








Research Article

# Selection of Genotypes for Enhancing Tef Productivity Through Farmers' Participation in Potential Environments of Ethiopia

Tsion Fikre<sup>1,\*</sup> , Yazachew Genet<sup>1</sup> , Worku Kebede<sup>1</sup> , Kidist Tolossa<sup>1</sup> , Solomon Chanyalew<sup>1</sup> , Kebebew Assefa<sup>1</sup> , Atinkut Fentahun<sup>2</sup> , Nigus Belay<sup>3</sup>, Chekole Nigus<sup>4</sup>

<sup>1</sup>Tef National Research Program, Debre Zeit Agricultural Research Center, Debre Zeit, Ethiopia

<sup>2</sup>Adet Agricultural Research Center, Bahir Dar, Ethiopia

<sup>3</sup>Tef Research Program, Holetta Agricultural Research Center, Holetta, Ethiopia

<sup>4</sup>Axum Research Center, Axum, Ethiopia

## Abstract

Tef, *Eragrostis tef* (Zucc.) Trotter is the main crop grown in Ethiopia. However, its productivity remains low compared to its potential yield. A multi-location trial was conducted to evaluate selected best-performing lines from previous trials in terms of stability and yield coupled with farmers' opinions and preferences, aiming to identify superior lines. A total of twenty tef genotypes, including a standard and a local check were field evaluated using RCBD with four replications. The lines were grown in 4 m<sup>2</sup> plots across eight different locations in Ethiopia during the 2018/19 and 2019/20 cropping seasons. Additionally, an on-farm participatory variety evaluation involving 198 participants, comprising farmers and agricultural experts, was conducted during the 2019 cropping season. Phenological and agromorphological traits were collected and subjected to statistical analysis to identify the best genotypes. The pooled analysis of variance revealed significant variation (at the 0.01% level) among genotypes, locations, and years for all traits except grain yield and days to maturity. While some genotypes produced comparable grain yields, none surpassed the standard check variety Negus. Additionally, Participatory variety selection was conducted during the crop maturity stage using the direct-matrix ranking method. Farmers sets their own selection criteria, these are crop stand, tillering capacity, panicle weight, lodging tolerance, culm strength, and pest infestation or infection. Based on their evaluation, the genotypes DZ-01-974 X GA-10-3 RIL 51, DZ-01-974 X GA-10-3 RIL 47 and DZ-01-974 X GA-10-3 RIL 68 were identified as farmers preferred varieties from direct matrix ranking evaluations and chosen for their performance in the field. Thus, this study highlights the feasibility of participatory variety selection in gaining insights into farmer's perceptions, preferences, strengths and weaknesses of tef genotypes.

## Keywords

Farmers, Genotype, Direct Matrix Ranking, Potential-Environment, PVS, Tef

\*Corresponding author: tsifikre21@gmail.com (Tsion Fikre)

Received: 12 July 2024; Accepted: 10 August 2024; Published: 27 August 2024



Copyright: © The Author(s), 2024. Published by Science Publishing Group. This is an **Open Access** article, distributed under the terms of the Creative Commons Attribution 4.0 License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution and reproduction in any medium, provided the original work is properly cited.

## 1. Introduction

Tef (*Eragrostis tef*) is the dominant crop grown in Ethiopia, contributing to more than 90% of global tef production [2]. More than 6.5 million households engage in tef cultivation [2]. The area under tef cultivation is increasing from time to time. The sustained use of cultivation is emphasized by the merits it has regarding both in farming and utilization [5]. Tef cultivation spans varied agro-ecological zones, even in areas less suitable for other crops. It can grow from sea level up to 3000 meters above sea level and performs well between 1700 and 2400 meters. Tef tolerates drought and waterlogging better than most cereals and can grow in various soil types. The nutritional profile of tef grains is comparable to major world cereals and provide two-thirds of Ethiopians' daily dietary protein intake [8].

The average national yield of tef stands at approximately 1.9 tons per hectare [3]. However, farmers who adopt improved varieties and management practices can achieve yields ranging from 2.2 to 2.8 tons per hectare. Reports from recent extension packages indicate yields exceeding 2.8 tons per hectare. Despite lodging reducing yields by 17-25 percent, experimental plots have recorded tef yields of up to 3.4 tons per hectare. Under non-lodging conditions, studies suggest that yields can be further increased to 4.6 tons per hectare. The genetic potential yield reaches up to 6 tons per hectare [8]. Overall, the development of improved varieties by federal and regional agricultural research centers has significantly contributed to raising the national yield plateau from 0.9 tons per hectare to 1.9 tons per hectare. Since 1957, the Debre Zeit Agricultural Research Center (DZARC) has been a key player in advancing tef research as the coordinator of the National Tef Research Program in Ethiopia. Till 2023, 61 improved tef varieties have been released to the farming community. Among these, DZARC introduced 30 varieties, with 20 obtained through hybridization, resulting in a 9 percent yield advantage over germplasm-selected varieties [9].

Despite ongoing efforts, the full potential yield in tef has not yet been realized, and current yields remain low. Developing tef varieties is a time-consuming and energy-intensive task, taking approximately seven years or more. Hybridization, a critical step, involves manual surgical techniques and emasculation under a stereo microscope. To intensify cross-breeding efforts, increasing the number of crosses made is essential. The national tef breeding program primarily employs this technique to develop tef varieties with desired traits such as yield. Genotypes developed through hybridization undergo several breeding steps until they reach homozygosity. These genotypes are then evaluated in multi-location variety/yield trials before being considered for release. Despite successful breeding, tef varieties face challenges in adoption among farmers.

To gain insights into the underlying factors contributing to the limited adoption of new crop varieties, which can subsequently inform future breeding initiatives in Ethiopia, direct

engagement with end-users primarily farmers is essential. During the multi-location stage, farmers assess the performance of these lines within their own environments, applying their unique selection criteria. This collaborative approach facilitates active farmer participation in breeding programs [4], leading to improved access to diverse varieties, increased agricultural production, food security, and the accelerated dissemination and adoption of pre- and released varieties [6].

Consequently, this experiment was undertaken to assess the performance of previously selected lines across multiple locations, considering stability, yield, and farmers' preferences. The goal is to recommend superior genotypes for further evaluation in variety verification trials, ultimately leading to their release in high-potential tef-producing environments.

## 2. Materials and Methods

### 2.1. Experimental Materials

The experimental materials comprised of twenty tef genotypes, including eighteen recombinant inbred lines resulting from the cross between DZ-01-974 and GA-10-3. Additionally, a standard check variety (DZ-Cr-429, also known as Negus) and a local check were included.

### 2.2. Experimental Design and Management

The field experiment was conducted at eight locations (Debre Zeit, Holetta, Ginchi, Adadi-mariam, Adet, Bichena, Axum, and Minjar) during the 2018/19 and 2019/20 seasons. The trial was carried out using randomized complete block design with four replications. Each plot measured 2 m x 2 m (4 m<sup>2</sup>), with distances of 1 m and 1.5 m between plots and blocks, respectively. Seeds were manually planted within rows spaced 20 cm apart in each plot, following recommended agronomic practices for each location.

### 2.3. Data Collection

Data on days to heading (DTH), days to maturity (DTM), lodging index (LI), shoot biomass yield (BY), and grain yield (GY) were collected at the plot level. Additionally, measurements of plant height (PH) and panicle length (PL) were taken individually from five random samples of plants in the central row of each plot, and the mean values were used.

### 2.4. PVS Study

Participatory Variety Selection (PVS) studies were conducted at eight locations representing the high potential

growing areas (Gimbichu, Adea, Adadimariam, Ambo, Axum, Shambu, Jimma, and Worabe) during the main cropping season of 2019 on farmers' fields. Direct-matrix ranking study was used to assess the preferences of farmers for genotypes with respect to their own traits. Farmers' selection was done based on primarily on their tef growing experience and willingness to participate in the research. A total of 198 participants including farmers and agricultural experts of both sexes were involved in the study. They were allowed to set their own selection criteria and then participants prioritized and jointly agreed on six traits (crop stand, tillering capacity, panicle weight, lodging tolerance, culm strength, and pest infestation or infection) during crop maturity stage. A direct matrix table was prepared for the evaluated genotypes listed in the row and traits preferred by farmers listed in the column. Rank were given to each genotype based on the selection criteria. During direct matrix ranking, farmers have given rating of performance of a genotype for each trait of interest based on their level of importance on the basis of common agreement of evaluators. Scoring and ranking were done as indicated by de Boef and Thijssen [10].

## 2.5. Statistical Analysis

Analysis of variance was made for each of the locations to know the existence of genetic variability among experimental genotypes and to verify the homogeneity of the error variances. The combined analysis of variance over the locations and year and Least significant difference (LSD) at 0.05 probability level were performed using SAS software version 9.00 [7].

## 3. Results and Discussions

### 3.1. Performance Evaluation of Genotypes

The combined analysis of variance conducted across eight locations and years revealed statistically significant ( $P < 0.01$ ) genotype effects for all assessed traits, except days to maturity and grain yield (Table 1). Although grain yield was not significantly impacted by genotype, it is important to note that this does not necessarily mean that none of the test genotypes outperformed the standard check variety. Negus. Indeed, as grain yield has been the primary goal of the tef improvement program, the test genotypes DZ-01-974 X GA-10-3 RIL 16, DZ-01-974 X GA-10-3 RIL 26, DZ-01-974 X GA-10-3 RIL 34B, DZ-01-974 X GA-10-3 RIL 47, DZ-01-974 X GA-10-3 RIL 51, DZ-01-974 X GA-10-3 RIL 66, DZ-01-974 X GA-10-3 RIL 68 and DZ-01-974 X GA-10-3 RIL 69 in that diminishing order yielded numerically higher than the standard check variety Negus. However, none of the tested genotypes exhibited a 10% yield advantage over the checks. Notably, DZ-01-974 X GA-10-3 RIL16 demonstrated the maximum yield advantages of 4.2% and 12.3% over the standard and local checks, respectively. When considering late-maturing genotypes for variety verification trials, they should outperform Negus and the recently released variety "Ebba" by at least 10% in grain yield while maintaining comparable or superior seed quality in terms of color whiteness. Thus, no promising genotype meets these criteria for further testing in the variety verification trial.

**Table 1.** Means of phonologic, yield and yield related traits of twenty tef genotypes combined over eight environments over two years.

Genotypes	DTH (days)	DTM (days)	GFP (days)	PH (cm)	PL (cm)	LI	BY (kg ha <sup>-1</sup> )	GY (kg ha <sup>-1</sup> )
DZ-01-974 X GA-10-3 RIL 16	58	113	58	100	39	73	9345	2362
DZ-01-974 X GA-10-3 RIL 17	58	112	59	97	35	73	8254	2190
DZ-01-974 X GA-10-3 RIL 19	57	112	59	96	34	75	8584	2254
DZ-01-974 X GA-10-3 RIL 26	55	114	62	94	35	76	8825	2397
DZ-01-974 X GA-10-3 RIL 31	61	115	58	109	41	74	9935	2197
DZ-01-974 X GA-10-3 RIL 33	61	115	57	108	39	74	10308	2241
DZ-01-974 X GA-10-3 RIL 34A	62	115	57	109	40	74	9825	2238
DZ-01-974 X GA-10-3 RIL 34B	60	114	58	100	38	76	9156	2305
DZ-01-974 X GA-10-3 RIL 47	61	115	58	108	40	72	10156	2350
DZ-01-974 X GA-10-3 RIL 5	62	111	54	107	39	77	9253	2098
DZ-01-974 X GA-10-3 RIL 51	62	115	57	105	36	75	10348	2353
DZ-01-974 X GA-10-3 RIL 55	57	113	61	98	36	74	8391	2207

Genotypes	DTH (days)	DTM (days)	GFP (days)	PH (cm)	PL (cm)	LI	BY (kg ha <sup>-1</sup> )	GY (kg ha <sup>-1</sup> )
DZ-01-974 X GA-10-3 RIL 66	55	113	62	100	38	73	8984	2301
DZ-01-974 X GA-10-3 RIL 67	59	112	57	101	38	76	9131	2263
DZ-01-974 X GA-10-3 RIL 68	62	114	56	110	41	73	10577	2327
DZ-01-974 X GA-10-3 RIL 69	62	116	58	109	40	74	9969	2330
DZ-01-974 X GA-10-3 RIL 8	56	112	59	99	36	74	8991	2268
DZ-01-974 X GA-10-3 RIL 29A	59	112	57	101	36	78	8516	2149
Local check	56	112	59	96	35	83	8491	2134
Negus	55	112	61	96	35	75	8978	2300
Grand Mean	59	113	58	102	38	75	9301	2263
LSD (0.05)	1.3	3.7	1.8	2.9	1.2	4.2	929.8	226.4
CV	4.9	7.4	7	6.5	7.6	12.8	22.8	22.8
R <sup>2</sup>	0.9	0.8	0.9	0.8	0.8	0.5	0.6	0.3
MSG	**	NS	**	**	**	**	**	NS

CV-Coefficient of variation, R<sup>2</sup>- coefficient of determination, LSD- Least significance difference, and MSG-Mean square of Genotype. \*, \*\* Significant at  $p \leq 0.05$ , and  $p \leq 0.01$  probability level respectively and <sup>NS</sup> non-significant.

### 3.2. PVS

Farmers' selection criteria play a crucial role [1]. None of the evaluated genotypes was previously grown by farmers except the local check. Thus, the selection criteria farmers used in identifying the suitable genotype depend on the existing constraints and opportunities farmers faced in each location. The key selection criteria used by farmers were crop stand, tillering capacity, panicle weight, lodging tolerance, culm strength, and pest infestation or infection, and the genotypes were evaluated at the crop maturity stage (Table 2). The selected six traits are ones with high priority in the national program. Accordingly, direct matrix ranking was used to identify the prioritization order of the farmers' selection criteria. They gave the highest weight to crop stand ability, tillering capacity, and panicle weight. Moreover, lodging resistance and culm strength were also selected by farmers'

as moderate significance. This result aligns with previous PVS studies which indicate that beyond a certain minimum yield, the acceptability of a variety is influenced by factors beyond grain yield alone [11]. Notably, the test genotype DZ-01-974 X GA-10-3 RIL 68 exhibited high crop stand-ability, tillering capacity, and panicle weight. Additionally, DZ-01-974 X GA-10-3 RIL 51 demonstrated strong lodging resistance and culm strength, while DZ-01-974 X GA-10-3 RIL 69 showed good pest resistance. Although no single variety fully met all farmer needs, DZ-01-974 X GA-10-3 RIL 51 ranked first among tested genotypes due to its superior yield compared to the checks and congruence with research field results. The inclusion of near-finished genotypes could enhance farmer participation in variety selection within tef breeding programs. By involving farmers in PVS, breeders can develop locally adapted tef varieties that meet specific needs.

**Table 2.** Direct matrix ranking evaluation of tef genotypes for high potential areas by group of farmers' (on field) average at nine locations (n=198).

Genotypes	Crop stand ability	Tillering capacity	Panicle weight	Lodging tolerance	Culm strengthen	Pest free	Aver- age	Rank
Negus	20	9	19	3	18	20	15	17
DZ-01-974 X GA-10-3 RIL 16	8	11	10	14	8	14	11	11
DZ-01-974 X GA-10-3 RIL 17	16	7	20	4	17	16	13	13

Genotypes	Crop stand ability	Tillering capacity	Panicle weight	Lodging tolerance	Culm strengthen	Pest free	Average	Rank
DZ-01-974 X GA-10-3 RIL 19	6	8	5	8	9	6	7	5
DZ-01-974 X GA-10-3 RIL 26	14	6	14	20	13	15	14	16
DZ-01-974 X GA-10-3 RIL 31	15	20	17	15	7	17	15	17
DZ-01-974 X GA-10-3 RIL 33	10	14	2	13	11	3	9	7
DZ-01-974 X GA-10-3 RIL 5	5	5	9	12	3	13	8	6
DZ-01-974 X GA-10-3 RIL 8	17	19	15	2	14	12	13	13
DZ-01-974 X GA-10-3 RIL 29A	13	3	16	5	20	19	13	13
DZ-01-974 X GA-10-3 RIL 34A	4	7	6	7	4	4	5	2
DZ-01-974 X GA-10-3 RIL 34B	11	13	8	11	12	11	11	13
DZ-01-974 X GA-10-3 RIL 47	2	4	4	10	16	2	6	3
DZ-01-974 X GA-10-3 RIL 51	3	6	3	1	1	7	4	1
DZ-01-974 X GA-10-3 RIL 55	7	12	7	19	2	9	9	7
DZ-01-974 X GA-10-3 RIL 66	9	2	12	16	15	10	11	11
DZ-01-974 X GA-10-3 RIL 67	18	10	11	6	10	5	10	9
DZ-01-974 X GA-10-3 RIL 68	1	1	1	17	5	8	6	3
DZ-01-974 X GA-10-3 RIL 69	12	18	13	9	6	1	10	9
Local check	19	15	18	18	19	18	18	20

## 4. Conclusion and Recommendation

The genotypes did not exhibit significant superiority in grain yield and other related characteristics compared to the checks. Consequently, none of these genotypes will be promoted for further testing in the variety verification trial for release. The diverse variety selection criteria used by farmers reflect their multiple needs. However, no single variety fully meets all farmers' requests. Based on the evaluation, the genotypes DZ-01-974 X GA-10-3 RIL 51, DZ-01-974 X GA-10-3 RIL 47 and DZ-01-974 X GA-10-3 RIL 68 were identified as farmers preferred varieties and chosen for their performance in the field. Additionally, further research on PVS is essential to capture farmer's tef variety selection criteria.

## Abbreviations

DZARC	Debre Zeit Agricultural Research Center
PVS	Participatory Variety Selection
RCBD	Randomized complete Block Design

## Conflicts of Interest

The Authors declare no conflict of interest.

## References

- [1] Adugna Wakjira, Gemechu Keneni, Musa Jarso, and Bulcha Woyessa. Opportunities for participatory crop improvement and supporting informal seed supply in Oromia region, Ethiopia. In farmers, seed and varieties: Supporting informal seed supply in Ethiopia, ed. M. H. Thijssen, Zewdie, Bishaw, A., Bashir, and W. S. de Boef. Wageningen: Wageningen International, 2008.
- [2] Anadolu Agency. Ethiopia's 'super grain' seeks to capture global market, 2017.
- [3] Central Statistics Agency, Agricultural Sample Survey (CSA). Area and Production of Major Crops. (Private peasant holding-Meher Season), 2022, Statistical Bulletin, 593, Addis Ababa, Ethiopia.
- [4] Joshi A., Witcombe J. R. Farmer Participatory Approaches for Varietal Improvement, 1996, Cambridge Univ. Press 31: 461-477.
- [5] Kebebew Assefa, Solomon Chanyalew, and Zerihun Tadele. Tef, *Eragrostis tef*(Zucc.) Trotter, In: Millets and Sorghum, Biology and Genetic Improvement (J.V. Patil, ed.), 2017, John Wiley & Sons Ltd. UK, pp 226-266.

- [6] OJulong H., Letayo E., Sakwera L., Mgonja F., Sheunda P. and Kibuka J. Participatory Variety Selection for enhanced promotion and adoption of improved finger millet varieties: A case for Singida and Iramba Districts in Central Tanzania, 2017, International Africa J. Rural Dev. 2: 77-93.
- [7] SAS Institute. SAS/STAT Guide for Personal Computers, Version 9.00 editions, 2002, Cary, N. C., SAS Institute Inc.
- [8] Seyfu Ketema. Tef (*Eragrostis tef*): Breeding, Genetic Resources, Agronomy, Utilization and Role in Ethiopian Agriculture, 1993, Institute of Agricultural Research, Addis Ababa, Ethiopia.
- [9] Yifru Teklu and Hailu Tefera. Genetic improvement in grain yield potential and associated agronomic traits of tef (*Eragrostis tef*, 2005, *Euphytica*. 141: 247-254.
- [10] de Boef, W. S. and J. B. Ogliari. Participatory Crop Improvement and Supporting Informal Seed Supply. In: M. H., Thijssen, Zewdie Bishaw, Abdurahman Beshir and W. S. de Boef, 2008 (eds.). *Farmers, seeds and varieties: supporting informal seed supply in Ethiopia*, 2008, Wageningen, Wageningen International, pp: 177-185.
- [11] Kitch, L. W., Boukar, O., Endondo, C. and Murdock, L. L. Farmer acceptability criteria in breeding cowpea, 1998, *Experimental Agriculture* 34: 475-486.