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Teff (*Eragrostis tef* [Zucc.] Trotter) Variety Development for Moisture Deficit Areas in Northern Ethiopia

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ABSTRACT

Teff is the most widely cultivated food crop in Ethiopia, accounting for around one-third of the total acreage and one-fifth of the gross grain production of all cereals cultivated in the country. In Ethiopia, more than fifty-eight improved teff varieties have been developed and released by agricultural research institutes. Most of these varieties were released for high-potential areas of the country except the very few early maturing varieties that were specifically released for the low moisture stress areas. The objective of this experiment was to identify and release stable and high-yielding teff genotypes which are preferred by farmers and adapted to the moisture deficit areas of Northern Ethiopia. Twenty selected teff genotypes including standard and local checks were evaluated at Ataye and Sirinka in 2019 and 2020, whereas during 2019 at Simada and at Shewarobit in 2021 cropping season using randomized complete block design with three replications. Analysis of variance detected significant differences among genotypes for all observed traits both separated and combined analysis. The combined ANOVA for grain yield across environments revealed genotypes are significantly affected by environments, Genotype and their interaction accounted for 70.5 %, 9.5 %, and 13.3 % respectively. Among the genotypes tested, DZ-01-974 XGA-10-3 (RILL-16) was found predominant in terms of yield and stability at tested moisture-stress environments. This genotype was later released as DZ-CR-459(RIL-16) or Ataye by the National Variety Release Committee in 2023, with a yield advantage of 21.3% and 35.2% over the standard (Mena) and local check, respectively.

1. INTRODUCTION

Teff (Eragrostis tef [Zucc.] Trotter), is a tiny-seeded cereal with huge importance, has originated and diversified in Ethiopia (Vavilov, 1949). These crops are commonly known as orphan or underutilized crops due to the little scientific attention that they have received globally. On the other hand, in recent years, teff is receiving global attention among cash crops and has been attracting an export market due to attention for its nutritional and health-related benefits (Provost and Jobson, 2014), especially due to the absence of gluten, which makes it an alternative food for people with celiac disease (Fikadu et al., 2019). The low glycemic index (Wolter et al., 2013) and high iron content, as well as a high amount of lysine, a major limiting amino acid in cereals (Kavi Kishor et al., 2021), have resulted in teff being heralded as global 'super food'(Provost and Jobson, 2014).

Teff is the most widely cultivated food crop in Ethiopia, accounting for around one-third of the total acreage (29.3 %) and one-fifth of the gross grain production (19.3 %) of all cereals cultivated in the country (ESS, 2022). It takes up more than 2.9 million hectares (29.3 percent of the cereals crop area), which is higher than any of the other major cereals crops, such as maize (25.6%), sorghum (13.5%) and wheat (18.7%) (ESS, 2022). In Ethiopia, teff is annually cultivated by over 6 million smallholder farmers, and it is the staple food for about more than 50 million people (Assefa et al., 2017) but its productivity is very low as compared to other cereal crops.

The most important bottlenecks constraining the productivity and production of teff in Ethiopia are: i) low yield potential of farmers' varieties under widespread cultivation; ii) susceptibility to lodging particularly under growth and yield promoting conducive growing conditions; iii) biotic and abiotic stresses such as drought; iv) the culture and labor intensive nature of the teff husbandry; v) inadequate research investment to the improvement of the crop as it lacks global attention due to localized importance of the crop coupled with limited national attention; and vi) weak seed and extension system (Assefa et al., 2012). Among these yield limiting factors lack of cultivars tolerant to drought and lodging are the major factors (Assefa et al., 2011). The huge amount of yield reduction accounted by moisture stress during

vegetative and anthesis stage of teff reaches up to 40% (Mulu, 1993)and 77% (Takele, 2001)

In Ethiopia, in order to increase teff productivity, more than 58 improved varieties have been developed and released by national and regional agricultural research institutes (EAA, 2022) Most of these varieties were released for high-potential areas of the country except the very few early maturing varieties that were specifically released for the low moisture stress areas. Therefore the objective of the study was to identify and release stable and high-yielding teff genotypes which are preferred by farmers and adapted to the moisture deficit areas of Northern Ethiopia.

2. Materials and Methods
2.1 Experiemental sites

The field experiment was conducted on four locations of six environments at Sirinka and Ataye in 2019 and 2020 for two years, whereas during 2019 at Simada and at Shewrobit in 2021 main cropping season under rain-fed condition. These test locations are selected as they are representative for moisture deficit areas in the Amhara Regional State. The location year-combinations represents six environments. The description of the experimental locations is indicating on the table (table1).

2.2. Planting materials and experimental managements

A total of twenty teff genotypes including the standard and local cheeks, inbreed lines bred for moisture deficit areas, and accessions collected from Ethiopian institute of biodiversity (table 2) were evaluated using a randomized complete block design with three replications on a plot size of 4m² for each genotype ten rows of 2m length and 0.2m apart. Sowing was done by hand drilling on the surface of each of the ten rows at seeding rate 15kg ha⁻¹, 6 g plot⁻¹ on the plot area of 2m×2m with a net harvest area of 1.8m× 2m. The experimental plots were fertilized with Urea and NPS at the rate of 40 kg N and 60 kg P_2O_5 per hectare for light soil, and 60 kg N and 60 kg P_2O_5 per hectare for vertisols respectively. The whole NPS was applied at planting, while urea was applied two weeks after sowing and top-dressed at tillering stage. All other pre and post-planting management practices were done as per the recommendations for teff husbandry in all test locations.

Table1. Description of the experimental locations

Code	Name	Altitude (m.a.s.l.)	Geographical Location		Soil type	Weather data		
			Latitude	Longitude		Rain fall (mm)	Temperature (°C)	
							Maximum	Minimum
E1	Simada-2019	1950	$11^051'$ N	$38^001'$E	Nitosol	950	28	10
E2	Ataye-2019	1490	$10^029'$N	$39^091'$ E	Nitosol	1040	28.1	14.7
E3	Sirinka-2019	1850	$11^045'$ N	$39^036'$ E	Vertisol	876	32	21
E4	Ataye-2020	1490	$10^029'$N	$39^091'$ E	Nitosol	1040	28.1	14.7
E5	Sirinka-2020	1850	$11^045'$ N	$39^036'$ E	Vertisol	876	32	21
E6	Shewarobit-2021	1450	$10^00'$ N	$39^054'$E	Vertisol	1089	32	16

m.a.s.l. = meter above sea level, E=east, N=north.
Source: (Tariku et al., 2020)

Tabel 2. List of genotypes evaluated in the study

Genotype	Code	Source	Genotype	Code	Source
ACC#236766-2	G-1	EBI	DZ-Cr-387 X Alba(RILL-279)	G-11	DZARC
ACC#236331-2	G-2	EBI	DZ-Cr-387 X Alba(RILL-226)	G-12	DZARC
ACC#229228-1	G-3	EBI	DZ-01-974 XGA-10-3 (RILL-16)	G-13	DZARC
ACC#219852-2	G-4	EBI	DZ-01-974 XGA-10-3 (RILL-17)	G-14	DZARC
ACC#230774-3	G-5	EBI	DZ-01-974 XGA-10-3 (RILL-26)	G-15	DZARC
ACC#236364-3	G-6	EBI	DZ-01-974 XGA-10-3 (RILL-34)	G-16	DZARC
ACC#242138-3	G-7	EBI	DZ-01-974 XGA-10-3 (RILL-109)	G-17	DZARC
ACC#242138-4	G-8	EBI	DZ-01-974 XGA-10-3 (RILL-121)	G-18	DZARC
ACC#242139-1	G-9	EBI	Standard check Mena	G-19	SARC
ACC#550114-3	G-10	EBI	Local check	G-20	Each locations

Note: EBI= Ethiopian Biodiversity Institute; DZARC=Debre Zeit Agricalture Reserch Center; SARC=Sirinka Agricalture Research Center

2.4. Data collection

Data on grain yield and yield-related traits were recorded on a plant and plot basis. Date of heading was taken once each plot accomplished 50% of heading (panicle emergence) and days to maturity were taken when the plant 85% physiological maturity stage on plant basis, and days were determined begin from the date of planting. Data for plant height (cm), panicle length (cm) were recorded from five sample plants that were randomly taken from each plot and therefore the average of five sample plants were utilized for analysis.

2.5. Statistical analysis

The analysis of variance was analyzed by using the Generalized Linear Model (GLM) procedure in (SAS, 2013) software to compute genotype and environment main and interaction effects, yield, and yield-related traits. Mean separation and significance test was performed using Least Significant Difference (LSD) at 5 % probability level. R software version 4.3.2 (Olivoto and Lúcio, 2020) was used to visualize GEI patterns. GGE biplot methodology, which is composed of two concepts, the GGE biplot and GGE concept (Yan *et al.*, 2000) was used to visually analyze multi-environment data. This methodology uses a biplot to show the factors of genotype, environments, and their interaction that are important in genotype evaluation and the source of variation in GEI analysis of multi-environment data (Yan *et al.*, 2000).

$$Yij-\mu-\beta j=\lambda 1\varsigma i1\eta j1 + \lambda 2\varsigma i2\eta j2+ \varsigma ij$$

Where: Yij is the performance of the ith genotype in the jth environment; μ is the grand mean; βj is the main effect of the environment j; $\lambda 1$ and $\lambda 2$ are singular value for IPCA1 and IPCA2, respectively; $\varsigma i1$ and $\varsigma i2$ are Eigen vectors of genotype i IPCA1 and IPCA2, respectively; $\eta i1$ and $\eta i2$ are Eigen vectors of environment j for IPCA1 and IPCA2, respectively; ςij is the residual associated with genotype i and environment j.

Pair-wise correlation analysis among the traits was done using R software to see the relationship between traits that contribute to improved grain yield (Malik *et al.*, 2005).

3. Result and Discussion
3.1. Genotype performance variations

According to the results of the combined analysis of variance over environments (Table 3), grain yield was highly significantly (P<0.0001) affected by genotypes, environments, and their interaction, which accounted for about 9.5%, 70.5% and 13.3 of the total variance, respectively. This indicates the presence of wide variability among the genotypes as well as environments under which the experiment was conducted. In this case, the variation explained by the environment was about seven times higher than what was explained by genotype. The large sum of square and highly significant mean square of environment indicated that the environments were diverse, with the large differences among environmental means causing most of the variation in grain yield. The significant difference in the combined analysis of variance on the grain yield performance indicates that needs further stability analysis. This result was in agreement with the findings of (Ashamo and Belay, 2012; Fentahun *et al.*, 2022; Worede *et al.*, 2020), in teff multi-location trials. The significant difference among test locations might be due to variations in temperature, soil type, rainfall, and other environmental factors as also reported by (Kassa and Fufa, 2006).

Highly significant variations among the genotypes were observed in days to heading, days to maturity, grain filling period, plant height, and panicle length, shoot biomass yield, grain yield and harvest index across locations (Table 4). Similar significant results were reported for most traits in earlier studies (Fentahun *et al.*, 2022).

Table 3. Sum of squares, mean squares and percent of variance explained by different sources of variation from the analyses of variance of grain yield of 20 teff genotypes tested at six environments

Source of variation	DF	S.S	M.S	Explained variance (%)	Pr>F
Environment	5	238521729.0	47704345.8	70.5	<.0001
Blocks (Environments)	12	2974264.8	247855.4	0.88	.001
Genotype	19	32307232.3	1700380.6	9.51	<.0001
Genotype × Environment	95	45016440.4	473857.3	13.3	<.0001
Error	228	19681167.9	86320.9	5.81	
Total	359	338500834.5		100	
	Mean=2131.2		CV (%) =13.8		R^2=0.94

Note: CV= coefficient of variation, R^2= Coefficient of determination, DF= degree of freedom, SS= sum square, MS= mean square

Table 4. Mean performance of 20 teff genotypes for measured agronomic traits evaluated in the regional variety trial across 6 location-year environments

Code no.	Genotypes	Days to heading	Days to maturity	Grain filling period	Plant height (cm)	Panicle length (cm)	Shoot biomass (Kg/ha)	Grain yield (Kg/ha)	Harvest index
1	ACC#236766-2	46.9	97.2	50.2	107	40.2	8711.2	2016.1	23.6
2	ACC#236331-2	50.2	97.9	47.7	110	39.6	8423.1	1663.0	20.1
3	ACC#229228-1	50.7	97.1	46.4	106	38.5	8811.8	1505.0	17.2
4	ACC#219852-2	43.4	95.3	51.8	104	38.6	8728.9	2093.9	23.6
5	ACC#230774-3	47.7	95.3	47.6	108	39.4	10012.5	2355.2	23.9
6	ACC#236364-3	48.3	96.2	47.8	106	41.8	8620.2	1988.4	23.0
7	ACC#242138-3	48.7	97.1	48.3	109	42.7	8820.0	2141.3	24.2
8	ACC#242138-4	49.9	96.1	46.2	105	38.7	7872.5	1784.8	22.6
9	ACC#242139-1	47.6	96.5	48.9	103	39.8	8324.8	1883.7	22.7
10	ACC#550114-3	49.3	96.5	47.2	112	43.6	9075.0	2074.2	23.0
11	DZ-Cr-387 X Alba(RILL-279)	48.6	96.7	48.1	113	43.4	8460.7	2087.5	24.6
12	DZ-Cr-387 X Alba(RILL-226)	49.3	97.1	47.8	111	44.7	9601.2	2266.9	23.0
13	DZ-01-974 XGA-10-3 (RILL-16)	**47.5**	**92.7**	**45.2**	**113**	**45.2**	**9608.6**	**2682.9**	**27.5**
14	DZ-01-974 XGA-10-3 (RILL-17)	49.0	96.9	47.8	107	40.4	8447.0	1947.5	22.8
15	DZ-01-974 XGA-10-3 (RILL-26)	46.3	97.6	51.2	112	41.2	8275.8	2458.4	28.8
16	DZ-01-974 XGA-10-3 (RILL-34)	48.6	97.4	48.8	113	43.7	10088.3	2435.1	23.9
17	DZ-01-974 XGA-10-3 (RILL-109)	45.3	97.9	52.6	110	44.2	9295.4	2628.7	27.9
18	DZ-01-974 XGA-10-3 (RILL-121)	44.8	96.7	51.8	112	41.6	8659.7	2414.5	27.2
19	Mena	47.3	98.1	50.8	108	43.6	9500.2	2212.3	23.8
20	Local check	45.4	97.2	51.8	109	39.5	8845.9	1984.9	22.3
	Mean	47.8	96.7	48.9	108.9	41.5	8909.1	2131.2	23.8
	CV (%)	3.7	2.0	5.0	7.7	8.4	14.2	13.8	11.6
	LSD (5%)	1.15	1.3	1.5	5.5	2.3	830	193	1.81
	Genotype (G)	**	**	**	**	**	**	**	**
	Environment (E)	**	**	**	**	**	**	**	**
	G*E	**	**	**	**	**	**	**	**
	R^2	98.3	98.5	96.8	86.2	85.9	86.6	94.2	89.5

Note: **= highly significant, LSD= least significant difference, CV=coefficient of variation, R^2= Coefficient of determina tión, G*E= genotype by environment

Table 5. Mean grain yield (kg ha⁻¹) performance of teff genotypes evaluated in regional variety trial (for moisture deficit areas) across six environments

No.	Genotypes	E1	E2	E3	E4	E5	E6	Mean
1	ACC#236766-2	1549	2070	1533	3121	2797	1027	2016

2	ACC#236331-2	1288	1698	1421	2211	2244	1117	1663
3	ACC#229228-1	1050	1432	1088	1842	2642	977	1505
4	ACC#219852-2	1742	2001	1123	3333	3306	1060	2094
5	ACC#230774-3	1277	2227	1514	4395	2981	1738	2355
6	ACC#236364-3	1714	2254	1371	2260	3378	953	1988
7	ACC#242138-3	1546	2356	1637	3648	2552	1110	2141
8	ACC#242138-4	1225	2083	1037	2128	3192	1043	1785
9	ACC#242139-1	1283	1986	1683	2062	3351	937	1884
10	ACC#550114-3	1421	2352	1361	3323	2929	1060	2074
11	DZ-Cr-387 X Alba(RILL-279)	1360	2543	1773	2833	3002	1013	2088
12	DZ-Cr-387 X Alba(RILL-226)	1664	3077	1245	3422	3084	1110	2267
13	DZ-01-974 XGA-10-3 (RILL-16)	1832	2763	1971	4515	3266	1750	2683
14	DZ-01-974 XGA-10-3 (RILL-17)	1192	2050	1319	2793	3252	1080	1948
15	DZ-01-974 XGA-10-3 (RILL-26)	1695	2272	1615	4586	3104	1479	2458
16	DZ-01-974 XGA-10-3 (RILL-34)	1651	2791	1978	3761	3270	1160	2435
17	DZ-01-974 XGA-10-3 (RILL-109)	1667	2254	1960	4886	3299	1706	2629
18	DZ-01-974 XGA-10-3 (RILL-121)	1258	1898	1808	4753	3233	1539	2415
19	Mena	1606	2293	1843	3404	3052	1075	2212
20	Local check	1403	1920	1497	3399	2975	715	1985
	Mean	1471	2216	1539	3334	3045	1182	2131
	CV(%)	9.1	16.2	12.1	12.6	12.8	7.5	13.8
	LSD (5%)	221.3	594.1	308.3	695.4	642.6	146.5	192.9

Note: LSD= least significant difference, CV=coefficient of variation

According to Table 4, the newly released teff variety DZ-01-974 XGA-10-3 (RILL-16) reaches a plant height of 110 cm, a panicle length of 44 cm, a panicle emergence stage of 47 days, and a physiological maturity of 93 days after sowing in overall averaged environments. These desirable traits can be suggested for fast-track release and to be used as parental lines for future teff breeding programs. DZ-01-974 X GA-10-3 (RILL-16) is ranked 1st in average total panicle length among other genotypes across all environments. The relationship between plant height and panicle lengthindicates the possibility of increasing grain yield and biomass yield by improving either of the two traits (Table 4). The average grain yield of DZ-01-974 XGA-10-3 (RILL-16) was (2682.9 kg ha^{-1}) and shoot biomass yield (9608.6 kg ha^{-1}) (Table 4), which is the 1st in grain yield and 3rd in biomass yield recorded among tested genotypes across pooled environments. This genotype "DZ-01-974 XGA-10-3 (RILL-16)" scored a grain yield advantage of 21.3% and 35.2 % over the standard (Mena) and local check across environments, respectively. The genotype DZ-01-974 XGA-10-3 (RILL-16) ranked first in grain yield performance in half of the six environments (Simada and Sirinka in 2018 and Shewarobit in 2021) (Table 5). It performs very well in areas having an altitude 1450-1950 m above sea level (Table 6), thus being suitable for low rainfall and terminal low moisture stress areas of the country. Therefore, based on multi-location data, DZ-01-974 XGA-10-3 (RILL-16) has been selected for its high grain yield and moisture stress tolerance as well as other desirable traits. Consequently, the candidate line was then tested in a variety verification trial during the main cropping season of 2023, and the National Variety Release Committee approved for release in 2023. This study indicated the presence of substantial variations among teff genotypes for all measured traits. These results are in agreement with that of Jifar *et al*. (2011) who reported that highly significant genotype variation for days to panicle emergence and maturity, plant height, culm and panicle length, basal culm diameter, shoot biomass and grain yield, harvest index, lodging index, and thousand seed weight. Similarly, highly significant ($P<0.01$) genotype differences for days to panicle emergence, lodging percentage, thousands kernel weight, grain yield per plant and grain yield per hectare were also reported by Ayalneh *et al*. (2012). The tested genotypes expressed their grain

yield potential at Ataye and Sirinka in 2020, where the crop management was excellent and there was no unexpected rainfall, which reduces the grain shattering. However, unexpected rainfall at the maturity stage in 2019 resulted in significant grain yield shattering, leading to low grain yield in both locations.

3.2. GGE Biplot analysis

GGE biplot identifies GEI patterns of multi-location data and clearly shows which variety performs best in which location. In the present study, the first principal component axis (PC1) explained 76.55 % of total variation while the second principal component (PC2) explained 10.81%. Thus, the two axes together accounted for 87.36 % of the GGE variation of grain yield (Figure 1 &2).

3.3. Which genotypes (s) won where?

Yan and Kang (2003) indicated that the polygon view of a biplot is the best way to visualize the interaction patterns between genotypes and environments. Figure 1 represents a polygon view of teff genotype multi-environment data. In the polygon view, genotypes found to be extremely far from the origin are the vertex genotypes having the highest yield in their respective sectors (Farshadfar et al., 2011). The genotype code "13 (DZ-01-974 XGA-10-3 (RILL-16)," 12 (DZ-Cr-387 X Alba (RILL-226)", "17 (DZ-01-974 XGA-10-3 (RILL-109))", "18 (DZ-01-974 XGA-10-3 (RILL-121)", "6 (ACC#236364-3)" and "3 (ACC#229228-1)" were the corner or vertex genotypes (Figure 1). This infers that the genotype code "13 (DZ-01-974 XGA-10-3 (RILL-16))" best performed in grain yield at three environments. The environments of Ataye and Shewarobit fell in the sector in which genotype code "17 (DZ-01-974 XGA-10-3 (RILL-109))" was the vertex genotype. This means that the genotype code "17 (DZ-01-974 XGA-10-3 (RILL-109))" was the best genotype for those environments. Among the tested genotypes, the genotype code "13 (DZ-01-974 XGA-10-3 (RILL-16))" had the highest mean yield, followed by genotype code "17 (DZ-01-974 XGA-10-3 (RILL-109))" and "15 (DZ-01-974 XGA-10-3 (RILL-26))", whereas genotype code "2 (ACC#229228-1)" and "3 (ACC#236331-2)"

had the lowest mean yield. Similar findings were reported on teff using similar methodology (Fentahun et al., 2022; Tariku et al., 2018).

3.4. Comparison of genotypes relative to ideal genotype

A genotype which is found at the center of concentric circle is considered as an ideal genotype with its high mean yield and stable characteristics and genotypes close to an ideal genotype are considered as desirable genotypes. Accordingly, genotype code "13 (DZ-01-974 XGA-10-3 (RILL-16))" being near to the center of concentric circle and is considered as relatively an ideal genotype with high mean yield and stable characteristics, whereas genotype code "16 (DZ-01-974 XGA-10-3 (RILL-34))" and "15 (DZ-01-974 XGA-10-3 (RILL-26))" that were close to the ideal genotypes are considered as desirable genotypes based on their yield performance as well as stability. On the other hand, genotype code "3 (ACC#236331-2)", "2 (ACC#229228-1)" and "8 (ACC#242139-1)" are located farther from the ideal genotype (center of concentric circle) were undesirable genotypes (Figure2). Similar findings were reported on teff multi-location trial using similar methodology (Worede, 2021; Worede et al., 2020).
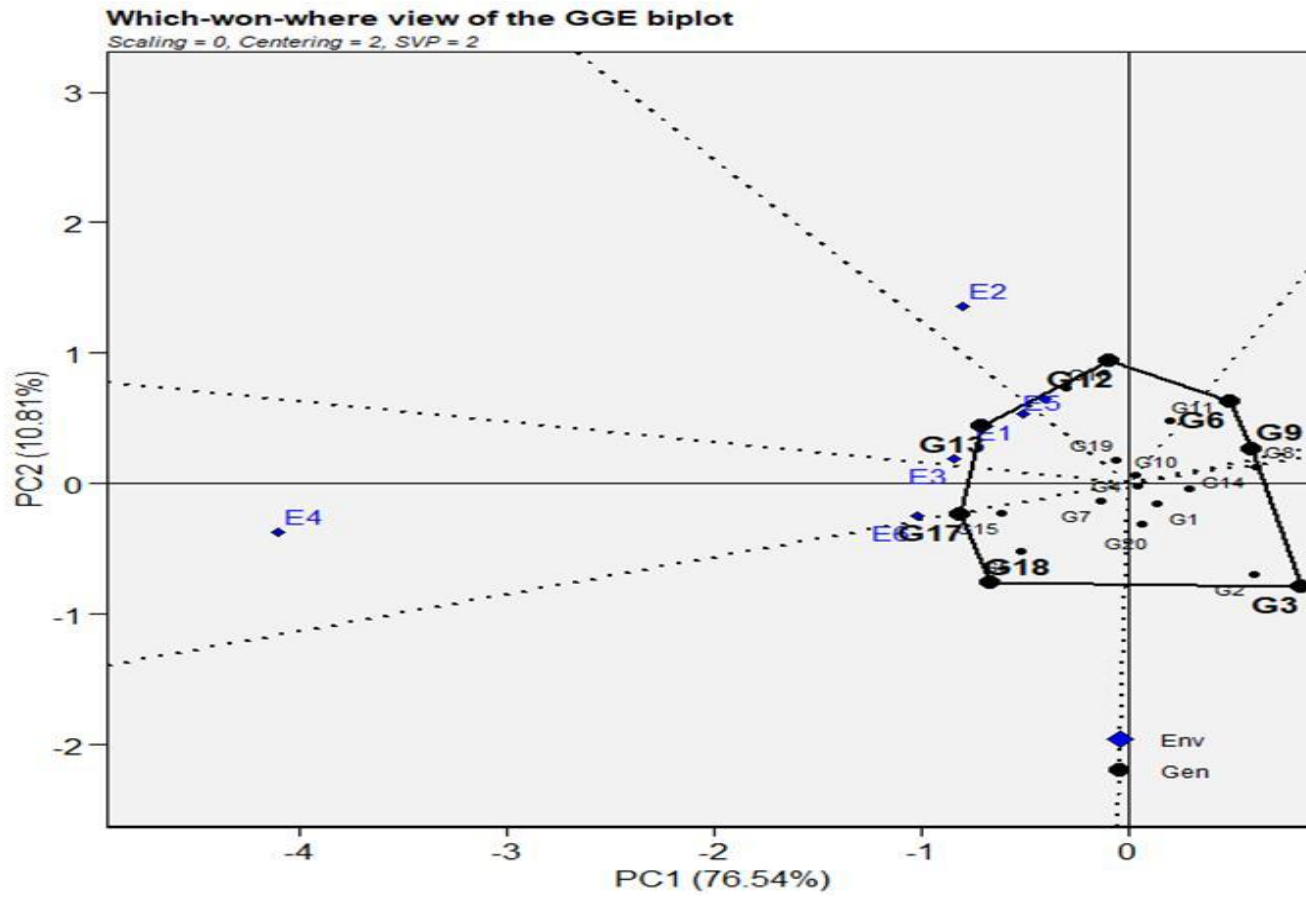
Figure 1. Which won where or which is best for what view based on genotype by environment interaction yield data of 20 genotypes evaluated in six environments. Environment and genotype code is indicated in Table 1 and 2
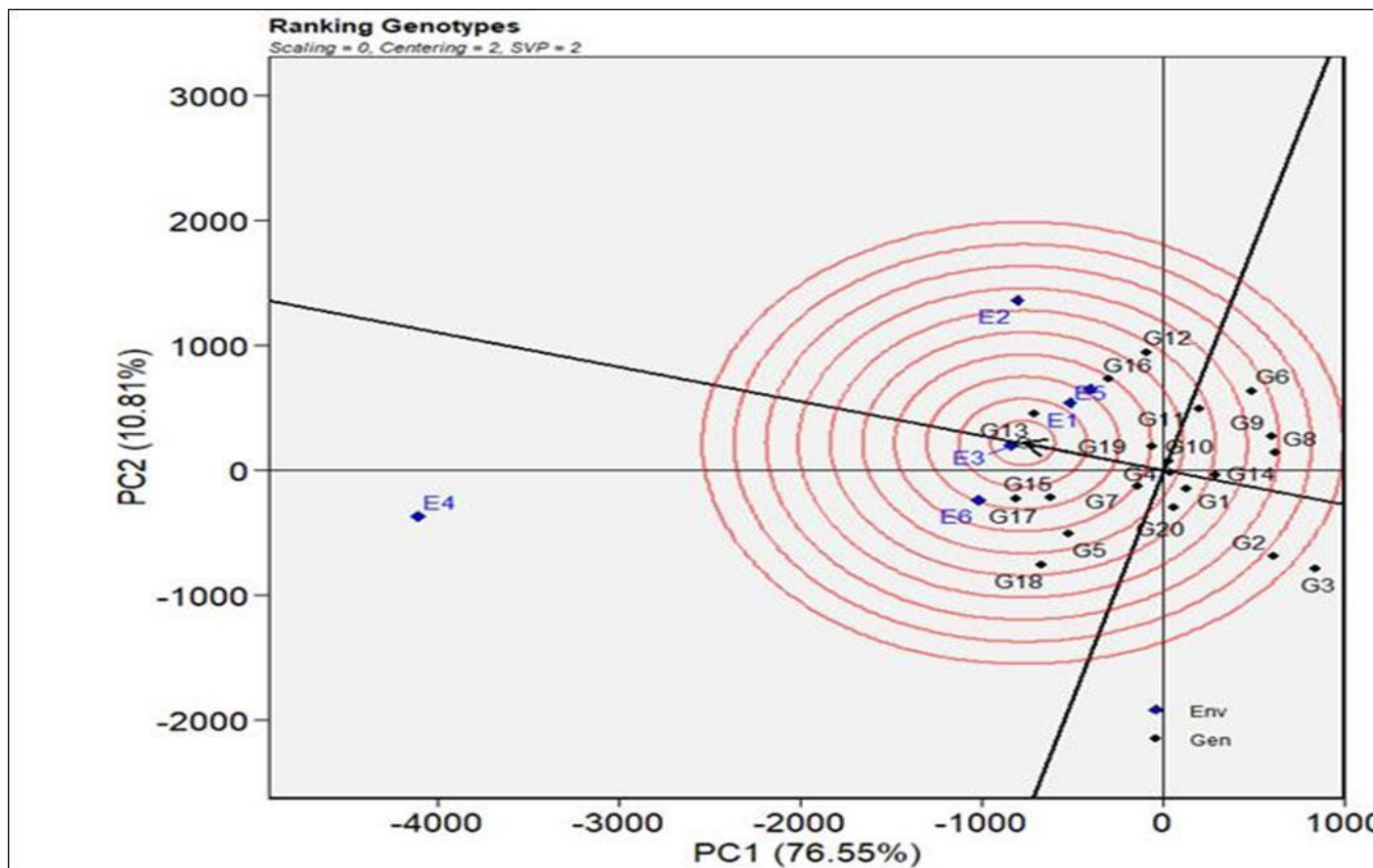
Figure 2. GGE-biplot based on genotype-focused scaling for comparison of the genotypes with the ideal genotype Environment and genotype code is indicated in Table 1 and

3.5. Association of grain yield with yield and yield-related traits

Yield is the result of the sum of agronomic and phonological traits resulting from the interaction of genetic and environmental factors (Tshikunde et al., 2019) Therefore, it is important to identify the association of genetic and phonological traits with yield. Studies of correlations among different traits enable the determination of the level and magnitude of the components that affect a character. In the present study, panicle length, harvest index, and dry shoot biomass showed a highly significant correlation with grain yield (Fig. 3). The result of this study is in line with the reports of (Asaye, 2017; Assefa et al., 2022). A strong correlation coefficient among grain yield, dry shoot biomass, and plant height had a direct contribution to grain yield and became

used to improve yield productivity. Likewise, Bekana et al. (2022) reported a high direct effect of above-ground dry shoot biomass on grain yield. However, days to heading and maturity have been negatively correlated with grain yield (Fig. 3). This may be due to an insufficient amount of moisture at the test locations at the time of heading and maturity. The test locations are moisture-deficient areas, and as a result, long-maturing genotypes will be affected by moisture stress. The huge amount of yield reduction accounted by moisture stress during vegetative and anthesis stages of teff reaches up to 40% (Mulu, 1993; Takele, 2001). Similarly, Asaye (2017) reported that days to heading and grain filling periods are negatively correlated with grain yield.
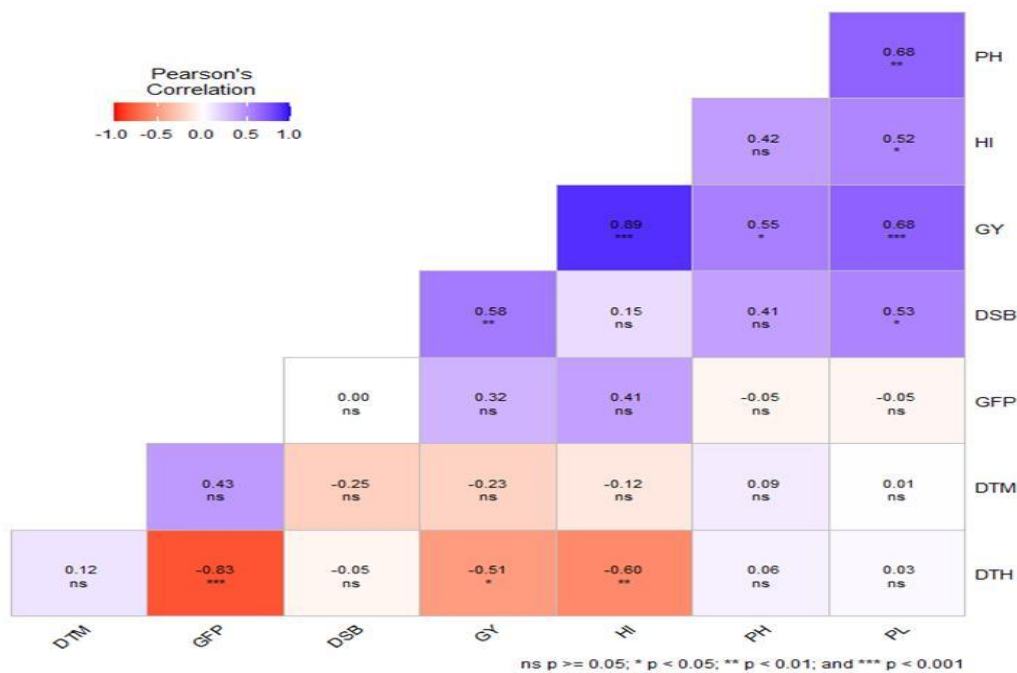

Figure 3. Correlation coefficient for yield and yield related traits
Note: DTM=days to maturity, GFP=grain filling period, DSB=dry shoot biomass, GY=grain yield, Hi=harvest index, PH= plant height and PL=panicle length

3.6. Description of the new teff variety DZ-01-974 XGA-10-3 (RILL-16)

An effective crossing was done in 2011 between varieties Dukem (DZ-01-974) and GA-10-3 (RILL-16) by the Debre Zeit Agricultural Research Center. Dukem (DZ-01-974) was used as a female parent for its high

yielding potential, and GA-10-3 (RILL-16), which derived from Tseday via TILLING, was used as a male parent for its dwarfliness, earliness, and white seed color. The cross was made to combine the earliness of Tseday and the high yield potential of Dukem into one elite variety. Consequently, intraspecific recombinant-inbred lines (RILs) have been developed, and multi-stage multi-location evaluations of the lines have been conducted.

The description of the new variety Dz-CR-459 (RIL-16) is indicated in Table 6.

Table 6. Summary description of the new teff variety DZ-CR-459(RIL-16)

Descriptor parameter	Description
Breeders name	DZ-CR-459(RIL-16)
Pedigree	DZ-01-974XGA-10-3 (RILL-16)
Vernacular name	Ataye
Days to heading	38-61
Days to maturity	83-96
Plant height (cm)	99-128
Panicle length (cm)	32-51
Lemma color	White
Seed color	White
Panicle form	Loose
Average grain yield	2683
O n station (Kg/ha)	2683
On farm (Kg/ha)	18-24
Straw yield (Kg/ha)	9600

4. CONCLUSIONS

The results of this study revealed that, genotypes had sufficient variability for identifying stable and high-yielding teff genotypes. Analysis of variance for combined over six environments showed significant differences among genotypes, environments, and genotypes × environments interaction (GEI) for grain yield, and the genotype DZ-01-974 XGA-10-3 (RILL-16), gave the highest average grain yield of 2683 kg ha^{-1} across all environments. The significant GEI effects indicated the inconsistent performance of genotypes across the tested environments except DZ-01-974 XGA-10-3 (RILL-16) which is relatively stable and best performance genotype at all tested environments, which had a grain yield advantage of 21.3% and 35.2 % over the standard (Mena) and local check across environments, respectively. This newly released genotype (DZ-CR-459(RIL-16)) with the vernacular name of "Ataye" can be used as parental material in the genetic improvements of teff.

5. ACKNOWLEDGEMENTS

6. CONFLICT OF INTEREST: There is no conflict of interest.

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