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Research Article

Reduction of genetic integrity of Tef [*Eragrostis tef* ((Zuccagni) Trotter)] landraces and its root causes in East Gojjam Zone, Northwest Ethiopia

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Abstract: *Tef is one of the most multi-purpose cereal crops, grown by Ethiopian farmers for food and nutritional security and income generation. The study aimed to assess the reduction of genetic integrity for tef landraces and associated factors in East Gojjam Zone. The data were collected by a semi-structured questionnaire with a purposive selection of 267 farmers based on their age and farming experience. Out of 267 farmers 78% of them were more than 45 years old. Of the 22 identified total tef landraces, only 32% and 27.1% of the landraces were exclusively grown in Enemay and Shebel Berenta district, respectively. The rest 40.9% of them were cultivated in common in both districts. The estimated genetic erosion of tef landraces was found to be 65.5% in Enemay followed by that of Shebel Berenta 60%. Expanding and favoring the growing of improved tef varieties on much wider areas contributed to replacing the tef landraces. The major causes for shifting from landrace to the modern varieties were water lodging, susceptibility to diseases and pests, low productivity, market access and climate change. Only 8 landraces were under cultivation and the remaining 14 were eroded from the district(s) constituting the highest (63.64%) combined genetic erosion, suggesting loss of important agronomic traits and, thus, a major bottleneck for further improvement and conservation plans. Thus, attention should be given to tef conservation by the government and other concerned bodies in providing strategies that enable farmers to cultivate both landraces and improved varieties side by side.*

Keywords: *Enemay*, Genetic erosion, Shebel Berenta, Tef landraces, Tef varieties
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1. Introduction

Crop genetic erosion is the loss of crop diversity in a given area over a given time, typically measured by the decline of species, variety and/or within-variety (genetic/genomic) variation (Brown and Hodgkin, 2015; Molla, 2020; Chala and Tahir, 2021). Several approaches such as DNA marker technics have been employed to estimate the degree of genetic erosion that a particular taxon faces in certain regions over a given time (Almanza-Pinzon *et al*., 2003; Tura and Zemede, 2018) or comparison between the number of species/landraces still in use by farmers at present time to those found in previous time (Hammer *et al*., 1996; Hammer and Teklu, 2005). Traditional varieties (landraces) are farmers' varieties that have been bred and selected by farmers and tend to contain high levels of genetic diversity and can adapt to changing environmental and ecological conditions. Modern varieties are the products of formal, institutional and scientific plant breeding, typically

having a high degree of genetic uniformity, and therefore cannot cope with changing conditions. Therefore, the loss of landraces is a threat to global food security (Negash and Hinrich, 2013).

The Ethiopian Federal Ministry of Agriculture has been encouraging farmers to grow high-yielding improved commercial varieties and other important crops to fulfil food security demands (Katungi *et al*., 2010). Dependency on few commercial varieties is, however, leading to loss of varietal diversity (Gouveia *et al*., 2011). Besides, low grain yield, moisture stress, weed and shoot fly infestation, lodging and seed shattering are the most important challenges to tef production (Mizan, 2016). Nowadays, tef is annually cultivated on 2,932,670.03 hectares of land with a mean yield of 1914 Kg ha^{-1}, used by over seven million farmers and more than 50 million people used as staple food (CSA, 2022). Compared to other cereals, tef has broad adaptation to the heavy, water-logging, clay soil areas of the Ethiopian highlands and tef in general is resilient to marginal areas (Tiguh *et al*., 2024; Hantalo and Tafesse, 2025).

Grain of tef, in our country, is mainly adopted for food after baking the ground flour into pancake-like soft and sour bread, "*injera*", which forms the major component of the most favorite national dish. It is also consumed in the form of porridge, and somewhat fermented or unfermented non-raised breads ("*kita*" and "*anebabero*"), native beer, "*talla*", and more alcoholic cottage liquor, "*katikalla*" or "*arakie*" (Assefa *et al*., 2015). Unlike other cereals, the seeds of tef can be easily stored under local storage conditions without losing viability since the grains are resistant to attack by storage pests (Ketema, 1997). Tef has remarkable genetic traits useful for most Ethiopian farmers to utilize for coping with erratic climatic conditions, generating household income, and fulfilling concerns of nutritional needs (Tiguh *et al*., 2024). Moreover, the conservation and utilization of tef genetic resources offer a reliable basis for enhancing food security and developing crop diversification in the moisture stress and challenging agro-ecological areas of the country (Assefa *et al*., 2015).

East Gojjam of Amhara Regional State is one of the potential agricultural areas in the country and is well known for its higher diversity and wider cultivation of the landraces (Agegnehu *et al*., 2020; Setotaw *et al*., 2020). However, in recent days, both diversity and cultivation have highly declined to the extent of a total loss of some previously important tef landraces from areas where they had been widely cultivated and most are pushed to marginal growing conditions. The decline tef landraces is attributed to several interrelated factors such as the widespread adoption of modern varieties, climate change, such as recurrent drought, and high demands of agricultural inputs and technology including a shift towards using mechanized farming that favoured crops like wheat that are largely produced in bulk for commercial and industrial purposes (Molla, 2020).

In addition, the lack of research activities targeting breeding improvement of tef and the absence of well-documented research findings on the extent of its genetic erosion have hampered tef conservation and improvement programs (FAO, 1999; Friis-Hansen, 1999; Gizaw *et al*., 2018). Therefore, the current research was commenced to determine and document the extent of genetic erosion and challenges in the production of tef landraces from East Gojjam of Ethiopia, based up on the indigenous knowledge and experience of farmers who have been growing tef for the last few decades. The evident light from the same office also indicated that tef farming has been practised much longer than other crops in the Enemay and Shebel Berenta districts of EGZ.

Furthermore, the districts of Enemay and Shebel Berenta had more elderly farmers who possessed the necessary indigenous knowledge for this study. Consequently, the present study targeted these two potential districts to assess the extent of genetic erosion and its associated factors for the reduction of tef production in the EGZ of Ethiopia. The findings would help as first-hand information for conservation and improvement programs of tef production and will also be useful for policy planners, researchers, and the farming community. Moreover, farmers' indigenous knowledge along with their cultural practices of keeping landraces of ancestral crop populations is also another equally important strategy for conserving crop species (Guarino, 1995; Chala

and Tahir, 2021). This is because landraces are more adapted to a broader range of climatic conditions and resist to both biotic and abiotic stresses than modern varieties (Akhalkatsi *et al*., 2012).

2. Materials and Methods

2.1. Description of the study area

The study was conducted during the year 2020/21 in Enemay and Shebel Berenta districts of East Gojjam Zone (EGZ), Amhara National Regional State of Ethiopia. According to CSA (2020), EGZ is a leading and most commonly known administrative zone in tef production. Upon the preliminary information gathered from the Agriculture Office of EGZ (AOEGZ), Tef is the primary cereal crop representing close to 23% of the overall food grain output and around 30% of the total cultivated land of food grains. The total production of tef in EGZ is estimated to be about 557,843.8 tons harvested from 268,691.3 hectares of land and with the average productivity of about 2.1 t/ha. Enemay and Shebel Berenta districts are the key potential areas for tef production in the zone (Alemayehu *et al*., 2016; AOEGZ, 2021; Setotaw *et al*., 2020).

Enemay district, having the capital of Bichena town, is located at 10^0 39' 59.99" N latitude and 38^0 00' 0.00" E longitudes (Figure 1) at about 264 kilometers (Km) northwest of Addis Ababa (Mekuriaw and Yeshitila, 2020). The district covers a total land area of 76,265 ha with widely varying altitudinal ranges of 1600 to 3200 meters above sea level (m.a.s.l) (Agricultural Office of Enemay District, AOED, 2021). Accordingly, 88% of the total land area lies in the midland, 7% in the highland, and 5% lowland. The area receives a mean annual rainfall of 1150 mm with a mean maximum temperature of 24 °C and a mean minimum temperature of 17 °C. Enemay district has 27 rural kebeles and 26,971 household heads (AOED, 2021).

Shebel Berenta district is located at 10^0 29' 59.99" N latitude and 38^0 09' 60.00" E longitudes, Figure 1. It is situated 283 Km to the northwest of Addis Ababa, Ethiopia. The district covers a total land area of 37,085 ha with widely varying altitudinal ranges of 1105 to 2459 m.a.s.l. Accordingly, 72.3% of the total land area lies in the lowland and 27.7% in the midland (Birhan *et al*., 2023). The area receives a mean annual rainfall of 780 mm with a mean maximum temperature of 24.6°C and a mean minimum temperature of 20.7 °C. (Agricultural Office of Shebel Berenta District, AOSbD, 2021).

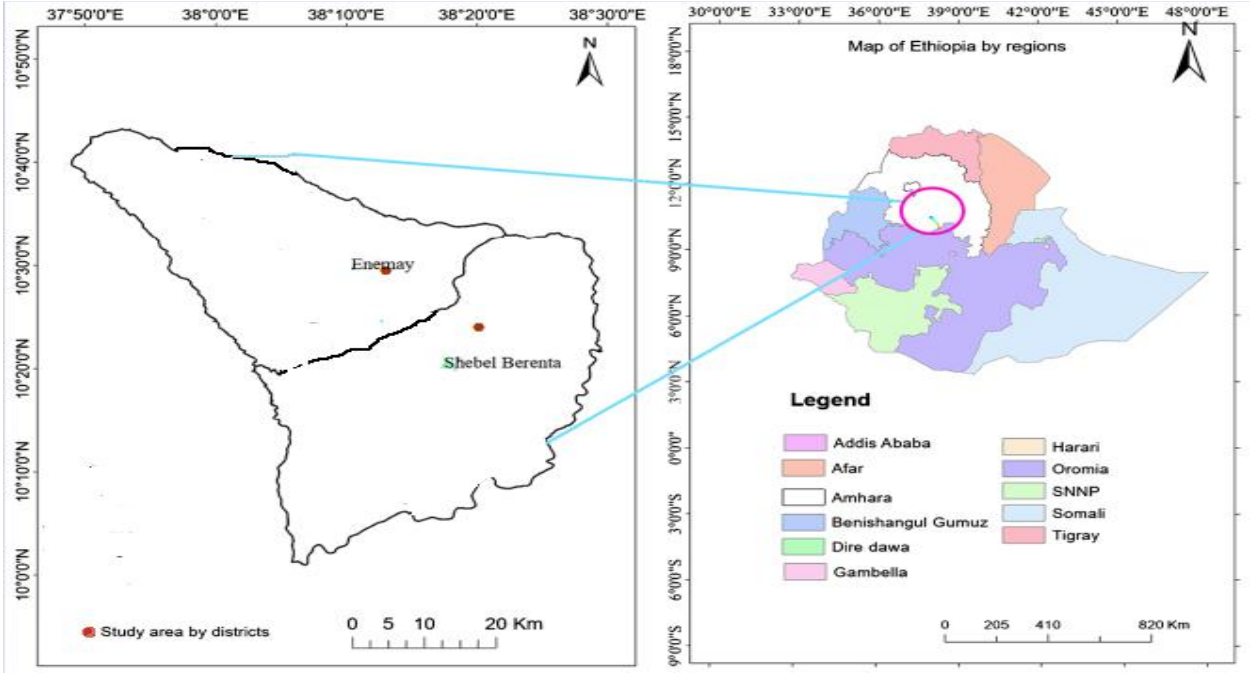

Figure 1: Map of study area, Enemay and Shebel Berenta districts
Source: modified from Alemayehu *et al*. (2022)

2.2. Research design and study population

A community-based cross-sectional research design was used, focusing on the selected farmers' districts. All cultivars in the hands of farmers over the last two to three decades were assessed in the study districts. The source populations were all tef- producing farmers who lived 41 and above years in Enemay and Shebel Berenta districts of East Gojjam Zone. Therefore, the study populations are tef cultivating farmers in the sampled kebeles (Table 1).

2.3. Sample size determination and sampling techniques

Purposive sampling technique was employed to select the study kebeles and the participants from the Enemay and Shebel Berenta districts of EGZ. Three kebeles from each district were chosen intentionally, Table 1, as they were seen as more suited and potential areas for tef production, and were characterized by the availability of a relatively high population of elderly and well-experienced tef cultivating model farmers who spent their lifetime in tef farming. Age index (41≤) was used to select experienced farmer participants to get reliable and convincing information about the genetic erosion that has been happening over the last twenty years, considering the involvement of women in East Gojjam Zone, Northwest Ethiopia.

Table 1: Tef-producing population of the selected kebeles and the corresponding sample size used in the study

Study districts	Study kebeles*	Number of HHs per kebele			Total sample farmers		
		Male	Female	Sum	Male	Female	sum
Enemay	Endeshignt	860	75	935	37	3	40
	Bichena Debr	504	90	594	21	4	25
	Hagere Hyiwet	1062	116	1178	45	5	50
	Subtotal	2426	281	2707	103	12	115
Shebel Berenta	Webo Were	1282	430	1712	54	18	72
	Werego	762	150	912	32	7	39
	Selel kula	787	185	972	33	8	41
	Subtotal	2831	765	3596	119	33	152
Grand total		5257	1046	6303	222	45	267

*Kebele is the smallest administrative unit

Based on the Dickson and Nyariki (2009) principle in agricultural socio-economic research, usually with a 95% confidence level and an error margin of less than 10% representative, the total number of households that participated in the study was 267 (Table 1). This was calculated using a standard formula following Freund and Williams (1983).

$$n = \frac{(Z)^2\ (p*q)}{(d)^2}, n = \frac{(1.96)^2\ (0.5*0.5)}{(0.06)^2} = 267 \qquad [1]$$

Where: n = sample size, z = 1.96 usually chosen at 95% confidence level, p = estimated level/coverage to be investigated, usually p = 0.5 is chosen q = 1-p, d = precision desired, which need to be less than 10% and then for this research d = 6%.

2.4. Data collection

A preliminary informal survey and discussion with the zonal and district agricultural bureau experts was conducted before the main data collection. This was to identify the appropriate districts, kebeles and participant farmers who have predominantly been producing tef in the zone from the long history to the present. Required data were collected through a questionnaire, focus group discussions (FGD) and personal observations of the growing fields. Questionnaires were distributed to the 267 sampled households to be used to collect information from the respondents. The questionnaires were prepared in English and translated into Amharic, the local language. The purpose of the questionnaires was to ask respondents about their indigenous knowledge regarding the past and the current status of tef landraces, local names, management practices, conservation, challenges of tef production and utilization in the study areas. The recordings and registered books from the zonal and district agricultural offices containing the number and names of kebeles in a district, as well as the household population per kebele, were used as sources of secondary data for this study.

In order to supplement the information collected from individual farmers during the questionnaire and to reduce missing data, focal group discussions (FGD) were held with selected knowledgeable and elder tef growing farmers in each of the six targeted kebeles. Accordingly, eight participants per FGD and one FGD per kebele were employed. Besides this, during FGD, participants were asked to: explain why certain tef landraces were lost or unavailable on their farmland, provide a list of tef production challenges or constraints, and discuss the extent of tef production in comparison with other cereal crops and modern tef varieties.

Finally, after a thorough discussion, consolidated ideas were noted. Moreover, during field observation, a team of integrated experts from the Agricultural offices of Eastern Gojjam Zone, as well as those of Enemay, and Shebel Berenta districts, verified the tef landrace lists provided by the farmer participant farmers to differentiate them from the contemporary and released tef varieties.

2.5. Data analysis

Quantitative data of the socio-demographic characteristics of respondents were collected. Moreover, the data were checked for completeness and consistency during the data collection and then

cleaned, coded, and entered into a Statistical Package for Social Science (SPSS) Windows version 21 computer software for analysis.

The qualitative data, such as name of the landraces and their attributes, were scrutinized by categorizing them into different thematic areas and narrating each topic separately. The extent of genetic erosion of the landraces as a rate of change over time was analyzed following the procedure stated by Hammer *et al*., 1996 and Friis-Hansen, 1999) and indicated below

GE = 100% - GI

Where GE is genetic erosion and GI is genetic integrity, which is given as:

$$GI = \frac{N2}{N1} \times 100\%;$$

Where N1 is the number of landrace varieties collected in previous times and N2 is the number of presently collected landrace varieties.

In the present study, the number of all listed landraces once grown by the farmers was considered as N1 (over the last 30 years) and the number of present (2020/21) available landraces represents N2.

3. Results and Discussion

3.1. Socio-demographic characteristics of the respondents

The information produced to address the stated research objectives was solicited from respondents with diverse demographic characteristics. The demographic characteristics of the respondents are summarized and described below. The majority of the household heads were males. About 90% (103) and 78% (119) of the household respondents were males (Table 2). The rest 10% (12) and 22% (33) were females in Enemay and Shebel Berenta districts, respectively. However, The dominance of men's participation in agricultural practices in general and tef production in particular can mostly be due to significantly fewer female-headed households in most rural areas of the study kebeles compared to male-headed households. This finding is consistent with that of Molla (2020) from the North-West Amhara Region of Ethiopia, who conducted a study to identify and evaluate the causes of genetic erosions and the degree of threatened varieties of tef in which only 19 (5.7%) female-headed were involved out of the total 332 participants.

Nevertheless, it has been noted that in a few rural areas, particularly in Webo Were and Selel Kula kebeles of the Shebel Berenta district, women are occasionally prohibited by culture from engaging in agricultural activities, such as tef cultivation, but are permitted to devote more of their time to household duties like gathering firewood, fetching water, tending to their children, and cooking.

Concerning the information from the age category, most of the respondents [56% (64)] were between the age interval of 46 $\leq$ 50 years old followed by the age group above 50 years [29% (33)] while the respondents in the age group of 41 $\leq$ 45 had the least participation consisted of only about 16% (18) in Enemay district (Table 2). In the case of the Shebel Berenta district, most of the respondents, 55% (83), were between the ages of 46 to 50 years, followed by the age group above 50 years 24% (36), and while age group 41 to 45 were the least which consist of only about 22% (33).

In general, the majority of the respondents in both districts were found in the age interval of 46 $\leq$ 50 years. It is evident that respondents between the ages of 46 $\leq$ 50 were extensively engaged in agriculture and have accumulated significant indigenous knowledge regarding the landraces over the past three decades. This could be because elder farmers acquire traditional farming knowledge which grows extensively over time, and they spend more of their lifetime in tef farming when compared to the lower age groups. This could also be justified because indigenous farming knowledge could vary significantly even among farmers who are one year apart in age, as it increases over time. This finding is partially in agreement with that of (Chuma *et al*., 2022; Mellash *et al*., 2023).

However, respondents between the ages of 41 $\leq$ 45 were less involved might be because they had less indigenous knowledge and were less experienced about the tef landrace grown over the last 30 years, when compared to their elders. This might be related to the fact that indigenous knowledge depends on customs, traditions, beliefs, and insights gathered over time as well as historical experiences that

contributed to solving a given local problem, such as biodiversity conservation, resource management and uses (Senanayake, 2006; Mosissa *et al*., 2017; Degaga and Angasu, 2017). The old age category, (>50), was also less involved because they were very weak and could not participate in agricultural activities.

Concerning educational level, a larger proportion of respondents [54% (62)] and [86% (130)] had only read and write education in both study areas, while in Enemay, 46% (53) and Shebel Berenta, 14% (22) had primary school education. With regard to marital status, most of the respondents [90% (103)] and [78% (119)] were married in Enemay and Shebel Berenta, respectively whereas, 10% (12) in Enemay and 22% (33) in Shebel Berenta of the respondents were divorced. Accordingly, in this study, it was observed that farmers who were married and had established families had significantly higher levels of wealth in tef and other crop landrace diversity compared to those who were divorced. This can be due to marriage generating family labuor, and because women and children can assist and encourage the household to engage in more complex agricultural practices such as quality seed selection, crop rotation, intercropping, processing, crop production, and marketing.

Based on the findings from the FGD in this research, it was revealed that within a household, a wife can support and guide her farmer-husband by using her indigenous knowledge to preserve their crop resources, particularly through the preparation of traditional meals. This can play a vital role in the crop to be sustainably cultivated on their farmland, not to be exposed to genetic erosion. Marriage plays a significant role in enhancing the conservation and restoration of crop landrace diversities in contrast to the divorced lifestyle of farmers. Therefore, marriage exhibits an adverse relationship with the erosion/ loss of crop genetic diversity, thereby promoting the preservation of genetic integrity (GI) to ensure the stability of crop biodiversity. This was the same for the tef landrace conservation in the study area.

Another witness identified during the FGD in the present study was that divorced farmers were significantly less involved in agricultural activities, especially in tef cultivation, compared to their married counterparts. This finding is almost in line with the findings of Negash and Heinrich (2013) who studied on on-farm diversity and genetic erosion of tetraploid wheat landraces in Ambo and Dandi districts, West Shewa, Ethiopia and that of (Bayush, 1997) who identified the significance of biodiversity for sustaining agricultural production and role of women in the traditional sector from the Ethiopian experience.

Regarding the educational level of the respondents, despite the fact that a significant percentage of the participants (54% from Enemay and 86% from Shebel Berenta (Table 2) had received less than primary school education, it was observed that they have been actively participating in selection, preservation, and cultivation of tef landraces for a considerable period of time. This can also be a witness that the farmers possess concrete experience and a wealth of indigenous knowledge that informs their worthy agricultural practices. The rest respondents, 46% from Enemay and 14% from Shebel Berenta, had primary school education where, fortunately, there was no illiterate farmer participated in this study; which indicates that the existence of integrated/ traditional indigenous and scientific knowledge among the tef farmers of EGZ of Ethiopia. In this regard, different researchers from different countries, for example, Waithaka (2011) worked on maize from the Netherlands, Girma (2014) worked on barely from Ethiopia, Wang *et al*. (2015) from China and Ruzol *et al*. (2021) worked on rice from the Philippines asserted that the importance of integrating indigenous knowledge with scientific knowledge for the development of sustainable agriculture. This can also indicate that agricultural activities cannot be separated from indigenous knowledge, yet they can be significantly enhanced through the use of science and technology obtained through modern education.

Table 2: Demographic Characteristics of tef producing respondents in Enemay and Shebel Berenta districts

Study variable	Category	Enemay		Shebel Berenta	
		Frequency	Percentage	Frequency	Percentage
Sex	Male	103	90	119	78
	Female	12	10	33	22
	Total	115	100	152	100
Age	41≤45	18	16	33	22
	46≤50	64	56	83	55
	Above 50	33	29	36	24
	Total	115	100	152	100
Education level	Unable to read and write (illiterate)	0	0	0	0
	Only Read and write	62	54	130	86
	Primary school	53	46	22	14
	Total	115	100	152	100
Marital status	Married	103	90	119	78
	Divorced	12	10	33	22
	Total	115	100	152	100

3.2. Local name of tef landraces and their attributes

Ethiopia is the center of diversity and origin of tef (Vavilov, 1951; Assefa *et al*., 2015). Landraces are often better referred to as farmer varieties and are often excellent sources of genetic variation with desirable traits for breeding (Aremu, 2011; Molla, 2020). Furthermore, landraces have better adaptation and yield stability in marginal and stressed environments. Therefore, the present study explored historic and present-day tef landraces being grown by farmers in the study areas.

Farmers in all the study areas were asked to describe the names of tef landraces that have been cultivated over the last 3 decades and are still in production. Respondents in the study district identified different kinds of landraces which differ in their maturity (early, intermediate and late), seed colour (cream-white, white, white and red, red-brown and mixed all), grain yield, and resistance to lodging. Respondents indicated that, majority of the early maturing landraces are red-brown seeded with low grain yield, and highly susceptible to lodging. On the other hand, the majority of the late maturing landraces are cream-white and white seeded with high grain yield, high biomass yield and relatively lodging-tolerant (Table 3). In terms of market preference, the cream-white and white seed colour fetches high prices, while in terms of adaptation to harsh environments such as moisture stress and poor soil fertility, the red-brown seeded landraces are preferred. Previous studies have also identified tef landraces with their respective uses grown in other parts of Ethiopia (Anteneh and Mekbib, 2013; Anteneh *et al*., 2014; Mizan, 2016).

Table 3: Tef landraces with selected characteristics in Enemay and Shebel Berenta districts

S/No	Vernacular name	Seed color	Maturity	Yields and other related characters
1	*Amargna*	White	Late	-
2	*Absh lemne*	Cream-white	Intermediate	High yielder
3	*Adal*	White	Late	High yielder
4	*Afesa*	White	Late	Resistant to moisture stress
5	*Blto*	Red-brown	Early	-
6	*Daboo*	Red-brown	Intermediate	-
7	*Dursa*	White	Intermediate	-
8	*Fenql*	Red	Late	-
9	*Gorad /qomite*	White	Late	-
10	*Gra gomez*	Red-brown	Late	-
11	*Mekole*	Red-brown	Intermediate	-
12	*Murie*	Red and White	Intermediate	-
13	*Nech bunign*	White	Early	High yield in moisture stress
14	*Nech eblabsh*	White	Intermediate	Poor lodging resistance
15	*Qebetu*	White	Late	-
16	*Qey bunign*	Red-brown	Early	High yield in moisture stress
17	*Qey eblabsh*	Red-brown	Intermediate	Poor lodging resistance
18	*Qezez*	Cream-white	Intermediate	High yield
19	*Sergegna*	Mixed all	Late	-
20	*Sheye nech*	Cream-white	Late	High yield
21	*Wendie*	White	Late	-
22	*Zige*	Red and White	Late	-

(-) indicates no response

The respondents were asked to describe the tef landraces that were available over the last 3 decades and still grown in the study area. About 94.8% of the respondents revealed that Daboo had been grown highly in the area followed by Adal (92.2%) and Fenql (73.9%) whereas Qebetu (7.8%) and Afesa (4.3%) were less grown over the last 30 years. Daboo (80%) was also highly grown, followed by Adal (72.2%) and other landraces such as Qey bunign (44.3%), Nech bunign (43.5%), Fenql (5.2%), and Qebetu (5.2%) are grown currently (2020/21) in Enemay district (Table 4). But, Absh lemne, Afesa, Dursa, Gorad /qomite, Gra gomez, Mekole, Murie, Nech eblabsh, Qey eblabsh and Zige were lost currently from Enemay district and are not in production during the study year. This finding is in agreement with the findings of a team of researchers, Assefa *et al*. (2015), who clearly stated the rapid decline of genetic variability among the tef genotypes as farmers are quickly adopting improved cultivars and using them instead of landraces. On the other hand, of the 22 total explored tef landraces, seven (31.8%) of them, namely Feql, Gira Gomez, Murie, Qebetu, Nech embilabish, Qey embilabish and Zige, were identified as unique to Enemay district (Table 4) whereas six (27.27%) of them, such as Amargna, Bilto, Qezez, Sergegna, Sheye Nech and Wendie, were found only in Shebel Berenta district, (Table 5). However, the majority, nine (41%) of the discovered tef landraces have commonly been found in both study districts of EGZ. This finding is almost consistent with the findings of Molla (2020).

Most (98%) of the respondents replied that Absh lemne was highly cultivated followed by Daboo (81.6%), Nech bunign (80%), Adal (79.6%), Qezez (76.3%), Qey bunign (70.4%) and Dursa (51.3%) whereas; Gorad /qomite (38.8%), Afesa (33.6%), Wende (31.6%), Bilto (28.3%), Sheye nech (27.6%), Amargna (7.9%), Mekole (2.6%) and Sergegna (2.6%) were less cultivated over the last 30 years in Shebel Berenta district (Table 5). Currently, Absh lemne (92.8%) was also the leading tef landrace among others. However, Afesa (5.3%) is rarely in

production currently. In general, six (6) tef landraces such as Absh lemne, Nech bunign, Daboo, Qey bunign, Adal and Afesa were cultivated over the last 30 years and are still in production, but the remaining nine (9) of them were not cultivated in 2020/21 in Shebel Berenta district. Molla (2020) conducted a study on the challenges of farmers' varieties of tef production and on-farm conservation in the North-West Amhara Region of Ethiopia, 35 farmers' varieties of tef were in the situation of under threat.

Table 4: Proportion of tef landraces in Enemay and Shebel Berenta districts

S/No	Vernacular name	Over the last 30 years		During study time	
		Frequency (n =115)	Percentage	Frequency (n=115)	Percentage
1	*Absh lemne*	23	20.0	-	-
2	*Adal*	106	92.2	83	72.2
3	*Afesa*	5	4.3	-	-
4	*Daboo*	109	94.8	92	80.0
5	*Dursa*	5	4.3	-	-
6	*Fenql**	85	73.9	6	5.2
7	*Gorad /qomite*	42	36.5	-	-
8	*Gira Gomez**	15	13.0	-	-
9	*Mekole*	14	12.2	-	-
10	*Murie**	73	63.5	-	-
11	*Nech bunign*	70	60.9	50	43.5
12	*Qey bunign*	78	67.8	51	44.3
13	*Qebetu**	9	7.8	6	5.2
14	*Nech emblabsh**	56	48.7	-	-
15	*Qey emblabsh**	70	60.9	-	-
16	*Zige**	72	62.6	-	-

n indicates number of respondents; - indicates no response; *indicates tef landraces unique to Enemay district

Table 5: Proportion of tef landraces described by farmers in Shebel Berenta district

S/No	Tef landraces	Over the last 30 years		During study period (2020/21)	
		Frequency (n = 152)	Percentage	Frequency (n = 152)	Percentage
1	*Amargna**	12	7.9	-	-
2	*Absh lemne*	149	98.0	141	92.8
3	*Adal*	121	79.6	33	21.7
4	*Afesa*	51	33.6	8	5.3
5	*Bilto**	43	28.3	-	-
6	*Daboo*	124	81.6	52	34.2
7	*Dursa*	78	51.3	-	-
8	*Gorad /qomite*	59	38.8	-	-
9	*Mekole*	4	2.6	-	-
10	*Nech bunign*	122	80.3	86	56.6
11	*Qey bunign*	107	70.4	38	25.0
12	*Qezez**	116	76.3	-	-
13	*Sergegna**	4	2.6	-	-
14	*Sheye nech**	42	27.6	-	-
15	*Wendie**	48	31.6	-	-

n = number of respondents; - indicates no response. *indicates tef landraces unique to Shebel Berenta district

3.3. Extent of genetic erosion and genetic integrity of tef landraces in East Gojjam Zone

The findings of this study revealed that the genetic erosion of tef landraces was 62.5% and 60% was observed in the Enemay and Shebel Berenta districts, respectively, within the last 30 years (Table 6). Most of the landraces were replaced by improved tef varieties. In contrary, genetic integrity/genetic diversity of the landraces is less than genetically lost landraces. In the study conducted by Girma (2014) genetic erosion of 65% was observed on barley landraces in North Shewa Zone of Ethiopia, where the introduction of improved varieties along with the replacement of barley with other crops were the major reason. According to Brush (1999), genetic erosion may be defined as the global process under which landraces, previously adapted through thousands of years to different natural and manmade conditions are displaced by modern, mostly uniform and high-yielding varieties.

Farmers in both districts described that the continuous cultivation of some landraces might be due to their high grain yield trait, unique end-use quality and wide adaptation to changing environments. For example, almost all farmers in both districts explained that they prefer a tef landrace called Absh lemne because of its exclusively expensive at the market due to its end-use quality or cream-white color whereas Nech bunign, Daboo and Qey bunign were preferred for their short period maturity and resistance to harsh environments (drought, water stress or soil moisture, shattering, poor soil fertility, etc.). This result is similar to the findings of Molla (2020), who identified early maturing (<85 days) local tef cultivars such as "Gea-Lamie, Dabi, Shewa-Gimira, Beten and Bunign" are widely cultivated during the low moisture stress seasons in North-West Amhara region.

These findings are also in agreement with a previous study, which indicated that Daboo is a landrace grown under severely acidic soils of the Amhara National Regional state, showed relatively better performance over the improved varieties Ambo toke, Estuib, Quncho, Kora and local check (Misgana, 2018). Use of early- maturing varieties was a highly valued option during moisture- stress seasons (Mizan, 2016). The continuous cultivation of some landraces might be due to their unique end-use quality and wide adaptation to changing environments that is not obtained from other landraces or improved varieties.

Table 6: Status of genetic erosion and integrity of tef landrace in Enemay and Shebel Berenta districts

Study districts	Landraces over the last 3 decades	Landraces lost over the last 3 decades	Landraces lost in the last 3 decades	Landraces cultivated during the study year	Landraces available during the study	Estimated genetic integrity (%|)	Estimated genetic erosion (%)
Enemay	16	Abshlemne, Afesa, Dursa, Gorad/ qomite, Gragomez, Mekole, Murie, Nech eblabsh, Qey eblabsh and Zige	10	Daboo, Adal, Qey bunign, Nech bunign, Fenql and Qebetu	6	37.5	62.5
Shebel Berenta	15	Amargn, Bilto, Dursa, Gorad/ qomite, Makole, Qezez, Sergegna, Sheye nech and Wendie	9	Daboo, Adal, Qey bunign, Nech bunign, Abish lemine and Afesa	6	40	60
Combined (%)						36.363%	63.637%

3.4. Temporal trends of loss of tef landraces

Regarding the proportion of tef landrace losses over the last 3 decades in the study areas, the majority of the respondents, 72.3% reported having lost a maximum number of their tef landraces over the last 10 years in both study districts, while few landraces were lost in the past 20 to 30 (9.3%) years in both districts. Therefore, the trend of loss of tef landraces has been exhibiting increasingly over the last 30 years (Figure 2). The farmers reasoned out that the extreme loss of the landraces was observed particularly over the last 10 years, because improved varieties were released increasingly by the agricultural extension system and Ethiopian agricultural research institute giving wide options for farmers to depend on and prefer modern tef varieties over the landraces. In this regard, a remarkable increase use of improved tef varieties was observed year to year in both study districts over the last ten years. However, since 2004, the speed and use of new varieties has dramatically increased and constituted about 30% of grain traded (Addisu, 2016; Negash and Heinrich, 2013). According to the majority of the respondent farmers, improved tef varieties are preferred over the landrace due to the increased productivity and high quality grains. Almost all farmers in the study area believed that white colored-seed tef varieties are with high quality grains and hence more marketable.

3.5. Underlying causes of genetic erosion for tef landraces

The respondents in the present study had listed many natural and manmade factors that have contributed to the underlying causes of genetic erosion or losses of tef landraces in the study area. The major factors were the influence of the agricultural extension system favoring the use of modern improved varieties, lack of market and low grain quality, low productivity, climate change, straw yield and soil fertility as illustrated in Table 7. This finding is almost similar to that of Girma (2014), who confirmed the major causes for genetic erosion were the introduction of improved varieties, replacement of other crops, weather variability, and change in land use pattern and lack of policy support (76, 14, 14, 8, 13 and 90%, respectively). Negash and Heinrich (2013) also estimated the extent of genetic erosion as 75% and 62% in Ambo and Dandi district, respectively and identified the causes for the loss of landrace varieties were the expansion of improved bread wheat varieties, low soil fertility and poor yield of landraces, and a shorter rainy season.

Based on the information presented in Table 7 about 65.8% of the respondents replied that the influence of agricultural extensions system favoring the use of improved varieties. This was the most causes of genetic erosion of tef landraces followed by lack of market and low grain quality (38.7%), low productivity (53.8%), climate change (27.3%) and poor straw yield (20%) in Enemay district while soil fertility (12%) was considered as the least cause for the loss of tef landraces. This was the same information from most (51.1%) of the respondents from the Shebel Berenta districts, who asserted that the influence of modern improved varieties caused genetic erosion of the landraces at large.

Tura and Zemede (2018) stated that the agricultural extension system combined with the lack of a market was the major cause of landraces' loss linked with the escalating promotion of improved varieties. Farmers in the study area obtained the improved tef seed from the agricultural extension and sowing in their farmland by giving a sufficient amount of inorganic fertilizer (Assefa *et al*., 2014). The desire of farmers to secure food at the family level accepts this extension system and tries to show a strong affinity towards improved tef varieties rather than landraces. This finding is partially in line with the findings of (Tura and Zemede, 2018; Molla, 2020).

During the FGD of this study, farmer respondents described that farmers who adopt and cultivate improved tef varieties were considered as model farmers by the government system. All tef growing farmers in the study area were required to use seeds of the improved tef varieties. There was no option for farmers to use seeds of their tef landraces to cultivate tef on their farm lands. Likewise, few Agricultural Research Centers and seed provider organizations have been disseminating only seeds of improved tef varieties to the farmers in the area. Farmers have been highly praised and respected as diligent workers, after they receive such improved seeds and grow them on their farmland and then return the whole grain yield to the institute by a high price.

On the other hand, farmers who depend on and grow tef landraces are recognised as slow workers and backward farmers. This was the leading reason that agricultural extensions system influence to divert farmers towards the use of improved tef varieties. When compared to the traditional tef landraces, the improved verities give high grain yield, grain quality, market price and lodging resistance. FAO (2012) and Assefa *et al*. (2015) stated that the spread of improved crop varieties, commercial agriculture and the introduction of new varieties of crops has been the main cause of the loss of genetic diversity through affecting the local landraces.

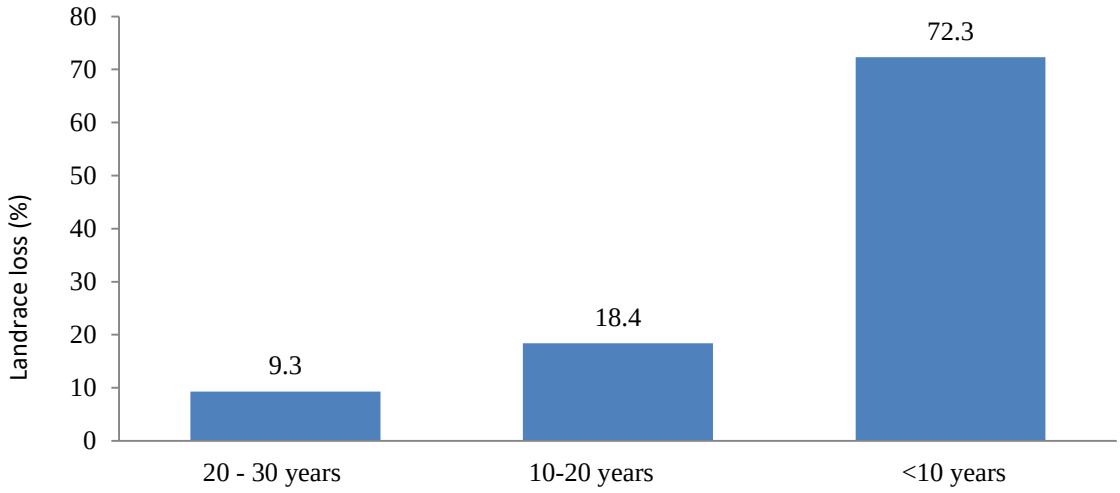

Figure 2: Trend of tef landraces lose over the last 3 decades in Enemay and Shebel Berenta districts

Table 7: Causes of genetic erosion of tef landraces in Enemay and Shebel Berenta districts of East Gojjam zone, North West Ethiopia

Causes of genetic erosion for tef landraces	Enemay district				Shebel Berenta district			
	Endeshignit n=40	Hagere Hiywet n=50	Bichena Debir n=25	Average (%)	Webo Were n=72	Selel Kula n=41	Werego n=39	Average %
Influence of agricultural extensions system favoring use of modern improved varieties	15(37.5)	38(76.0)	21(84.0)	65.8	41(56.9)	28(68.3)	11(28.2)	51.1
Low productivity	31(77.5)	16(32.0)	13(52.0)	53.8	12(16.7)	17(41.5)	19(48.7)	35.6
Poor straw yield	4(10.0)	19(38.0)	3(12.0)	20.0	21(29.2)	13(31.7)	13(33.3)	31.4
Lack of market and low grain quality	8(20.0)	14(28.0)	17(68.0)	38.7	27(37.5)	20(48.8)	13(33.3)	39.9
Poor soil fertility	0(0.0)	4(8.0)	7(28.0)	12.0	9 (12.5)	3(7.3)	5(12.8)	10.9
Climate change	12(30.0)	6(12.0)	10(40.0)	27.3	15(20.8)	11(26.8)	9(23.1)	23.6

Numbers in the brackets in each column under each study kebele in this table are representing percentage of respondents selected the cause of genetic erosion for tef landraces indicated in the corresponding rows. The percentage can add up to more than 100 since there are multiple answers per individual 'n' respondents in each kebele

There were four most common improved tef varieties in the study area, which were recalled by respondents and being cultivated in both study districts (Figure 3 and 4). These modern tef cultivars are Quncho (DZ-Cr-387), Etsuib (Dz-Cr-3186), Kora (Dz-Cr-438-RIL-133b) and Boset (DZ-Cr-409, RIL-50d). Almost all respondent farmers reported that tef landraces have been stopped to be cultivated in most of the cropping seasons in the study areas over the last two to three decades. In some Kebeles, only very few farmers are growing landraces intermittently on very small plot of land to reduce the dependency on improved tef varieties. This result is in line with the finding of Abebe and Workayehu (2015) who stated that the discussion on crop genetic erosion remained largely anecdotal and the presence of modern varieties in a farming system is a primary causes of diversity loss. Similar results were also been reported by Kiambi (1998), FAO (1999) and Mbabwine, 2004).

Moreover, respondent farmers also reported that much loss of traditional varieties (landraces) had been occurred due to the arrival of many improved varieties like Quncho (DZ-Cr-387), Kora (Dz-Cr-438-RIL-133b), Etsuib (Dz-Cr-3186), and Boset (DZ-Cr-409, RIL-50d). Due to the superior qualities of improved varieties (high yields, high seed quality and high prices) over the landraces, farmers increasingly replace the traditional varieties with modern varieties in many fields. The majority of the respondents mentioned that the landraces were replaced by high yielding improved varieties such as DZ-Cr-387 (Quncho) in the optimum environments and Etsuib (Dz-Cr-3186) in water lodged environments, which has significantly reduced the genetic diversity of the landraces in these study areas.

While 100% of the respondents in Endeshignit and Bichena Debir have grown the variety Quncho (DZ-Cr-387), about 95% of the farmers in Hagere Hiywet kebele have grown Quncho variety. Kora (Dz-Cr-438-RIL-133b) tef variety has been produced by 61%, 18% and 26% of the farmers in Endeshignit, Hagere Hiywet and Bichena Debir kebeles of Enemay district, respectively. The variety Etsuib (Dz-Cr-3186) was the second most commonly cultivated variety in Endeshignit (94%), Hagere Hiywet (92%) and Bichena Debir (84%) kebeles next to Quncho. The least cultivated tef variety observed in the study areas was Boset (DZ-Cr-409, RIL-50d) (Figure 3).

Similarly, all respondents from Webo Were, Selel Kula and Werego kebeles of Shebel Berenta district grew Quncho (DZ-Cr-387) (Figure 4). Kora (Dz-Cr-438-RIL-133b) variety followed by Etsuib and Boset were also grown in Webo Were, Selel Kula and Werego kebeles. Generally, the results showed that all most all farmers in the study districts substituted tef landraces by the improved varieties long time ago and relied on the improved tef varieties.

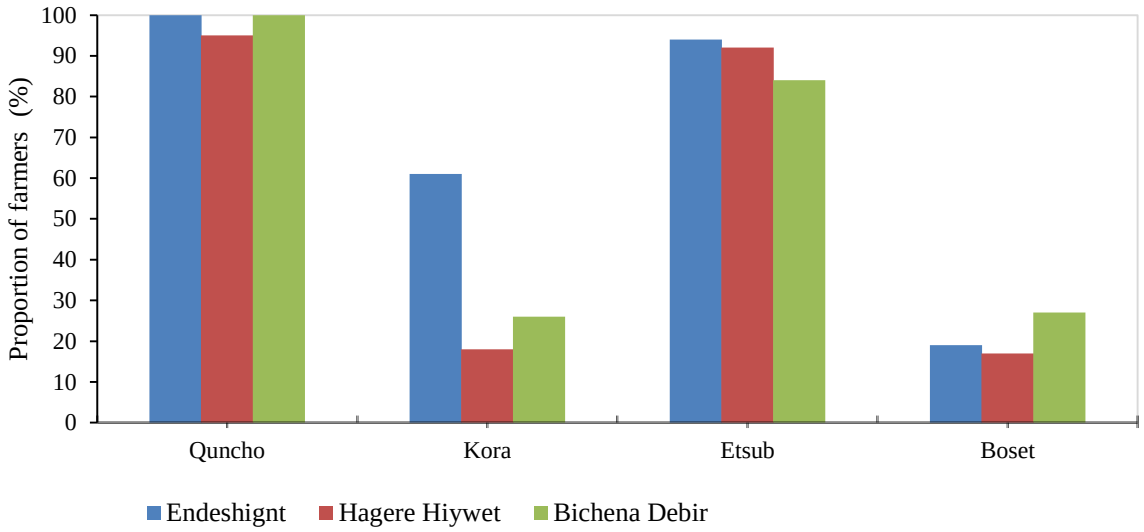

Figure 3: Proportion of farmers growing improved tef varieties in Endeshignit, Hagere Hiywet and Bichena Debir kebeles of Enemay district during the 2020/21 growing season

4. Conclusion

The present study found that, the Enemay and Shebel Berenta districts in the East Gojjam Zone (EGZ) are notable hotspots and hold huge potential for the conservation and breeding of tef landraces. About 22 distinct tef landraces with diverse characteristics were identified in these areas. On the other hand, genetic erosion led to the disappearance of numerous tef landraces, reducing genetic integrity in the last three decades,. From the present study, the estimated genetic erosion of tef landraces in EGZ has exceeded 60%. This calls for the due attention of every stakeholder to enhance genetic integrity for conservation programs. The improved tef varieties distributed by the government to farmers could offer high yielders, address existing issues related to increased grain production, and meet the growing food demand. This led farmers to relay on improved tef varieties, ignoring the landraces. However, in the absence of a sufficient range of landrace genetic resources, the future of genetic improvement programs may be at risk. Therefore, an urgent need to collect, document, conserve and utilize the tef landraces along with the improved ones, side by side.

Indigenous knowledge should be recognized as an important component of conserving local-varieties and should carefully be documented when necessary. Farmers in the study area never always stick to only improved or newly released tef varieties. Farmers should also be trained to grow both landraces and modern varieties side by side on their farm lands not to lose the tef landraces on their hands containing high potential of genetic diversity. The eroded tef landraces from the study areas might be available in other areas of the country. Therefore, farmers and relevant organizations like the Ethiopian Biodiversity Institute should make efforts to bring the tef landraces to these potential tef producing areas and increase them. The government should formulate policies that will protect tef landraces from further loss. There should be provision of training and awareness by the government for tef grower on the issue of genetic erosion and on how to conserve tef genetic resources.

Data availability statement

Data will be made available on request.

Conflicts of interest

The authors declared that there is no conflict of interest.

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