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# "People Gathered by Sorghum": Cultural Practices and sorghum Diversity in Northern Ethiopia

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**Abstract**
Sorghum is an important crop in the livelihoods of Kunama and Tigrayan farmers in Northern Ethiopia and we present here a study of what factors have shaped the genetic diversity of the varieties cultivated in neighboring communities of the two ethnolinguistic groups. Using a combination of methods from crop science and cultural anthropology, we investigate patterns of historical and contemporary relationships between crop genetic diversity and cultural and social factors. The spatial genetic structure reveals patterns of ethnolinguistic differentiation and admixture that reflect deep affinities between cultures and crops, but the seed systems of the two communities are also open to exchange and gene-flow. Our findings highlight the importance of understanding cultural factors for genetic resource conservation, as well as for plant breeding and seed system development efforts.

**Keywords** Crop diversity · Ethnolinguistic diversity · Kunama · Northern Ethiopia · Sorghum · Tigrayan

## Introduction

Crops are genetically shaped by cultural selection and cultures are shaped by the characteristics of the crops (Geertz, 1972; Harlan, 1975; Sauer, 1952). Archaeological evidence for human collection and use of wild sorghum (*Sorghum bicolor* (L.) Moench) in present-day southeastern Ethiopia dates to 9000 – 8000 B.P. (Ehret, 2002; Wendorf et al., 1992; Wendorf & Schild, 1998). Today, sorghum is the fifth most cultivated crop worldwide and a staple food crop across the drylands of the African and Asian continents (Ehret, 2002; Xin et al., 2021). In several areas, sorghum is a cultural keystone species. In many regions of the world, linguistic diversity and biological diversity coincide, and threats to one is

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simultaneously a threat to the other (Amano et al., 2014; Brondizio et al., 2019). The biocultural diversity describes the interlinkages between variation in cultural and natural systems (Brondizio et al., 2019; Maffi, 2007; Sterling et al., 2017). The part of this biocultural diversity often referred to as agrobiodiversity is particularly important for food security and fundamentally relies on sociocultural institutions such as seed systems (Pautasso et al., 2013). However, these interconnections between cultural and biological diversity are at risk of erosion in processes of social and environmental change (Pretty et al., 2009). There are multiple biological, economic, and ethical reasons for maintaining this diversity. At the most fundamental level, crop genetic diversity is the evolutionary basis for maintaining and increasing food production. In the face of climate change and other biophysical and social stressors, it is of paramount importance that farmers have access to quality seeds of well-adapted varieties (McGuire & Sperling, 2013). In efforts to adapt crops and seed systems to such stressors it is necessary to focus not only on production related traits in the breeding and dissemination of varieties, but also the cultural and social preferences of the growers and consumers (Westengen et al., 2023). Thus, understanding the relationship between crop diversity and cultural diversity is important to address cultural and genetic erosion, as well as for maintaining long-term food security. This requires an explicit inclusion of social and cultural factors in crop genetic diversity studies (Leclerc & Coppens d'Eeckenbrugge, 2012).

Several studies have addressed the importance of culture in shaping the geographic patterns of crop diversity. For example, Orozco-Ramírez et al. (2016) found genetic and morphological variation of maize landraces cultivated by Mixtec and Chatino farmers in Central America was associated with ethnolinguistic differences. In West Naino Jika et al. (2017) found that the genetic structure of pearl millet was strongly associated with ethnolinguistic diversity. In the case of sorghum, previous studies have shown that there is an association between the distribution of ethnolinguistic groups and patterns of morphological and genetic diversity in the crop across the African continent. Stemler et al. (1975a) noted the coincidence of the distributions of Caudatum sorghums and Chari-Nile-speaking peoples, and Westengen et al. (2014) showed that the genetic structure of sorghum landraces in Africa reflects the distribution of major language families. Specifically, in Kenya spatial distribution of sorghum landraces and genetic patterns are correlated with ethnolinguistic patterns (Labeyrie et al., 2014a, 2016). Faye et al.(2019), found that in Senegal the ethnolinguistic origin of the sorghum accessions contributed to the genetic variation of sorghum (see also Westengen et al., 2014 for South Sudan, and Deu et al., 2008 for Niger).

In this study, we relate the geographical distribution of sorghum morphological and genetic diversity in a cultural boundary area in northern Ethiopia to the cultural history and current cultural practices of the two major ethnolinguistic groups. We used an interdisciplinary approach, combining genomic and morphological analysis with qualitative and quantitative ethnographic methods. Our approach differs from most earlier sorghum diversity studies from Ethiopia by explicitly investigating the role of the cultural and historical background of the area in shaping diversity. Ethiopia is a center of diversity for crops and the importance of the country's cultural diversity in generating and maintaining this agricultural diversity has long been recognized (Mekbib, 2008a; Stemler et al., 1977; Vavilov et al., 1992). According to the literature, sorghum varieties of the Durra landrace were originally grown primarily in arid Sahelian zones by African Muslims and people of Arabic descent, while the Caudatum morphotype is associated with Chari-Nile speakers, the dominant ethnolinguistic group in Chad and Sudan (Harlan & Stemler, 1976; Stemler et al., 1975a, 1977). In more recent analyses of the genetic diversity of Ethiopian sorghum little attention is given to ethnolinguistic factors (Adugna et al., 2013; Wondimu et al., 2021). However, in-depth studies of cultural practices around sorghum seed systems management from eastern Ethiopia have shown that strong affinities between cultures and crop diversity remain (Mekbib, 2008b; Mekbib et al., 2009).

We focus on the Kunama and Tigrayan ethnolinguistic groups in Northern Ethiopia. According to the last national population census, the Tigrayan group numbers about 4.3 million out of the total population of approximately 73 million in Ethiopia (Federal Democratic Republic of Ethiopia Population Census Commission 2008) and is the majority group in the Tigray region. The Tigrinya language belongs to the Semitic branch of the Afroasiatic family together with Amharic. The minority Kunama ethnolinguistic group has a population of only about 4,800 people inhabiting the border area between Eritrea and Ethiopia (Federal Democratic Republic of Ethiopia Population Census Commission 2008), with the majority living in Eritrea (Woldemikael, 2003). The Kunama language belongs to the Nilo-Saharan language family. Thus, the two communities represent two language families and have purported deep historical differences in sorghum cultivation (Stemler et al., 1977). We first identify morphological and genetic differences in the varieties of sorghum grown in the two communities and subsequently relate them to culturally embedded management practices. We conclude with a discussion of the implications of our findings for future crop diversity conservation initiatives, plant breeding, and seed system development efforts.

## Materials and Methods

### Study Site

We conducted fieldwork between November 2019 and October 2020 in seven villages (Tabias) in two districts (Woredas) in northwestern Tigray: Tahtay Adiyabo, with a mixed Kunama and Tigrayan population, and Asgede Tsimbila with a Tigrayan population. The study districts have a similar agro-ecological and topographic settings with three agroclimatic zones: warm semi-arid lower elevations, warm sub-moist mid elevations, and cool sub-moist higher elevation (Tesfay et al., 2016). The dominant farming system is mixed crop-livestock production (Tesfay et al., 2016). According to the Ethiopian National Meteorology Agency (NMA, 2015), the annual mean temperature ranges from 25 to 28 °C. The rainfall pattern is mono-modal with average annual rainfall ranging from 513.5 to 910.5 mm, with a rainy season (*Kiremti*) from June to September (Zenebe et al., 2012).

### Ethnographic Studies

We conducted key informant interviews with 50 knowledgeable sorghum farmers and seed selectors, both men and women (25 from each ethnic group). We asked questions related to varieties of sorghum grown in their locality, their origin, vernacular naming and associated meanings. We held focus group discussions (FGDs) with 12 groups consisting of farmers, extension agents, religious leaders, and elders, some including both men and women, and others with only men or only women. The topics of the FGDs included the sorghum varieties grown, the variety naming, and the socio-cultural practices related to cultivation. We collected oral histories and oral traditions relating to sorghum cultivation from 10 elders (> 75 years) (5 per ethnic group), including both male (5) and female (5) informants. In the key informant interviews, we asked about the historical reasons for changes in sorghum cultivation in the two communities. Additionally, we administered an ethnobotanical survey among 300 respondents randomly selected in the study areas which included questions of current and past variety use. We also reviewed historical documents on sorghum cultivation among the two communities.

### Morphological Characterization

We collected 43 sorghum panicles from farmers' fields representing all sorghum varieties identified in the participants' fields in November 2019. We used 20 morphological qualitative descriptors from the sorghum list developed by the International Board for Plant Genetic Resources (IBPGR, 1993) to develop the morphological characterizations of the sampled panicles: panicle (shape, density, tip, length, peduncle position, number of branches), seeds (color, shape, spot, form, and cover), endosperm texture, number of branches per whorl, rachis branch length, rachis branch position, number of rachis furrows, glume characteristics (color, shape, transverse depression, hairiness). Eight of the descriptors used in this study (panicle shape, seed color, seed shape, seed cover, endosperm texture, glume color, transverse depression, glume hairiness) were also used by (Labeyrie et al., 2014b).

### Genotyping by Sequencing (GBS)

Seeds from each landrace accession were germinated in a greenhouse and one leaf from a randomly selected plant from each accession was harvested for DNA extraction after 14 days. We harvested ~ 50 mg leaf, froze it with liquid nitrogen and extracted DNA using the DNeasy Mini Kit (Qiagen) following the manufacturers' protocol. Samples of 30 µl of DNA at 50-100 ng/µl concentration was prepared and dried with a thermocycler at 65 ºC and shipped for Genotyping by Sequencing (GBS) at the Elshire GBS services. GBS was performed according to (Elshire et al., 2011) using ApeKI restriction enzyme in a 96-plex library sequenced in 3 lanes of 2 × 150 bp on an Illumina HiSeq XTen machine.

The sequencing yielded a total of 410 million read pairs, with an average of 4 million read pair count per sample. The raw 150 bp paired end reads were filtered to remove the adaptor sequences, contaminations, and low-quality reads. Briefly, the GBS sequence reads were first demultiplexed, quality checked based on Phred scores and trimmed the bad reads using process radtag script in Stacks pipeline. The derived clean reads of approximately 3.8 millon read pairs per sample were used for Single Nucleotide Polymorphism (SNP) calling (identification) and filtering using Stack2.4 version pipeline (Catchen et al., 2013; Rochette et al., 2019). The sorghum reference genome version 3.1 was downloaded from Phytozome (McCormick et al., 2018; Paterson et al., 2009) and indexed the genome with Burrows–Wheeler Alignment version (BWA) 0.7.10 (Li & Durbin, 2009). The clean data from each sample were aligned using BWA and the bam files sorted using samtools. A reference-based analysis in the Stacks pipeline utilizing two modules "gstacks" and "populations" was used for SNP calling. The gstacks module, which reads in aligned reads to assemble loci, was executed to assemble and merge paired-end contigs, call variant sites in each sample followed by the populations program. The populations program was the final stage executed to filter SNPs and to calculate population genetics statistics. The SNPs were filtered based on the following criteria: (1) variant should be bi-allelic SNPs, (2) SNPs having more than 25% missing information were excluded, (3) genotypes having more than 25% missing information were excluded, and (4) markers with minor allele frequency MAF > 0.01 were retained.

### Genomic Analysis

We performed a set of population genomic analyses on the Tigray collection alone and in the context of common SNPs available for 1846 georeferenced accessions in the Integrated GBS dataset from (Hu et al., 2019) using a custom-made Python script we identified 18,992 common polymorphic SNPs between our VCF dataset and the Integrated GBS dataset and matched/combined the two datasets accordingly. Both the local level dataset (42 samples) and the combined dataset (1888 samples) were subject to population structure analysis using the Bayesian model-based clustering approach in ADMIXTURE (Alexander et al., 2009) and the Discriminant Analysis of Principal Components (DAPC) approach in Adegenet (Jombart et al., 2010). We identified the best K values employing the cross-validation method in ADMIXTURE (Alexander & Lange, 2011) and the Bayesian Information Criterion (BIC) in Adegenet. Maps were made in ArcMap with Ethnolinguistic spatial data from Ethnologue compiled in (GMI, 2013).

### Ethics Statement

A research permit was obtained from the Mekelle University Office of Research and Community Service. A permission to perform the research was also obtained from the local administrators of the two districts and the Office of Agriculture and Rural Development. We followed recommendations of the International Society of Ethnobiology Code of Ethics (Ethnobiology, 2006), and the involvement of local team members ensured that local procedures, rules, and customs were respected, and that authorizations were granted from legitimate authorities. First, government administrative and local community representatives were informed and kept updated of the activities, and their consent was sought before conducting the research. Then, the study objectives and the future data utilization were explained to study participants and their written prior informed consent was obtained before undertaking interviews and seed collection. All study participants were selected on a voluntary basis. Research activities were not conducted where such consent was not granted. The seed samples collected were deposited at the Mekelle University genebank. A sample of ~200 seeds from each accession was exported to Norway for germination in the greenhouse and DNA extraction. The samples were exported under a Material Transfer Agreement (MTA) concluded between one of the authors (TSG) and the relevant Ethiopian authority stating that the seed samples could only be used for the current research.

## Results

### Genetic and Morphological Diversity

The geographic distribution of the genetic groups identified in the genetic structure analysis reflects association with the ethnolinguistic distribution, but also admixture. The cross-validation error estimate from the admixture analysis and the BIC from the DAPC analysis indicate that a structure with three ancestral groups is plausible (Fig. S1). Plotting the K = 3 structure on a language family map shows that two of the groups are present in both language areas, while one group is cultivated only in the westernmost district (Fig. 1).

The colors/shades in Fig. 1 represent the genetic clustering at K = 3 determined by DAPC. The group K3 consists of farmer varieties and improved varieties morphologically classified as Durras. The group K1 consists of farmer varieties and improved varieties, mostly classified as Durras, but also including the wild type and some of the morphological Caudatums. The K2 group is exclusively found in the Kunama and mixed villages in the western district and consists of farmer varieties morphologically classified as Caudatum, Durra, and Bicolor. Thus, there is not a 1:1 relationship between genetic clustering and morphology-based grouping, as both Durra and Caudatum varieties cluster in several groups (Table 1).

Considering the collection in this study in the context of the global diversity panel from Hu et al. (2019), we find that at the lower K-levels it is clustered within a group of accessions originating primarily in Nilo-Saharan language areas and countries (Fig. S2, S3). At higher K-levels (K = 10 and upwards) we see a structure within our collection differentiating between a group with the K1 samples from the local level analysis presented above and the other samples (Fig. 2). This group (group 7 in Fig. 2) is a mixed groups in terms of language family origin and morphotypes, but with considerable representation from Nilo-Saharan speaking areas (43% of the global dataset samples). Interestingly, the Dagnew variety in our study, which also has a Caudatum morphotype, clusters in a group consisting primarily of Durra sorghum from Ethiopia, in which only 2% are Nilo-Saharan speakers in the global dataset (group 6 in Fig. 2).

Important differences were observed in the 43 sorghum samples based on the 20 morphological characteristics studied (Table. S1, Fig. 3). The 43 samples included in this study represent 14 farmer varieties and four improved varieties approved by the National Variety Release Committee (NVRC). Based on morphological markers we classified

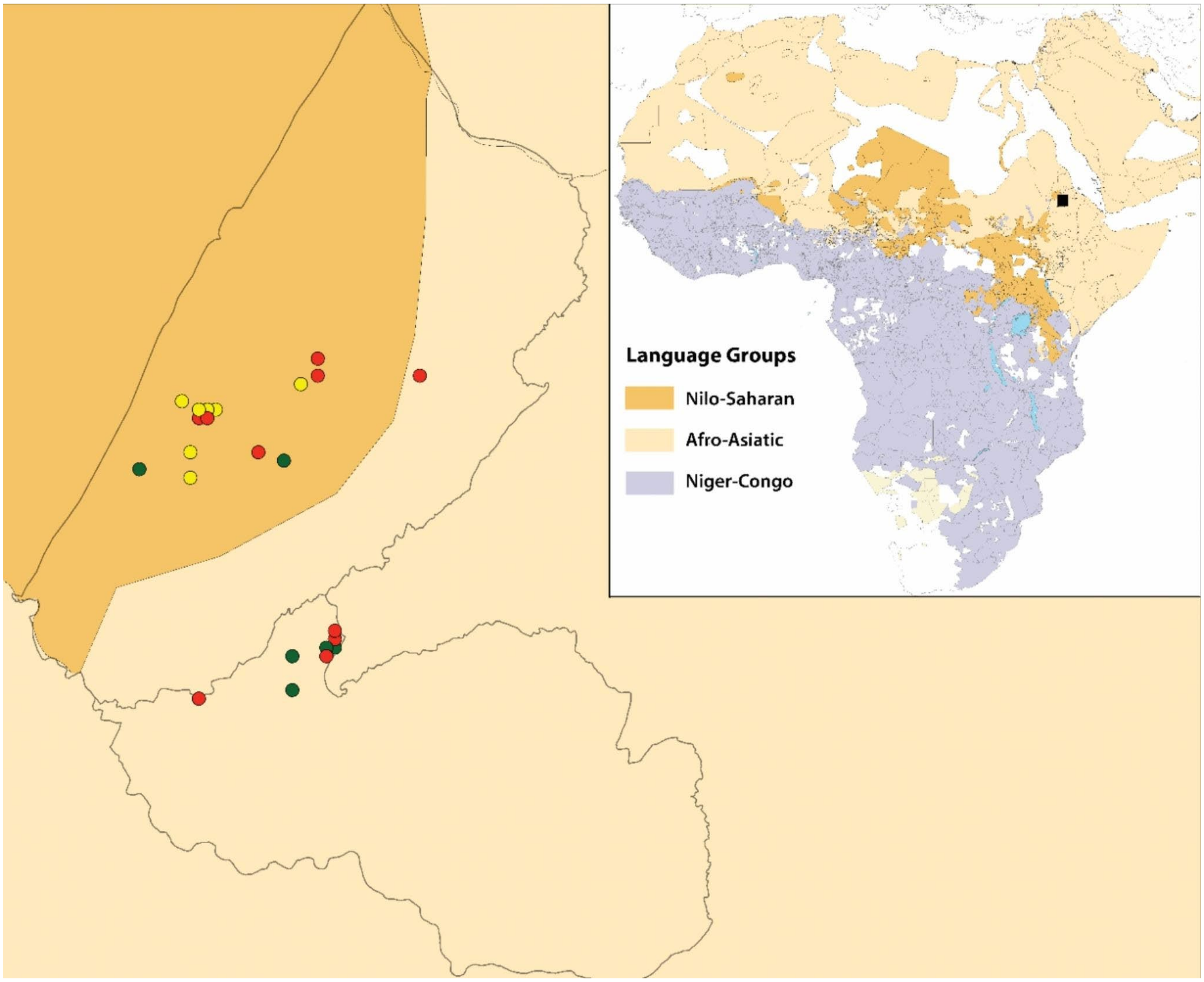


**Fig. 1** Sorghum population structure and language family distribution. Map of the study area with district and national borders. The map colors represent language families, and the color of the circles represent the clustering at K = 3 level for the 42 sorghum samples included in this study (K1 is green, K2 is yellow and K3 is red). The inset shows the location of the study area in relation to continent level language family distribution

seven of the farmer varieties as Durras, one as Durra-Bicolor, one as Bicolor, one as a wild type and two as Caudatums (Table 1).

## Varietal Naming and Folk Taxonomy

Farmers in the study areas named sorghum varieties according to their agro-morphological characteristics (panicle shape, seed color, yield, maturity, seed form), culinary qualities, or after the communities or person believed to be the original source of the variety (Table 2). Assessment of the consistency in the local naming of sorghum varieties among the two ethnolinguistic groups shows that the Tigrayan living in the same district as the Kunama use the same variety names, e.g., the Kunama and their Tigrayan neighbors (Tigrayan-T) use the names Wediaker, whereas the Tigrayan in the other district use the names Fkrey/Hishnur to refer to the same variety. On the other hand, the Kunama and Tigrayan in the same district use different variety names, Tsa'da chumurey/Chumurey/Zeriegebru, to refer to the same variety that belongs to the same morphotype (Durra) and cluster in the two different genetic groups (K1) and (K2).

In this study, 73%, 94% and 86% of Kunama, Tigrayan-T, and Tigrayan-A, respectively, reported lost sorghum varieties in their locality. Overall informants reported 13 lost local sorghum varieties (Table 3). The number of lost sorghum varieties reported differs slightly between the two ethnolinguistic groups. Kunama reported eight lost varieties of sorghum, while Tigrayan-T and Tigrayan-A reported 12

**Table 1** Sorghum varieties grown in the two districts. Race determined on the basis of 20 morphological markers and genetic clustering at K = 3 level determined by DAPC. The improved varieties are marked with an asterix, the rest are farmer varieties. Tigrayan-T: Tigrayan living in Tahtay Adiyabo district (together with Kunama); Tigrayan-A: Tigrayan in Asgede Tsimbila district

| Kunama and Tigrayan-T | Tigrayan-A | Race | Genetic group (K = 3) |
|---|---|---|---|
| Dagnew | Dagnew | Caudatum | 2 |
| Wediaker | Fikrey/Hishnur | Caudatum | 1 |
| Getsharas | Getsharas | Durra | 1 |
| Keyih chumurey | Keyih chumurey | Durra | 2 |
| Mereway | Mereway | Durra | 3 |
| Tsa'da chumurey /Zeriegebru | Tsa'da chumurey | Durra | 1/2 |
| - | Wedisibuh | Durra | 3 |
| - | Mereway Kemkem | Durra | 3 |
| Akoma | - | Durra | 2 |
| - | Shulkuit | Durra | 3 |
| Tewzale | Yikrebeleley | Durra-Bicolor | 1 |
| - | Merway Wedihidar | Durra | 3 |
| Ganseber | Ganseber | Bicolor | 2 |
| Zeriesystan | Zeriesystan | Wild-type | 1 |
| Dekeba* | Dekeba* | Durra | 1 |
| - | Melkam* | Durra | 1/3 |
| - | Argeti* | Durra | 1 |
| Mruts zerie* | Mruts zerie* | Durra | 3 |

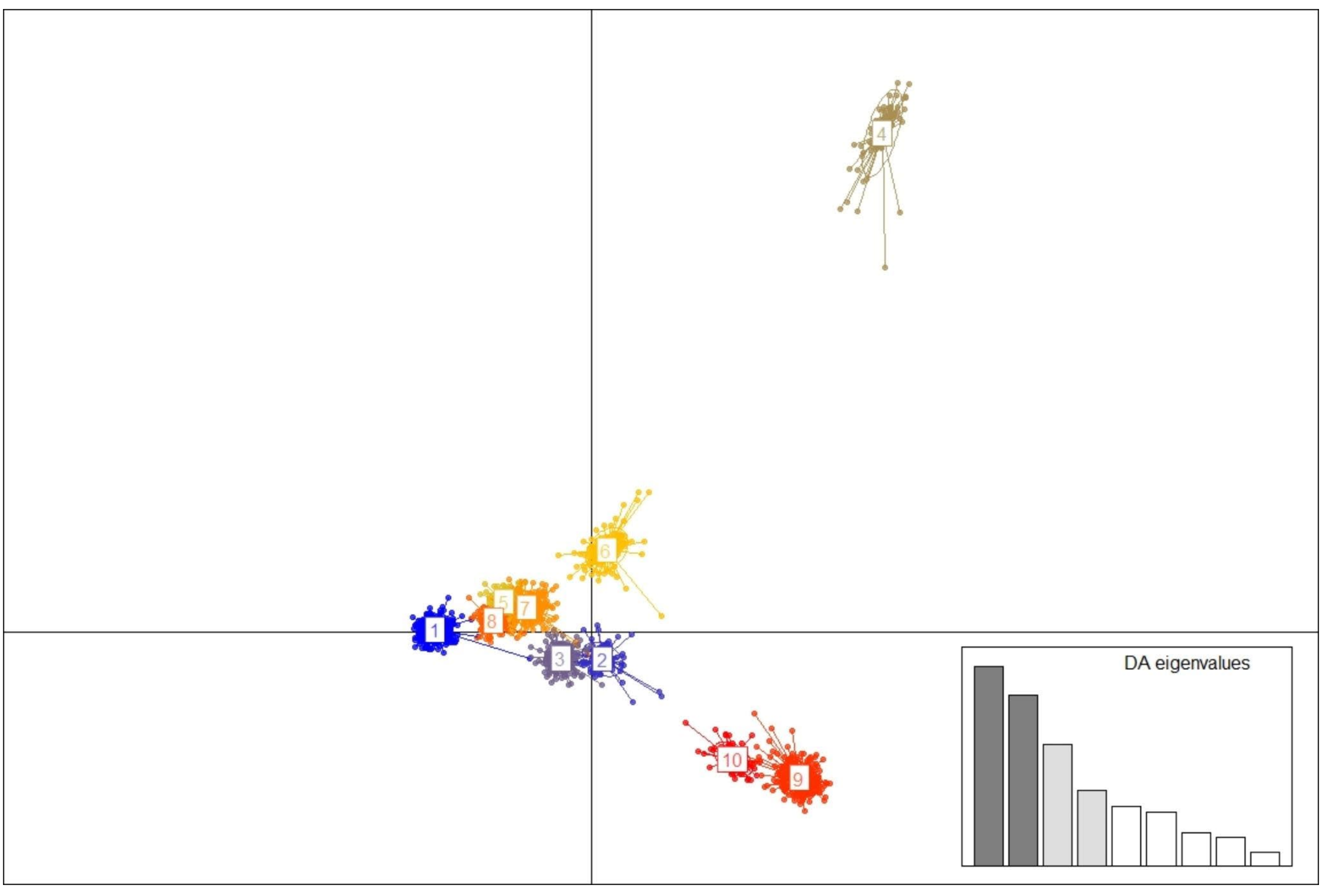


**Fig. 2** Discriminant Analysis of Principal Components (DAPC) scatter plot of global sorghum panel. Plots the structure (K = 10) of the sorghum samples in this study in the context of the global Integrated GBS dataset (Hu et al., 2019). The varieties from the local dataset cluster in groups 6 and 7. Group 4 consists of West African Guinea sorghums and groups 9 and 10 are Indian Durras. The other groups are mixed in terms of geographic origin and botanical race

**Fig. 3** Morphological diversity of sampled sorghum varieties from Tigray. From left to right: Wedisibuh (Durra), Wediaker (Caudatum), Ganseber (Bicolor), Tewzale (Durra-bicolor), and Getsharas (Durra)

lost varieties. The varieties most reported as lost by both ethnolinguistic groups are Ganseber, Koden, Tewzale, and Getsharas. The most common reason for the loss of sorghum varieties was drought. In the face of climate change, the study areas have experienced acute moisture stress over time. As a result, farmers gradually replaced late maturing and less drought tolerant varieties with earlier maturing and drought tolerant ones. Another reason for the loss of sorghum varieties, which we classify under the label "cultural change," is the substitution of other grain crops for dishes traditionally made with sorghum. For example, most Tigrayans in both districts mentioned that they now use finger millet rather than sorghum to prepare their traditional drink (*siwa)* and wheat flour for bread (*kicha*). Consequently, they have stopped growing sorghum varieties such as Tewzale, which was mainly used to prepare *siwa*.

## Discussion

We first interpret the results of our genetic, morphological, and folk taxonomic analyses in the context of the cultural history and contemporary cultural crop diversity management practices of the two study communities. We then discuss implications of our findings for genetic resource conservation and plant breeding and seed system development efforts.

### Associations Between Sorghum Diversity and Ethnolinguistic Diversity

Our morphological results indicate that the cultural history of the two communities is an important explanatory factor for the pattern of sorghum varietal diversity. Stemler at al. (1975b, 1977) stated that Caudatum growers in Ethiopia shared common linguistic and cultural roots as well as agricultural systems with the Nilotic peoples of Sudan and hypothesized that there is a close causal relationship between the distribution of Caudatum sorghums and the migration of Chari-Nile-speaking peoples. The fact that the majority of Kunama in our study grow Caudatum may be due to their descent from pastoralist Caudatum-cultivating agro-pastoralists belonging to the Nilo-Saharan language family. The agricultural vocabulary of the Nilo-Saharan Ch'aré people, historical neighbors of the Kunama, includes words for sorghum (Smidt, 2011). In line with Stemler et al., 1975b); Phillipson (2003) hypothesized that sorghum may have been introduced to northern Ethiopia from areas west of the Nile today covered by the Sahara dessert. Linguistic evidence indicates that the pre-Kunama society probably resided east of the Nile in the steppe lands between the Atbara River and the Red Sea hills (Ehret, 2002). According to Pankhurst (1977), the Shankila tribes of Walqayt, which include the Kunama, were known to grow sorghum called '*maSella*.'

Kunama oral tradition indicates a long history of sorghum cultivation. According to our key informant Ato Sahle, a Kunama elder, the first sorghum seed was discovered by a Kunama man who found a grass growing in elephant dung and subsequently domesticated it as a food crop. According to this oral tradition, the first sorghum variety was Bazenay/Keyih chumurey/Abinkafe. The variety Bazenay is named after King Bazen, the king of the Kunama in Aksum (Woldegiorgis, 2018) who ruled Ethiopia from 7 BC to 10 AD (Horn & Hoffman, 1963). Historical sources indicate that elephants were highly prized and important as source of ivory as well as important military animals used by the king's army (Anfray, 1981). Visitors from the Byzantine Empire around the beginning of the sixth century documented Axumite kings using elephants to pull chariots (Phillipson, 2003). These historical sources thus provide interesting context for the oral tradition of the discovery of the first sorghum seed growing in elephant dung. According to the oral tradition of the elders of Kunama, the first varieties of sorghum that were cultivated included: Bazenay (and its synomyms Abinkafe /Keyih chumurey), Melbuba, Koden, Ganseber, Wanze, Embush, and Bultug (pearl millet). Thus, in Kunama folk taxonomy, pearl millet is considered a variety of sorghum. Pearl millet is also classified with sorghum in folk taxonomy in eastern Ethiopia (Mekbib, 2007).

According to their oral history, Tigrayans in Asgede Tsimbila district began cultivation of sorghum as late as the 1980s when settler farmers moved in from highland areas of the Tigray region, where crops such as teff, wheat, and barley dominate, and sorghum is not grown. As a result,

**Table 2** Vernacular names and meaning of some selected Sorghum variety names

| Variety names | Meaning | Ethnic group and district | |
|---|---|---|---|
| | | Kunama/ Tigrayan-T | Tigrayan-A |
| Ganseber | The name Ganseber means 'pot breaker' named by a woman whose pot was broken by Ganseber dough due to its heavy weight. | ✓ | ✓ |
| Getsharas | The name Getsharas is given to refer the bright red color of the variety which means 'the glowing face (red color)' of a woman who has delivered a baby. | ✓ | ✓ |
| Shulkuit | The name Shulkuit meaning 'small size' to refer the small panicle size of the variety. | | ✓ |
| Chumurey | For Tigrayan in the Asgede Tsimbila district, the variety name 'Chumurey' means short, to characterize the short plant structure of the variety.<br>-For Kunama and Tigrayan in the same district, Chumurey means 'excess' or 'additional' to refer to the twin-seeded form of the variety. | ✓ | ✓ |
| Tsa'da chumurey | The name Tsa'da chumurey is used to characterize the white color of the variety, meaning 'white Chumurey.' | ✓ | |
| Keyih chumurey | Named after the red color of the variety. Meaning 'red Chumurey' | ✓ | |
| Tewzale/Ykrebeleley | The Tewzale variety, also known as 'Ykrebeleley', a Tigrigna word meaning 'forgive me', symbolizing a person asking for forgiveness to characterize the curved (bended) peduncle position of the variety. | | ✓ |
| Dikal | Farmers in both districts use the term 'Dikal' as a *suffix* or *prefix* to the original name of the variety to mean 'breed' when a variety changes morphologically. | ✓ | ✓ |
| Wedisibuh (Zeri-takele) | The variety Wedisibuh also known as Zerie-takele named after the farmer who selected or introduced the variety. | | ✓ |
| Zeriegebru | Named after the name of the farmer who selected the variety. | ✓ | |
| Zerietsegay | Named after the name of the farmer who selected the variety. | | ✓ |

**Table 3** Sorghum varieties lost and reasons for loss reported by study respondents

| Sorghum varieties | | Kunama (n = 83) | Tigrayan- T(n = 37) | Tigrayan-A (n = 180) | Reasons for loss (n = 300) | | |
|---|---|---|---|---|---|---|---|
| | | | | Drought | Famine | Cultural change | Other |
| Chumurey | 0 | 10.8% | 11.1% | 72% | 0 | 24% | 4% |
| Dagnew | 0 | 2.7% | 2.7% | 13% | 0 | 32 | 5% |
| Tewzale/Ykrebeleley | 7.2% | 8.1% | 16.6% | 53% | 30% | 11% | 6% |
| Embush | 15.6% | 0 | 0 | 73% | 0 | 20% | 7% |
| Ganseber | 38.5% | 75.7% | 77.7% | 63% | 0 | 22% | 15% |
| Hishinur | 3.6% | 5.4% | 3.3% | 66% | 0 | 30% | 4% |
| Getsharas | 8.4% | 10.8% | 4.4% | 56% | 0 | 26% | 18% |
| Keyih chumurey | 6.0% | 37.8% | 1.1% | 50% | 0 | 24% | 26% |
| Koden | 16.8% | 24.3% | 8.8% | 59% | 14% | 14% | 13% |
| Shulkuit | 0 | 8.1% | 12.7% | 60% | 0 | 20% | 20% |
| Wanze | 22.9% | 2.7% | 0.5% | 66% | 0 | 24% | 10% |
| Wediaker | 0 | 45.9% | 6.6% | 62% | 15% | 13% | 10% |
| Tsa'da chumurey | 0 | 2.7% | 1.1% | 60% | 0 | 23% | 17% |

the Tigrayans in Asgede Tsimbila district are identified as "Meshela-akebo" meaning "people gathered by sorghum," a phrase used to describe the role of sorghum as a pull factor for the community to move to the area. The first sorghum varieties grown by Tigrayans in Asgede Tsimbila district according to the elders and other key informants include Tsa'da meshela, Newih meshela, Wedihatsirey, Fkrey, Hishnur, Shulkuit, Bultug (pearl millet), Tsa'da chumurey, Keyih chumurey, Wediaker, Mereway, Getsharas, and Ganseber, which is also known as Meshela baria[1] by the Tigrayans. Like the Kunama, some Tigrayan informants classify pearl millet as a variety of sorghum. According to key informants, most of these varieties were introduced during the great Ethiopian famine in the 1980s. However, most of those varieties except Mereway are reported as lost and replaced by other varieties due to poor resistance to drought and *Striga* infestation.

Our key informants reported that the variety Mereway has been cultivated, selected, and preserved for years due to its better adaptation to the local environment and preferred quality for cooking (good *injera* quality), good yield, market value, and livestock fodder. Currently, the most grown varieties among the Tigrayans in Asgede Tsimbila district are Mereway, Wedisibuh, and Melkam (all Durras), while the most cultivated varieties among the Kunama, Dagnew, Wediaker, and Tsa 'da chumurey, are reported lost by Tigrayans in Asgede Tsimbila districts. This could be due to the cultural preference and historical association of the Kunama with these varieties and also to the fact that Kunama are indigenous and have grown sorghum for a much longer time in the study area compared to Tigrayans (see Mekbib et al., 2009).

The genetic structure analysis partly agrees with the morphological pattern, but also deviates in significant ways. The sorghum genetic group found exclusively in the district where the Kunama live contains Dagnew, the most commonly grown variety among Kunama farmers. Dagnew is morphologically classified as Causatum, but in the context of the global diversity panel, it rather clusters with Durra varieties with origins in non-Nilo Saharan language areas. On the other hand, the morphological Caudatum Wediaker and its synonyms Fkrey and Hishnur, cultivated by both communities and in both districts, cluster in the group with high Nilo-Saharan origin. Thus, the genetic results defy a simple 1:1:1 relationship between sorghum morphotype, genetic clustering, and ethnolinguistic origin. Rather, we see the morphological pattern of more Caudatum cultivation among the Kunama community and more Durra cultivation among the Tigrayan community is partly masked by a pattern of genetic admixture in the varieties grown by both communities. The reason for the admixture is probably twofold. First, movement of people and seed exchange among people in the study areas have led to variety mixing. According to informants in Tahtay Adiyabo district, the area currently inhabited by the Kunama and Tigrayan in the district was originally inhabited only by the Kunama. Probably the Tigrayan moved in with their own sorghum seeds while also adopting from their Kunama neighbors. Second, variety mixing has most likely led to genetic admixture through cross-pollination. Barnaud et al. (2008), found an average outcrossing rate of 18% among sorghum landraces grown in mixtures by Duupa farmers in Cameroon. Interestingly, morphological and genetic differentiation among the landraces can be maintained even with high cross-pollination and admixture, testifying to the effect of farmers' seed selection (Barnaud et al., 2007, 2008).

## Contemporary cultural sorghum diversity management

The use and preference of farmers for specific sorghum varieties to prepare different dishes is more likely to contribute to current patterns of sorghum diversity in the study areas. Farmers prepare several local dishes from sorghum such as *injera* (a traditional fermented flatbread), *kicha* (thick unfermented bread), *ge'at* (porridge), *kolo* (popcorn), *tuktuko* (boiled grain), and *siwa/daga* (traditional local drinks). The most preferred varieties used to prepare these dishes differ among the ethnolinguistic groups. Wendmu et al. (2022) found that Kunama farmers prefer the Dagnew and Wediaker (both Caudatum) varieties to prepare *injera*, *kicha*, and *daga*, while Tigrayan farmers in the same district prefer Dagnew (Caudatum), Tsa'da Chumurey, and Mereway (Durras) to prepare good quality *injera*, *ge'at*, and *kicha*. The Tigrayans in the Asgede Tsimbela district prefer Mereway (Durra) to prepare *injera*, *kicha*, and *ge'at.*

The current sorghum landraces in the study areas are the result of long-term farmer selection and seed exchange. Culturally, seed selection is considered a mandatory practice and an integral part of sorghum cultivation in the study communities. The Tigrayan in the Asgede Tsimbila district believe that failure of farmers to select their seed every year results in low harvest and invasion of their sorghum field by Zeriesytan ('seed of the devil' or wild sorghum). A key informant in Asgede Tsimbila district commented that farmers are like researchers: "We make a continuous experiment with our sorghum varieties and evaluate and select a new sorghum variety on a small plot before adopting it." There are interesting differences between the two groups in terms of selection criteria. The main selection criteria considered by Kunama was early maturity, which is a prominent trait of Wediaker and Dagnew. The Tigrayan in the same district

[1] The term '*baria*' is a derogatory term referring to dark skinned people.

as the Kunama focus on yield, which is a commonly cited characteristic of the varieties Tsa'da chumurey and Mereway (both Durras). The Tigrayan in Asgede Tsimbila district focus on long and larger panicles typical of the Mereway variety. This shows there are cultural differences in trait preferences and selection criteria among the two ethnolinguistic groups. This is also found in other studies of local management practices. Pressoir and Berthaud (2004), highlighted that the morphological characteristics of maize landraces in Mexico are either maintained or created by farmers' selection criteria. Perales et al. (2005) also suggested that the difference in maize landraces in Mexico are shaped by different seed selection practices between geographically close communities with different ethnolinguistic origins. Labeyrie et al. (2014b), highlighted the role of farmers' seed selection and management practice in the type of sorghum varieties grown, stating that the divergence of the Kaguru variety between the ethnic groups Chuka, Mbeere, and Tharaka in Kenya could be the result of differences in their management practices.

### Varietal Naming and Folk Taxonomy

The phenomena that varieties are named after communities or a person also corresponds with studies on sorghum elsewhere in Ethiopia (Mekbib, 2007), in North-East Ghana (Kudadjie et al., 2004), and on rice varieties in Gambia (Nuijten & Almekinders, 2008). In a previous study, Wendmu et al. (2022) indicated that the Tigrayan in the ethnically mixed population district Tahtay Adiyabo use the same variety names as the Kunama in the same district, while the Tigrayan in Asgede Tsimbila also grow many of the same varieties, but in several cases use different names for the same varieties. The consistency in local naming between the Kunama and Tigrayan in Tahtay Adiyabo district is an indication of cultural influence and proximity between the ethnolinguistic groups and an indication of possible seed and knowledge exchange. In line with our study findings, Nuijten and Almekinders (2008) indicated that the uniformity of rice cultivars in Gambia reflected the intensity of seed exchange and frequent seed exchanges of the same variety between the two study villages. Conversely, Labeyrie et al. (2014b), reported that differences in the sorghum landraces nomenclature among the Mbeere, Chuka, and Tharaka groups was an indicator of cultural variations and limited dissemination of knowledge between the groups.

### Culture and Crop Development

Studies of adoption of improved sorghum varieties from Ethiopia generally indicate a low adoption rate of new varieties (Kosmowski et al., 2020). McGuire (2005) reported that only about 3% of farmers in Ethiopia had adopted improved sorghum varieties. A recent study on the adoption of varieties based on CGIAR-derived germplasm estimated that only 1.1% of sorghum growing households grew these varieties (Kosmowski et al., 2020). Our findings contribute to a growing literature on the importance of understanding cultural preferences to understand adoption and use of local as well as improved varieties (Leclerc & Coppens D'Eeckenbrugge, 2012; Makate et al., 2022; van Etten et al., 2023). Understanding of cultural preferences is important at three levels of crop development: conservation of genetic resources, plant breeding, and seed system development. At the level of germplasm conservation, it is important that efforts to conserve genetic resources both in situ and ex situ not only set priorities based on agroecological adaptations, but also cultural traits and adaptations (Labeyrie et al., 2014a, b, c). Our study shows that different ethnolinguistic groups farming under the same agroecological conditions have significant differences in varieties maintained and conserved. At the level of plant breeding, it is important that scientists involve farmers through participatory methods in the crop improvement process (Ceccarelli & Grando, 2007; Rattunde et al., 2021; Westengen & Winge, 2019). Finally, at the level of seed system development, cultural preferences play an important role in uptake of new varieties and data-driven approaches can help identify varietal and seed needs and preferences in heterogenous social, cultural, and agroecological farming contexts (Van Etten et al., 2023; Westengen et al., 2023). Furthermore, understanding cultural preferences is not only important for the technical functions mentioned here, but also for formulation of seed policy and law. In too many cases, the formal seed system overlooks the role of farmers' preferences and cultural factors across these levels of crop diversity management (Louafi et al., 2021).

## Conclusions

Sorghum is not only an important food crop but also plays a crucial role in the socio-cultural lives of farmers in Tigray. Our morphological analysis of the accessions collected indicates that the most used landraces among the Kunama belong to the Caudatum race while the most used sorghum varieties among the Tigrayans are Durras. This finding supports the historical hypotheses of Stemler et al. (1975b), 1977) about the associations between the Nilo-Saharan language family and Caudatum varieties and the Afro-Asiatic language family and Durras. However, present day Kunama and Tigrayan farmers are far from confined to cultivating sorghum of only one botanical race. Several Durra varieties are widespread and popular among the Kunama farmers in our study and several Caudatum varieties are popular among the Tigrayan. In addition, farmers from both communities cultivate a range of varieties also from other botanical groups. The genetic ancestry of the Caudatums currently grown by Kunama also reveal a more complex picture than that offered by the Nilo-Saharan-Caudatum association hypothesis alone. The Caudatums stem from two separate ancestral populations, one clustering with accessions with Nilo-Saharan language area origin and one clustering with accessions with origins in Afro-Asiatic language areas in Ethiopia. Similarly, the Durras cultivated by Tigrayans have a highly admixed ancestry. Present day variety and seed exchange among the two ethnolinguistic groups, especially in the community where both groups are represented and farm as neighbors, can explain this pattern. We also see that the folk taxonomy among the two groups converge in the mixed community. Thus, we conclude that a deep historical pattern of association between cultures and crops is overlaid by a pattern of variety exchange and genetic admixture. However, differences in traditional agroecological knowledge, variety use, and preferences, many of them with cultural roots, continue to maintain a broad diversity of sorghum. This research has important implications for conservation priorities, as well as for plant breeding and seed system development programs. In conservation efforts, cultural factors should be included alongside agronomic and agroecological factors when setting priorities for *ex situ* and in situ conservation programs. In plant breeding and seed system development efforts, understanding and including culturally driven preferences and needs is important for the uptake and adoption of new varieties. It is not sufficient if a new variety is "climate smart" if it is not also "culture smart."

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**Author Contributions** TAW, OTW, and HDB conceptualized and designed and interpreted the results of the study. TAW carried out the fieldwork, processed, analyzed the ethnographic data, and drafted the manuscript. KHR, MRK and OTW conducted the genomic analysis. TSG and TAW conducted the morphological analysis. The first draft of the manuscript was written by TAW. OTW, HDB, and FFA reviewed, commented, and edited on previous versions of the manuscript. All authors read and approved the final manuscript with TAW as lead author.

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**Data Availability** Data that support the findings of this study are available from the corresponding author upon reasonable request.

## Declarations

**Ethics Approval and Consent to Participate** A research permit was obtained from Mekelle University Vice president for research and community services (**Reference Number: VPRCS/3144/2019).** All participants were informed about the study objective and their prior informed consent was secured before undertaking the study.

**Competing interests** The authors declare no competing interests.



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