**	4	0.138	2	3	0.069	0.004
Mumbwa	Tonga	*Citrullus amarus*	**Matanga**	9	0.114	3	4	0.103	0.010
Mumbwa	Tonga	*Citrullus lanatus*	**Namunywa**	4	0.379	4	4	0.138	0.016
Mumbwa	Tonga	*Citrullus lanatus*	**Makabe**	4	0.138	1	4	0.034	0.002

***URs;** Use report per species, **CIs;** cultural importance per species, **FCs;** frequency of citations per species, **NUs;** number of uses per species, **RFC;** relative frequency of citation and **CVe;** cultural value per species.

In the overall study area, the quantitative ethnobotanical indices for *C. amarus*, *C. lanatus* landraces and wild relative showed considerable variation across different language groups. The **sikululu** landrace (*C. amarus*) under the Lozi language group demonstrated the highest values for multiple indices, including use reports (UR = 69), cultural importance (CI = 2.379), and cultural value (CVe = 0.923). The **mahapu** landrace (*C. lanatus*) showed the second-highest values for use reports (UR=50) and frequency of citations (FC = 21), while also having the highest relative frequency of citation (RFC = 0.724). The **namunywa** landrace exhibited the highest number of uses (NU = 11), despite having moderate values for other indices (Table 3).

Table 3. Ethnobotanical indices of *Citrullus amarus*, *C. lanatus* landraces and wild relative across the entire study area.

Language (Tribe)	Scientific Name	Landrace Local Name	URs*	CIs*	FCs*	NUs*	RFC*	CVe*
Tonga	*Citrullus lanatus*	**Namunywa**	25	1.103	11	11	0.379	0.063
Lozi/Tonga	*Citrullus amarus*	**Vikululu**	8	0.276	3	4	0.103	0.014
Lozi	*Citrullus lanatus*	**Mahapu**	50	01.724	21	8	0.724	0.078
Tonga	*Citrullus amarus*	**Matanga**	12	0.217	4	7	0.137	0.011
Tonga	*Citrullus lanatus*	**Makabe**	11	0.379	5	9	0.172	0.008
Lozi	*Citrullus amarus*	**Sikululu**	69	2.379	18	5	0.621	0.923
Lozi	*Citrullus amarus*	**Kanyang'ombe**	19	0.655	14	5	0.483	0.198

***URs;** use report per species, **CIs;** cultural importance per species, **FCs;** frequency of citations per species, **NUs;** number of uses per species, **RFC;** relative frequency of citation and **CVe;** cultural value

The data from the three districts studied revealed considerable diversity in *C. amarus*, *C. lanatus* landraces and wild relative documented in the local communities. The highest number of distinct taxa were documented in Sesheke and Kaoma Districts, with **sikululu, mahapu, kanyang'ombe, namunywa** and **makabe** reported in Sesheke, and local varieties **matanga, vikululu, mahapu, namunywa** and **makabe** reported in Kaoma. Mumbwa District exhibited lower landrace diversity, with only **matanga, namunywa and makabe** recorded. **Sikululu** and **kanyang'ombe** were unique to Sesheke, where their uses were specifically associated with fishing activities on the Zambezi River (Fig.3).

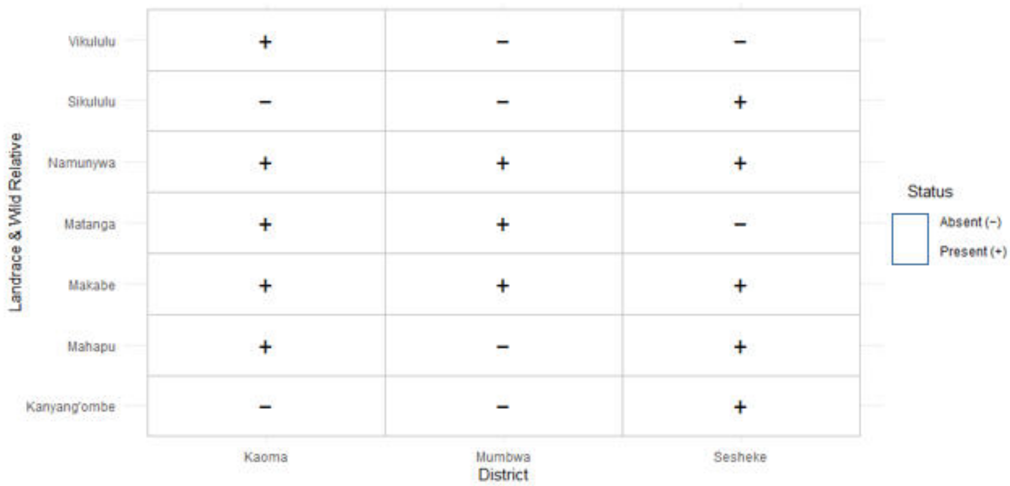

Figure 3. Presence and absence of *Citrullus* landraces and wild relative across districts

Of the four landraces (**sikululu, namunywa, makabe, and mahapu**) and one wild relative (**kanyang'ombe**) recorded in Sesheke District, **sikululu, mahapu and kanyang'ombe** demonstrated notably higher index values across the entire study area (Fig**.** 4).

Additionally, of the five landraces recorded in Kaoma District, **vikululu** showed the highest number of use (NU) values. **Namunywa, matanga,** and **mahapu** exhibited similar NU values, while **makabe** recorded the lowest values among the landraces in this district (Fig**.** 4).

In Mumbwa District, **matanga** and **namunywa** displayed nearly identical values across all calculated indices, while **makabe** consistently showed the lowest values in the indices presented (Fig**.** 4).

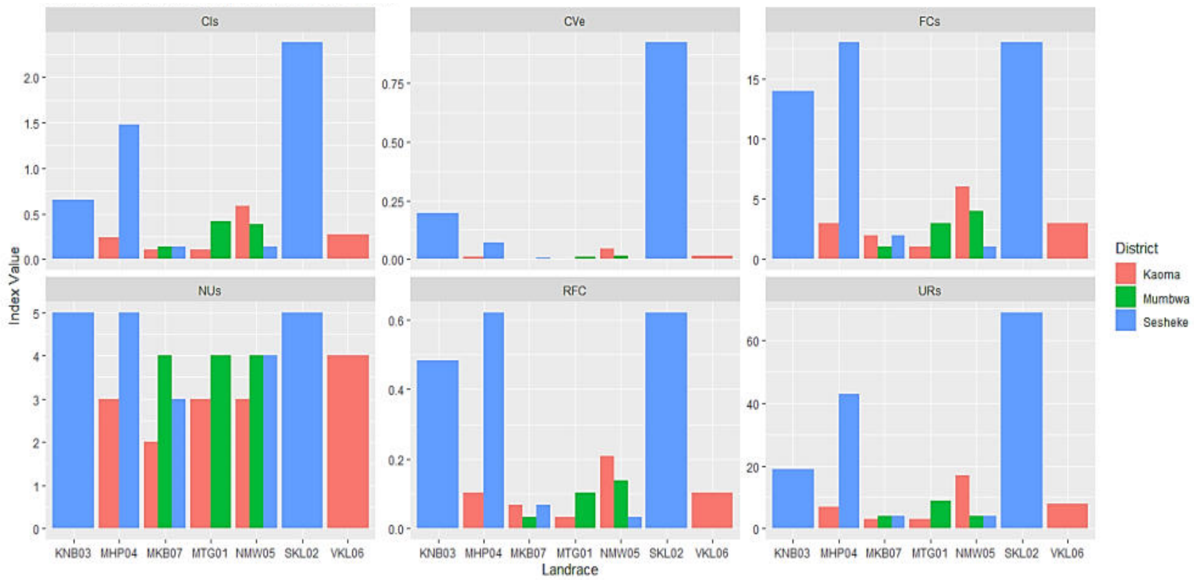

Figure 4. Ethnobotanical indices by landrace and District. **KNB03**; Kanyang'ombe wild relative of *Citrullus amarus*; **MPH04**; Mahapu, **MKB07**; Makabe, **MTG0**; Matanga, **NMW05**; Namunywa, **SKL02**; Sikululu and **VKL06**; Vikululu. **URs;** use report per species, **CIs;** cultural importance per species, **FCs;** frequency of citations per species, **NUs;** number of uses per species, **RFC;** relative frequency of citation and **CVe;** cultural value

The demographic characteristics of informants in this study showed a pattern across Sesheke, Kaoma, and Mumbwa Districts. The gender distribution showed a male dominance with 65% of respondents being male compared to 46% female participants. Age distribution indicated a skew toward older participants, with 73% of informants being above 45 years old, followed by 23% between 36-45 years, and only 15% between 26-35 years (Fig. 5).

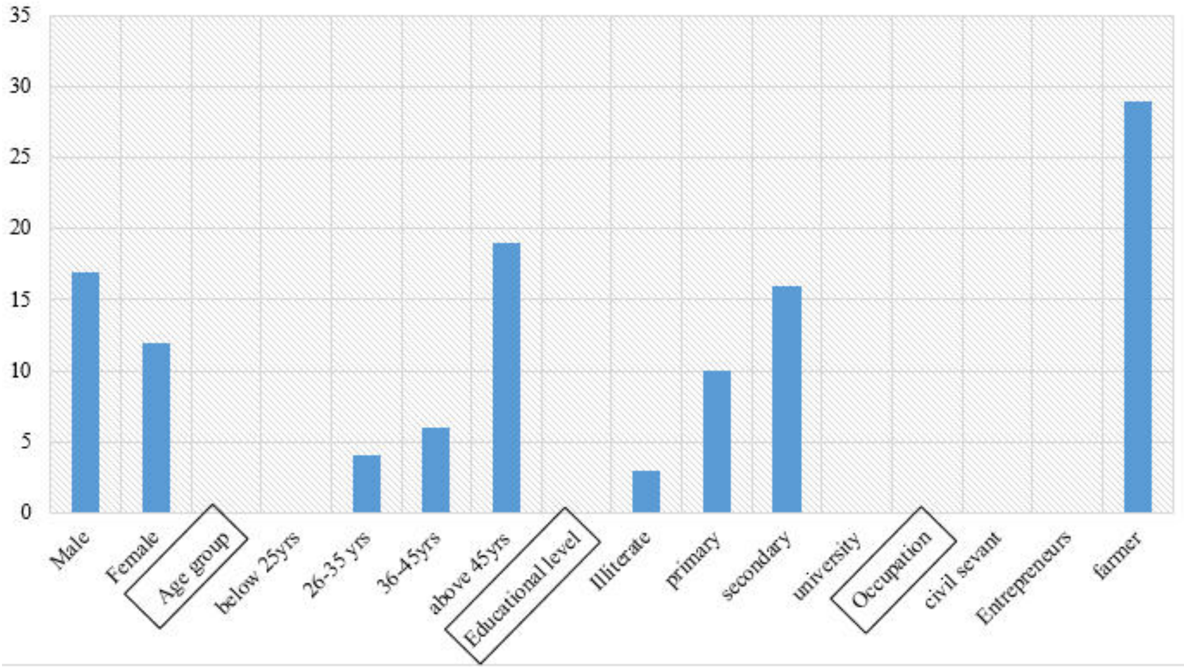

Figure 5. Characteristics of informants: Gender, Age group, Educational level, and Occupation.

The educational and occupational profile of informants provides insights into the socio-economic context of *Citrullus* cultivation in these districts. Educational levels were relatively basic among the participants, with 38% having primary education, 50% secondary education, and 12% being illiterate, while there were no university educated informants interviewed in the study area (Fig. 5). Finally, 100% of the informants were farmers, with no representation from other occupational categories such as civil servants or entrepreneurs (Fig. 5).

Discussion

The study aimed to conduct complementary qualitative and quantitative ethnobotanical assessments of *Citrullus* landraces and wild relatives in Zambia's Sesheke, Kaoma, and Mumbwa Districts. Its primary goal was to highlight the potential of these crops in ensuring food security while preserving the rich local biodiversity and cultural heritage. Notably, our research addresses a significant knowledge gap in the literature, as quantitative ethnobotanical indices for *Citrullus* landraces have been lacking, thereby rendering our findings a valuable and novel contribution.

The research has shown that local communities use *Citrullus* landraces in many different ways, revealing a wealth of traditional knowledge and creative applications. The findings indicate that *C. lanatus* landraces, *C. amarus* landraces and wild *C. amarus* serve multiple purposes, from basic food consumption to specialized agricultural and cultural uses, reflecting the deep integration of these plants into local communities' daily lives.

The geographical distribution of landraces shows variation across districts, with Sesheke and Kaoma exhibiting higher landrace diversity compared to Mumbwa. This distribution pattern appears to be influenced by environmental factors, particularly the semi-arid climate and sandy soils (Martinsen 2014) of the Western Province, providing favorable conditions for *Citrullus* cultivation. The lower diversity in Mumbwa can be attributed to the environment coupled with modern farming practices, including the use of agrochemicals that often eliminate these species when treated as weeds in maize fields (Mujaju 2009, Owemigisha *et al*. 2024).

The folk classification system used by local farmers closely aligns with formal taxonomic groupings, especially in differentiating between *C. lanatus* and *C. amarus*. Their traditional naming and classification practices, based on observable

traits such as fruit flesh quality, rind patterns, and leaf morphology, effectively distinguish these species into distinct groups that mirror scientific classifications reported by Mujaju *et al*. (2012), Munisse *et al*. (2011), and Nantuome (2011).
The *C. amarus* group (**matanga**, **vikululu** and **sikululu**) is distinguished in folk taxonomy by their hard, tasteless flesh requiring cooking for consumption. Despite some morphological similarities to *C. lanatus* in leaf structure and rind patterns, farmers distinguish these as a separate group based on prior knowledge of their edibility and characteristic flesh traits, which in turn determine their culinary use

The *C. lanatus* group (**namunywa**, **mahapu**, **and makabe**) is recognized by farmers through their sweet, juicy flesh (Pendidikan *et al*. 2025). While these landraces show slight variations in rind markings and flesh color, farmers group them together based on their common edible properties and cultivation practices, particularly their intercropping with maize and groundnuts. This traditional grouping reflects their taxonomic relationship as *C. lanatus* varieties.

Ethnobotanical indices reveal patterns of cultural significance and utilization. The CI index quantifies the relative importance of landrace species by evaluating the frequency of use reports, number of users, and diversity of use categories, enabling comparison of cultural significance across landraces while identifying priority species for conservation and illuminating the intricate connections between landraces and human cultural practices.

The **sikululu** landrace, particularly in Sesheke, demonstrates high use reports (UR = 69) and cultural importance (CI = 2.4) scores but slightly lower number of uses (NU = 9), indicating its central role in local traditions and practices. This discrepancy between UR and NU for **sikululu** indicates that while it may be used more frequently, its applications are somewhat more specialized compared to **namunywa** (NU = 11). These findings are consistent with previous ethnobotanical studies (Ali *et al*. 2025, Ayub *et al.* 2023, Luh *et al*. 2025, Shah *et al.* 2024).

Other landraces like **mahapu** (UR = 43) and **kanyang'omb**e (UR = 19) are more localized to Sesheke District, highlighting specific environmental or cultural factors that favor their cultivation in this area, which is drier than other districts studied. Similar results have been reported (Mwila *et al.* 2008, Ullah *et al*. 2024) that a range of local watermelon varieties are found especially in drier and hotter parts of the country. The UR index validated traditional knowledge by quantifying the cultural significance of plant species, supporting prioritization for conservation and development while facilitating cross-regional comparisons of plant use, which ultimately guides sustainable resource management based on local communities' needs.

Traditional preservation methods, particularly for *C. amarus* landraces, demonstrate holistic approaches to food security through sun-drying techniques. The integration of these preserved products with other food items indicated a detailed understanding of food complementarity as also been reported in similar studies (Fajinmi *et al.* 2022a, McGregor 2012, Olarewaju *et al*. 2021).

The comparatively higher cultural values (CVe) observed in Sesheke, particularly for **sikululu** (CVe = 0.621), indicate that this district functions as a major repository of traditional ethnobotanical knowledge; a finding that provides new insight into the spatial distribution of cultural knowledge within Zambia. The lower CVe values in Kaoma and Mumbwa suggest a gradual erosion of traditional practices, likely influenced by modernization and the introduction of commercial watermelon varieties. This trend may also reflect declining optimal growth conditions for the landraces as the environment transitions from the sandy, arid soils of Sesheke toward the less arid and clay-rich soils of Mumbwa, reinforcing the rationale for selecting these three districts to capture ecological and cultural variation in *Citrullus* diversity.

This index provided understanding of the cultural significance of plant species, allowing us to identify species with high cultural value, understand the complex relationships between plants and human cultures, and inform conservation and management strategies that prioritize culturally important species. These findings are consistent with previous ethnobotanical studies (Ali *et al*. 2025, Luh *et al.* 2025, Mwambo & Chuba 2024).

The medicinal applications, particularly the use of *C. lanatus* landraces as aphrodisiacs, demonstrate traditional knowledge of plant alternative uses. The recognition of specific parts of the fruit, such as the flesh near the rind, for its biological properties (L-citrulline content) shows an understanding of plant properties that aligns with modern scientific findings (Martirosyan *et al.* 2025). The antioxidant properties are attributed to the presence of lycopene, beta-carotene, and vitamin C in these fruit, which collectively contribute to improved blood vessel health. Additionally, watermelon seeds are rich in zinc, a mineral essential for testosterone production, highlighting the fruit's potential benefits for reproductive health. These findings are consistent with previous ethnobotanical studies (Collins *et al.* 2007, Martirosyan *et al.* 2025, Mujaju 2009 Pendidikan *et al*. 2025).

The study also reveals an important pattern in the adaptation of traditional knowledge to environmental and economic conditions. For instance, the specialized use of certain *C. amarus* landraces were reported for their use as livestock fodder for pigs, goats and cattle, which is similar to results reported elsewhere (Fajinmi *et al*. 2022a, Mujaju *et al*. 2012). This is further supported by its unique application as an earthworm cultivation medium for fishing activities along the Zambezi River, emphasizing the adaptation of traditional knowledge to local economic activities.

The socio-demographic analysis of informants across the study area can disclose insights into the custodians of traditional knowledge regarding *Citrullus* species. The gender distribution shows a male dominance, suggesting that men play a more prominent role in *Citrullus* cultivation and knowledge transmission in these areas. However, other studies have shown that women often possess extensive knowledge about the use of medicinal plants compared to men (Tinitana *et al*. 2025), implying that cultural and gender dynamics such as women's limited interaction with male researchers may have influenced the observed pattern.

The age structure, heavily skewed toward individuals above 45 years, with minimal representation from younger age groups, indicates a potential risk of knowledge loss as traditional practices may not be effectively transferred to younger generations. However, a cautionary approach should be adopted when interpreting these results due to a lack of consideration for knowledge transmission, particularly at household level. Other studies revealed traditional knowledge being dominated by women and that older people are perceived to be more knowledgeable because they have accumulated more experience over time (Ayub *et al*. 2023, Tinitana *et al*. 2025). The educational profile reflects the typical rural agricultural setting of these districts. The occupational homogeneity, with all informants being farmers, underscores that knowledge about *Citrullus* species is deeply rooted within farming communities, suggesting that traditional agricultural practices and knowledge are maintained primarily through practical farming experience rather than formal education or diverse occupational exposure in these districts (Martirosyan *et al*. 2025, Ullah *et al*. 2024).

The varying levels of cultural importance and use diversity among these *Citrullus* landraces have significant implications for conservation strategies and sustainable use programs. The high cultural value and wide recognition of **sikululu, namunywa** and **mahapu** suggest that these landraces should be prioritized in conservation efforts to ensure the preservation of culturally significant plant genetic resources. However, the specialized use of less prominent landraces like **vikululu, matanga** and **makabe** as well as the wild **kanyang'ombe** highlight the importance of maintaining agrobiodiversity. These less utilized landraces may possess unique genetic traits or potential uses that could prove valuable in the face of changing environmental conditions or evolving agricultural needs.

The diversity of uses across these landraces, ranging from human food to fodder and even medicinal uses (aphrodisiac properties of *C. lanatus* landraces), demonstrates the multifaceted role these plants play in supporting local livelihoods and cultural practices (Fajinmi *et al*. 2022a, b, Olarewaju *et al*.2021). This multi-functionality highlights the importance of *in situ* conservation approaches that maintain these landraces within their cultural context.

The findings emphasize the need for conservation strategies that consider both the biological diversity of *Citrullus* landraces and the associated traditional knowledge. The documented patterns of use and cultural significance provide valuable insights for developing targeted conservation approaches that can help maintain both the genetic diversity of these landraces and the cultural heritage they represent.

Conclusion

The results of this study highlight the significant diversity and utilization of *Citrullus* landraces in the Western and Central provinces of Zambia. The higher landrace diversity, use values, and cultural importance scores observed in Sesheke District suggest an important center of *Citrullus* genetic resources and traditional knowledge, warranting further investigations and conservation efforts to preserve this valuable agricultural and cultural heritage in this area. Future research efforts should include a comprehensive distribution study to systematically map the diversity of *Citrullus* landraces and their wild relatives in Zambia, thereby enhancing our understanding of these genetic resources and informing strategic conservation and utilization initiatives, including the enrichment of the holdings in local and regional gene banks.

Declarations

List of abbreviations: URs; Use Report per species, CIs; Cultural Importance per species, FCs; Frequency of Citations per species, NUs; Number of Uses per species, RFC; Relative Frequency of Citation, CVe; Cultural Value, NASREC; Natural and Applied Sciences Research Ethics Committee and UNZA; The University of Zambia

Ethics approval and consent to participate: Approved by Natural and Applied Sciences Research Ethics Committee (NASREC), reference number NASREC:2024-JUN-001 and all participants provided oral prior informed consent.

Consent for publication: Not applicable

Competing Interest: The authors declare no conflicts of interest between them.

Availability of data and materials: The voucher specimens, obtained during this research, have been made available through University of Zambia (UNZA) Herbarium. The data that support the findings of this study are available from the corresponding author (C.S.) upon reasonable request.

Author Contributions: Conceptualization, C.S, D.C and G.M.K.; methodology, C.S. and D.C.; software, C.S.; validation, C.S., D.C.; A.B.; E.K. and G.M.K.; formal analysis, C.S., investigation, D.C.; resources, C.S., D.C.; A.B.; E.K. and G.M.K.; data curation, C.S.; D.C. and G.M.K.; writing-original draft preparation, C.S.; writing-review and editing, C.S., D.C.; E.K. and G.M.K.; visualization, C.S.; supervision, D.C.; A.B. and E.K.; funding acquisition, D.C. and G.M.K. All authors have read and agreed to the published version of the manuscript.

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