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Kulle: A New Brown Seeded Tef Variety Released to Address the Emerging Demands of Growers and Consumers

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Abstract

Kulle is a common name given after official release to a brown seeded tef variety with a pedigree DZ-Cr-387 X DZ-01-99 (RIL-106). Kulle means "beautiful" in Afan Oromo language to express its deep brown colour preferred by several consumers. It was developed and released by Debre Zeit Agricultural Research Center by crossing a very white seeded variety DZ-Cr-387 (Quncho) as a female parent with a brown seeded variety DZ-01-99 (Asgori) as a male (pollen) parent. A yield trial consisting of 18 genotypes and a standard check (Felagot) was conducted at Debre Zeit, Chefe Donsa, Ginchi, Holetta and Debre Markos in 2019 and 2020 cropping season. ANOVA and *AMMI analyses showed highly significant ($p< 0.001$) effect of the environments (E), genotypes (G) and genotype × environment interaction (GEI) on grain yield. Based on AMMI analysis, 53.7%, 10.8% and 35.6% of the total sum of squares were justified by environment, genotype and GEI, respectively. The GEI was further decomposed into principal component axes where the PCA_1 and PCA_2 explained 42.64% and 23.4% of the GEI sum of squares, respectively. DZ-Cr-387 X DZ-01-99 (RIL-106) gave a combined mean grain yield of 2339.5 kg/ha which significantly ($P<0.01$) out yielded Felagot by 13.8%. Besides, it also showed 23.7% biomass yield and 20.1% panicle length advantage over Felagot. Hence, DZ-Cr-387 X DZ-01-99 (RIL-106) was verified in 2021 and got release approval in 2022 for commercial production in the high potential tef growing environments of Ethiopia by a new name called DZ-Cr-542 (RIL 106) or Kulle.*

Keywords: Felagot, Brown seeded tef, Genotype, Genotype by environment interaction, Kulle

Introduction

Tef [*Eragrostis tef* (Zucc.) Trotter] is an indigenous cereal crop adapting to a wide range of agro-ecological and climatic conditions in Ethiopia. However, growing environments were reported to significantly affect the yield and quality of tef (Seyifu, 1993). The improvement of tef mainly depends on the level of variability existing in its germplasm resources and the efforts made by Ethiopian researchers.

So far, about 60 varieties adapting to the high potential areas, low moisture environments, highland water logging environments and irrigated environments were developed through hybridization and selection from landraces (EAA, 2022). Out of these, about 30 varieties were released by Debre Zeit Agricultural Research center while the remaining varieties were released by seven federal and regional research centers. In such varietal development and release efforts, over 50% of the varieties were developed and released through hybridization. The varieties developed through hybridization showed over 10 percent yield advantage compared to those developed and released through selection from landraces (Kebebew et al 2011). The utilization of these improved varieties and agronomic practices enabled to increase the national average productivity of tef by over two-folds from 0.9 t ha^{-1} to 1.92 ha^{-1} (ESS, 2022).

Tef provides enormous agronomic, nutritional, health and economic merits for both the growers and consumers in Ethiopia and elsewhere in the world. Farmers prefer it due to its adaptation to different agro-ecologies with reasonable resilience to both drought and water logging (Kebebew *et al.*, 2011). The other merits include its suitability to various cropping systems and crop rotation schemes; low-risk catch crop value at times of failures of other long-season crops due to drought or pests; and little vulnerability to epidemics of pests and diseases (Solomon *et al.*, 2019). Consumers prefer tef due to its grain dietary qualities, its gluten-free nature, excellent composition and pattern of essential amino acids and high contents of fiber, minerals, and vitamins (NRC, 1996). In addition to its grain, the straw of tef is also a very valuable one due to its high feed quality, crude protein content, fast growth habit, and suitability for multiple harvests (Davidson, 2018).

Despite the fact that tef area coverage and productivity are increasing, its productivity compared to other major cereal crops is still very low (1.91 t/ha) (ESS, 2022) due to various biotic and abiotic factors. One means of increasing the productivity of tef is through the development and release of improved varieties. Out of the already released varieties, the proportion of the brown seeded variety is below 10% due to its limited local market preferences. However, the global demand for the brown seeded variety is increasing from time to time due to its enormous nutritional and health benefits. Therefore, it is essential to continue with developing and releasing varieties suitable for various tef growing corridors of Ethiopia as well as demands of the various consumers. This in turn requires designing a specific release for specific growing conditions, cropping patterns and consumer demands. The varietal development and release procedure generally passes through several breeding steps, series of yield performance evaluation trials and variety verification. Hence, this study was designed to develop stable, high yielding; and farmers and consumers preferred brown tef varieties for the high rainfall and optimum moisture high potential tef growing areas of Ethiopia.

Material and Methods

Plant Materials

Ninteen genotypes including 18 recombinant inbred lines obtained from the cross between DZ-Cr-387 X DZ-01-99 and a standard check *Felagot* were evaluated in the national variety trial of late set, brown seed group (Table 1).

Table 1. Lists of brown seeded tef genotypes evaluated in NVT late set (2019 and 2020)

Genotype Code	PEDIGREE NAME
G_1	Felagot (standard check)
G_2	DZ-Cr-387 X DZ-01-99 (RIL No. 23)
G_3	DZ-Cr-387 X DZ-01-99 (RIL No. 34)
G_4	DZ-Cr-387 X DZ-01-99 (RIL No. 35)
G_5	DZ-Cr-387 X DZ-01-99 (RIL No.138)
G_6	DZ-Cr-387 X DZ-01-99 (RIL No. 49)
G_7	DZ-Cr-387 X DZ-01-99 (RIL No. 70)
G_8	DZ-Cr-387 X DZ-01-99 (RIL No. 76)
G_9	DZ-Cr-387 X DZ-01-99 (RIL No. 101)
G_{10}	DZ-Cr-387 X DZ-01-99 (RIL No. 104)
G_{11}	DZ-Cr-387 X DZ-01-99 (RIL No. 106)
G_{12}	DZ-Cr-387 X DZ-01-99 (RIL No. 117)
G_{13}	DZ-Cr-387 X DZ-01-99 (RIL No. 145)
G_{14}	DZ-Cr-387 X DZ-01-99 (RIL No. 169)
G_{15}	DZ-Cr-387 X DZ-01-99 (RIL No. 137)
G_{16}	DZ-Cr-387 X DZ-01-99 (RIL No. 210)
G_{17}	DZ-Cr-387 X DZ-01-99 (RIL No. 246)
G_{18}	DZ-Cr-387 X DZ-01-99 (RIL No. 306)
G_{19}	DZ-Cr-387 X DZ-01-99 (RIL No. 340)

Experimental environments, Design and Management

The field experiments were carried out during the main cropping season of 2019 at Debre Zeit, Chefe Donsa, Ginchi and Holetta and in 2020 at Holetta, Debre Markos, Debre Zeit, and Chefe Donsa. A completely randomized block design with four replications was employed on 2 m x 2 m plot at a spacing of 1 m and 1.5 m between plots and blocks, respectively. Seeds were drilled within the rows at spacing of 0.2 m in each plot. All field management practices were done following the research recommendation for Chefe Donsa, Holetta, Debre Markos, Ginchi and Debre Zeit.

Data Collection

Data on days to heading, days to maturity, lodging index, shoot biomass yield and grain yield were collected on plot basis. Plant height and panicle length were taken on individual plant basis by measuring five random sample plants from the central row of each plot. The mean values of those five plants were considered for analysis.

Data Analyses

Hartley's (1950) F-max homogeneity of variance test was deployed for individual environment for each trait. A combined analysis of variance was then done upon getting positive results from the tests of homogeneity of variances. Appropriate models for the experimental design were employed as suggested by Gomez and Gomez (1984) for the analysis of variance using SAS software version 9.00 (SAS Institute, 2002). A statistical model which combines features of factor analytic and analysis of variance techniques (Gollob,1968) was employed, adaptability and stability analyses were done using the AMMI (Guach, 2013) and GGE-biplot methods (Yan et al., 2000; Yan, 2001 and Yan and Tinker, 2006) after confirming significant genotype by environment interaction. GGE biplot analysis was performed using the genotype by environment analysis in R (GEA-R) software v4.0 (Pacheco *et al*., 2016) and the first two principal components (PC_1 and PC_2) were used to graphically represent the GEI, to identify the rank of studied genotypes and environments (Yan *et al.*, 2000).

Results and Discussion

Analysis of Variance

The mean square from the pooled analysis of variance over eight environments showed statistically significant ($P \leq 0.001$) genotype, environment and genotype by environment interaction effects for grain yield (Table 2). The significant mean squares due to environments and genotypes suggest that the locations were diverse and the tested genotypes were variable. Similarly, the existence of significant genotype x environment interactions for yield of tef shows that the highest yielding genotype may not necessarily be the highest yielding in the other environments and vice versa (Table 2). This is in line with the previous reports of Habte *et al*. (2019); Tiruneh *et al*. (2000 and 2001).

Table 2: Analysis of variance for grain yield across eight environments

Source of Variation	Degree of freedom	Sum of squares	Mean squares	F-value	Pr
Genotype	18	10750629.42	597257.19	4.93	<.0001
Environment	7	20120357.66	2874336.81	23.71	<.0001
Rep	3	5500680	1833560	15.13	0.0001
Environment*Genotype	126	28668799.22	227330.15	1.88	0.0001

AMMI analysis of variance for grain yield

The AMMI analysis for grain yield at eight environments is presented in Table 3. Thus, the result revealed a highly significant ($P \leq 0.01$) difference for grain yield ($t\ ha^{-1}$) of 19 tef genotypes, eight environments and their interaction. This is in line with the previous works (Tiruneh *et al*., 2000, 2001; Habte *et al*. 2019). The AMMI analysis partitioned the G x E variance into principal component (PC) axes where the first and second principal component axis which were significant explained 66.04% (PCA1=42.64% and PCA2=23.4%) of the total variation. Similar findings were also reported by Fisseha (2020) IPCA1 (40.66%) and IPCA2 (25.40%) and by Habte et al (2019) IPCA1 (53.04%) and IPCA2 (19.49%). Contrary to this findings, PC_1 value of 66.1% (Dagnachew, 2015), 93.1% (Crossa *et al*., 1990) were reported due to various reasons.

Table 3. ANOVA Table for AMMI model of grain yield (kg/ha)

Source	DF	SS	MS	F	PROBF
ENV	7	35496327	5070904	44.20731	0
GEN	18	7130426	396134.8	3.45344	0
ENV*GEN	126	23535695	186791.2	1.62842	0.00016
PC1	24	10036594	418191.4	4.02116	0
PC2	22	5507835	250356.1	2.40733	0.00041
Residuals	480	52306557	114707.4	NA	NA

Genotype Performance

The pooled mean performances over years and environments showed significant genotypic variation for all studied traits. In this study, a cross- over type of interaction were observed since the best genotype at one location become inferior at the other locations (Table 3). The overall mean grain yield across eight environments ranged from 1806.1 kg ha^{-1} at Debre Zeit in 2019 to 2556.7 kg ha^{-1} at Debre Zeit in 2020 followed by Ginchi in 2019 and Debre Markos in 2020. Based this study, therefore, Debre Zeit, Ginchi and Debre Markos were found to be the highest yielding environments, respectively (Table 4).

In this study, 13 genotypes were found to perform better than both the standard check (*Felagot*). Among others, DZ-Cr-387 X DZ-01-99 (RIL No. 169) followed by DZ-Cr-387 X DZ-01-99 (RIL No. 106) gave 15.5%, and 13.8% yield advantage over the standard check, respectively (Table 5). DZ-Cr-387 X DZ-01-99 (RIL No. 169) gave the highest grain yield at Ginchi and Holetta in 2019 and Debre Markos in 2020 while DZ-Cr-387 X DZ-01-99 (RIL No. 106) gave the highest grain yield at Debre Zeit in both 2019 and 2020 cropping seasons. Especially, DZ-Cr-387 X DZ-01-99 (RIL No. 106) which gave the second highest yield was the most stable and performed above the grand mean in about 70% of the test environments (Fig. 1 & 2; Table 3). The huge variability in the grain yield among the 19 tef genotypes at eight environments might be due to wide variability in climatic and soil conditions. Earlier works also reported similar inconsistencies in yield performance which usually found to complicate the selection and recommendation of stable genotype across environments (Fufa *et al*., 2000; Tiruneh *et al*. 2000, 2001; Habte *et al*., 2019).

Furthermore, DZ-Cr-387 X DZ-01-99 (RIL No. 106) also had significantly higher mean biomass yield and panicle length as well as lower value of lodging index. For instance, it had 23.7% shoot biomass yield advantage and 20.1% panicle length advantage over the standard check (Table 5). Besides, it also had better crop stand and culm strength compared to the standard check *Felagot*. In general, DZ-Cr-387 X DZ-01-99 (RIL No. 106) is stable and gave 13.8% grain yield advantage, relatively lodging tolerant, higher biomass yield and longer panicle over Felagot. Hence, due to its stable performance and several other merits, this genotype was verified in 2021 and got approval of release in 2022 for the high potential tef growing environments of Ethiopia.

Analysis of GGE biplot and stability

The GGE biplot analysis was visualized on the basis of results explained for the first two principal components (Yan et al., 2001). In this study, the first and second PCs contributed for 41.5% and 22.9% of the total variation, respectively (Fig. 1). In GGE biplot graph, various lines are emanating from the origin and appear perpendicular to the line connecting the vertex genotypes. These lines are very useful to divide the testing environments and genotypes into different sectors. The vertex genotypes located at the greatest distance from the origin are the most responsive and high yielding genotype in their respective sector. In the present study, G1, G14 and G15 are among the vertex genotypes in the different sectors. Based on the lines emanating from the origin, the test environments were grouped into three sectors while the test genotypes were grouped into four genotypic groups. Thus, the sector in which Holetta 1, Debre Zeit 1, Ginchi and Chefe 2 exist had two vertex genotypes (G14 followed by G11) as the highest yielding and winning genotypes. This sector had five suitable genotypes unlike the sector where Debre Markos and Chefe 1 exist that had no suitable genotype. The sector in which Holetta 2 and DZ 2 existed had two suitable genotypes (G13 and G17) while, all the remaining genotypes in this study were not found to be good for any of the environmental sector (Fig. 1).

Table 4. Mean grain yield performances of 19 tef genotypes evaluated over eight environments

No.	ENTRY	2019 cropping season				2020 cropping season			
		Chafe Donsa	Debre Zeit	Ginchi	Holeta	Chafe Donsa	Debre Zeit	Holetta	Debre Markos
1	Felagot	2123.1	1673.8	2342.4	1177.2	2378.1	2183.1	1680.5	2689.4
2	DZ-Cr-387 X DZ-01-99 (RIL No. 23)	1580.6	1718.8	2337.7	2050.0	2121.3	2553.1	2172.7	2067.5
3	DZ-Cr-387 X DZ-01-99 (RIL No. 34)	2127.5	1715.0	2529.8	2131.2	2476.3	2694.4	1929.5	2435.6
4	DZ-Cr-387 X DZ-01-99 (RIL No. 35)	1961.9	1857.5	2255.5	2152.0	2041.3	2353.1	1805.6	2147.5
5	DZ-Cr-387 X DZ-01-99 (RIL No.138)	2393.8	1721.3	2176.4	1788.5	2036.3	2297.5	1609.9	2426.9
6	DZ-Cr-387 X DZ-01-99 (RIL No. 49)	2046.9	1500.0	2158.4	1957.8	2067.5	2207.5	1626.8	2705.0
7	DZ-Cr-387 X DZ-01-99 (RIL No. 70)	2041.3	1837.5	2265.1	2503.1	2333.8	2422.5	2121.2	2355.0
8	DZ-Cr-387 X DZ-01-99 (RIL No. 76)	1766.3	1965.0	2630.0	1964.1	2334.4	2904.4	2236.5	2106.3
9	DZ-Cr-387 X DZ-01-99 (RIL No. 101)	1678.8	1572.5	2501.3	1986.2	2130.0	2670.6	1815.6	2377.5
10	DZ-Cr-387 X DZ-01-99 (RIL No. 104)	2042.5	1892.5	2247.9	2067.6	2043.1	2839.4	1986.4	2191.3
11	DZ-Cr-387 X DZ-01-99 (RIL No. 106)	2140.0	2181.3	2574.1	2567.1	2238.1	2763.1	1998.1	2253.8
12	DZ-Cr-387 X DZ-01-99 (RIL No. 117)	1763.1	1271.3	2091.5	1914.9	2203.8	2534.4	1931.9	2122.5
13	DZ-Cr-387 X DZ-01-99 (RIL No. 145)	1758.1	1851.3	2363.8	2323.2	2061.3	2719.4	2083.9	2253.1
14	DZ-Cr-387 X DZ-01-99 (RIL No. 169)	1962.5	2000.0	2687.2	2764.8	2365.0	2711.9	1926.0	2669.4
15	DZ-Cr-387 X DZ-01-99 (RIL No. 137)	1592.5	1963.8	2109.6	1922.2	2000.6	2730.6	2007.2	2028.1
16	DZ-Cr-387 X DZ-01-99 (RIL No. 210)	1478.8	1861.3	2361.1	2128.5	2195.6	2597.5	2006.8	2223.1
17	DZ-Cr-387 X DZ-01-99 (RIL No. 246)	1902.5	1951.3	2178.8	2241.1	1900.0	2611.3	2152.3	2340.6
18	DZ-Cr-387 X DZ-01-99 (RIL No. 306)	2005.6	1883.8	2170.4	2751.3	2454.4	2401.9	2022.3	2210.0
19	DZ-Cr-387 X DZ-01-99 (RIL No. 340)	1672.5	2095.0	2189.1	2026.1	1872.5	2833.8	1628.0	2437.5
	Mean	1896.8	1816.5	2324.7	2127.2	2171.2	2580.5	1933.7	2317.9
	CV	16.33	15.04	12.35	5.02	11.05	12.3	16.05	18.09
	LSD (5%)	426.03	402	369.16	152.15	364.06	488.72	419.08	651.9

Table 5. Mean performances of eight traits of 19 tef genotypes evaluated over years and environments

No.	ENTRY	DTH	DTM	GFP	PH	PL	LI	SBM	GY
1	Felagot	58.9	125.8	66.9	90.0	33.9	69.5	7482.9	2054.9
2	DZ-Cr-387 X DZ-01-99 (RIL No. 23)	63.8	129.1	65.3	98.7	38.7	63.7	8919.0	2075.2
3	DZ-Cr-387 X DZ-01-99 (RIL No. 34)	64.8	129.1	64.3	99.3	39.5	62.6	8919.2	2252.6
4	DZ-Cr-387 X DZ-01-99 (RIL No. 35)	65.2	129.7	64.4	99.8	40.4	62.6	8801.7	2088.0
5	DZ-Cr-387 X DZ-01-99 (RIL No.138)	65.5	127.9	62.4	98.6	39.4	67.5	8016.9	2058.5
6	DZ-Cr-387 X DZ-01-99 (RIL No. 49)	65.4	130.3	64.9	99.5	39.7	58.7	8300.0	2037.0
7	DZ-Cr-387 X DZ-01-99 (RIL No. 70)	61.3	128.7	67.4	99.3	37.7	65.4	8665.3	2219.2
8	DZ-Cr-387 X DZ-01-99 (RIL No. 76)	61.7	126.5	64.7	90.8	33.9	69.4	8575.0	2245.5
9	DZ-Cr-387 X DZ-01-99 (RIL No. 101)	64.3	128.0	63.7	101.7	41.8	63.3	9421.5	2092.9
10	DZ-Cr-387 X DZ-01-99 (RIL No. 104)	65.8	129.2	63.3	100.5	38.8	67.4	8914.1	2163.8
11	DZ-Cr-387 X DZ-01-99 (RIL No. 106)	64.8	131.2	66.3	98.3	40.7	64.3	9255.2	2339.4
12	DZ-Cr-387 X DZ-01-99 (RIL No. 117)	65.3	129.9	64.6	99.1	40.1	61.3	8455.0	1985.7
13	DZ-Cr-387 X DZ-01-99 (RIL No. 145)	64.5	128.9	64.4	95.1	39.1	56.5	8573.3	2169.0
14	DZ-Cr-387 X DZ-01-99 (RIL No. 169)	62.1	127.7	65.5	95.4	36.9	68.0	8890.9	2374.4
15	DZ-Cr-387 X DZ-01-99 (RIL No. 137)	64.4	128.3	63.9	95.4	37.9	56.7	8326.6	2048.1
16	DZ-Cr-387 X DZ-01-99 (RIL No. 210)	65.9	129.3	63.4	104.3	41.5	61.1	8953.2	2109.5
17	DZ-Cr-387 X DZ-01-99 (RIL No. 246)	65.0	127.9	62.9	95.8	38.4	68.0	8391.9	2158.3
18	DZ-Cr-387 X DZ-01-99 (RIL No. 306)	67.4	128.1	60.7	95.8	39.5	66.1	8561.3	2219.4
19	DZ-Cr-387 X DZ-01-99 (RIL No. 340)	63.6	129.9	66.3	101.8	41.7	64.3	9100.0	2095.4
	Mean	64.19	128.71	64.49	97.85	38.93	64.02	8659.11	2146.67
	LSD	1.37	2.17	2.43	4.33	1.6	4.55	683.73	174.79
	CV (%)	4.3	3.5	7.9	8.6	7.2	14.32	15.79	16.9

DTH= Days to heading, DTM= Days to maturity, GFP= Grain filling period, PH= Plant height, PL= Panicle length, LI=Lodging index, SBM= Shoot biomass, GY= Grain yield

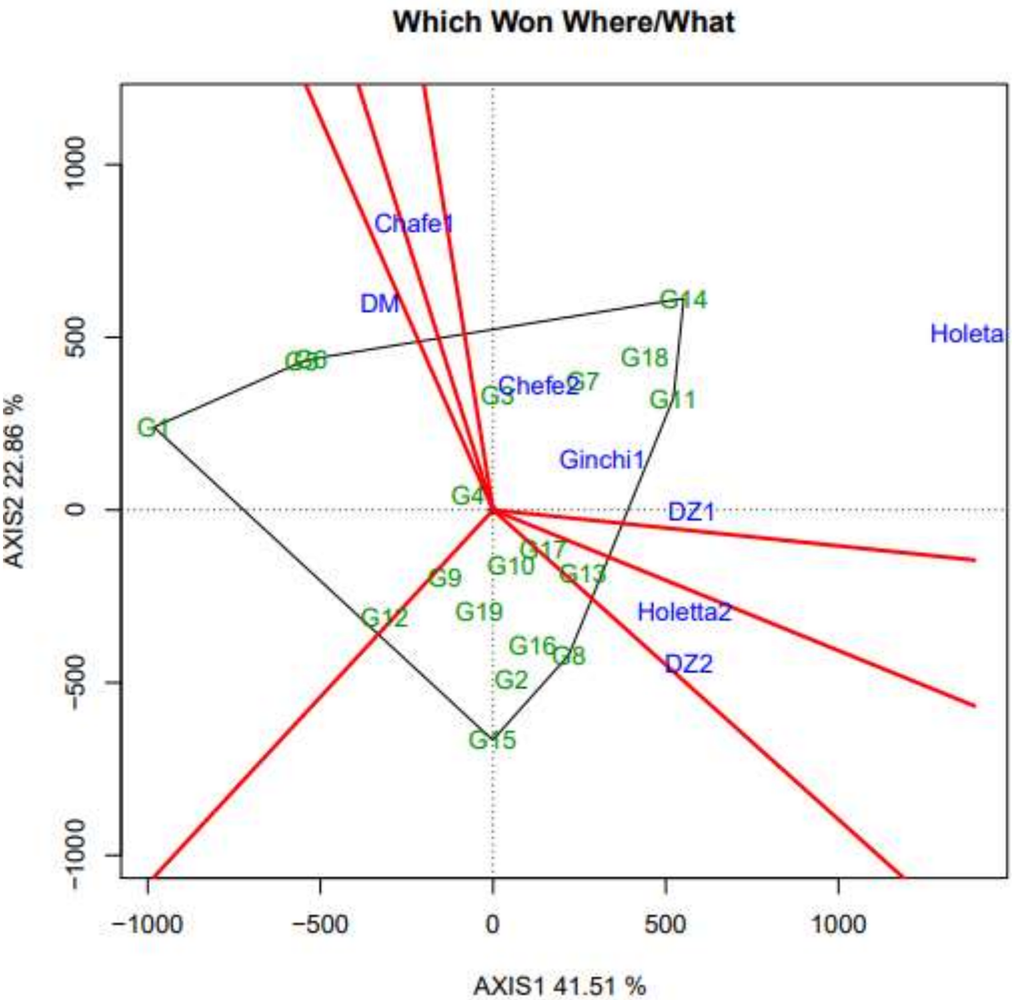

Figure 1. Which won where pattern of the GGE biplot of 19 tef genotypes evaluated at eight environments. DZ1= Debre Zeit 2019, DZ2= Debre Zeit 2020, Holetta1= Holetta 2019, Holetta2= Holetta 2020, DM=Debre Markos, Chefe1= Chefe 2019, Chefe2= Chefe 2020, Ginchi1= Ginchi 2019.

Based on mean grain yield and stability graph of the GGE biplot, genotypes like G11, G14, G18, G7, G17 and G13 had above average yield in all the test environments (Fig. 2). Among these genotypes, G11 was the most stable and the second higher yielding genotype identified to be suitable for all environments. All the remaining genotypes, however, were found to perform below the average in all test environments.

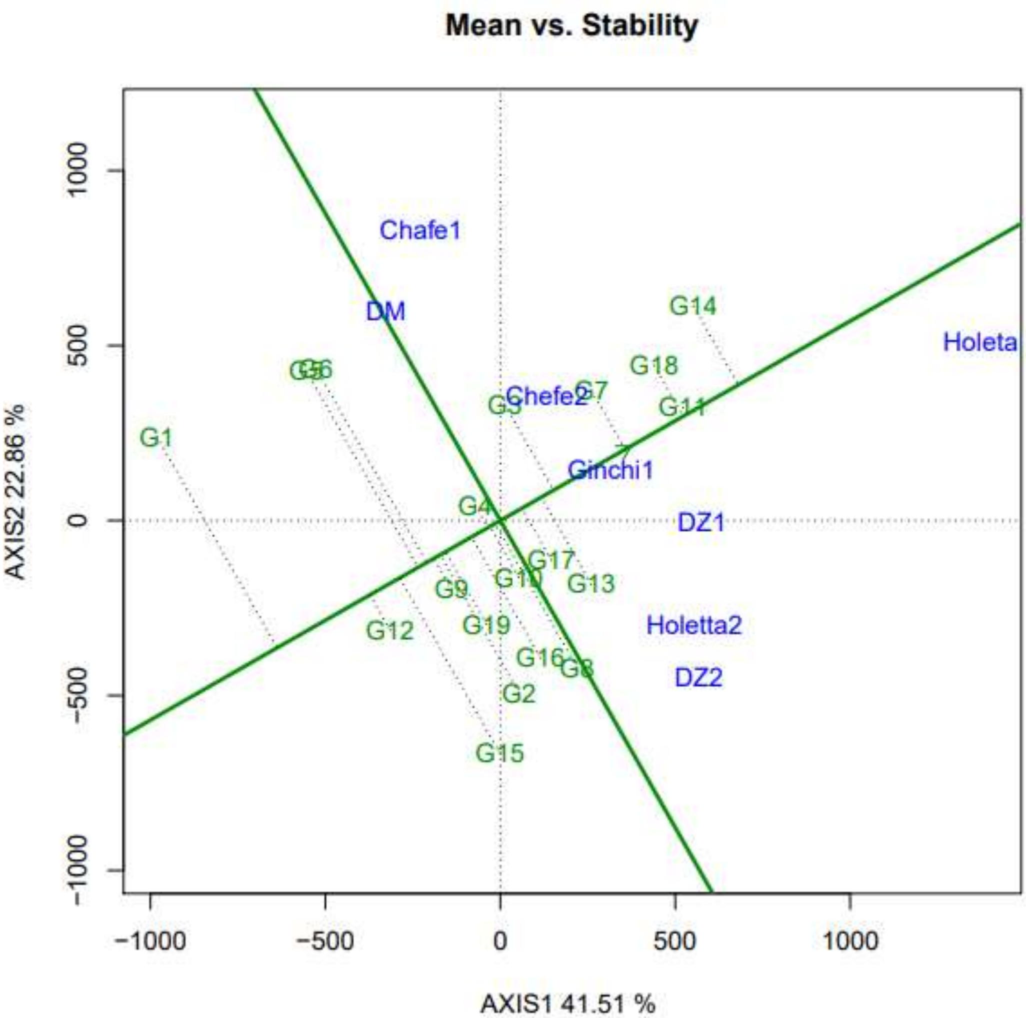

Figure 2. A graph showing the mean performances and stability of 19 genotypes studied at eight environments. DZ1= Debre Zeit 2019, DZ2= Debre Zeit 2020, Holetta1= Holetta 2019, Holetta2= Holetta 202, DM=Debre Markos, Chefe1= Chefe 2019, Chefe2= Chefe 2020, Ginchi1= Ginchi 2019.

The average environment coordination view of the GGE biplot shows the ranking of genotypes based on the performance of an ideal genotype (Fig. 3). The relative adaptation of the ideal genotype is evaluated by drawing a line passing through the biplot origin and the best genotype marker. This line is called a genotype axis and is connected to the best genotype (Yan et al., 2000). Such ranking of genotypes based on mean performance of ideal genotype revealed that G11 is closest to zero with respect to PC2 and showing that it is a more stable genotype with above average yield. Hence, this is also another justification for the identification of G11 for verification and commercial release in the high potential tef growing environments of Ethiopia.

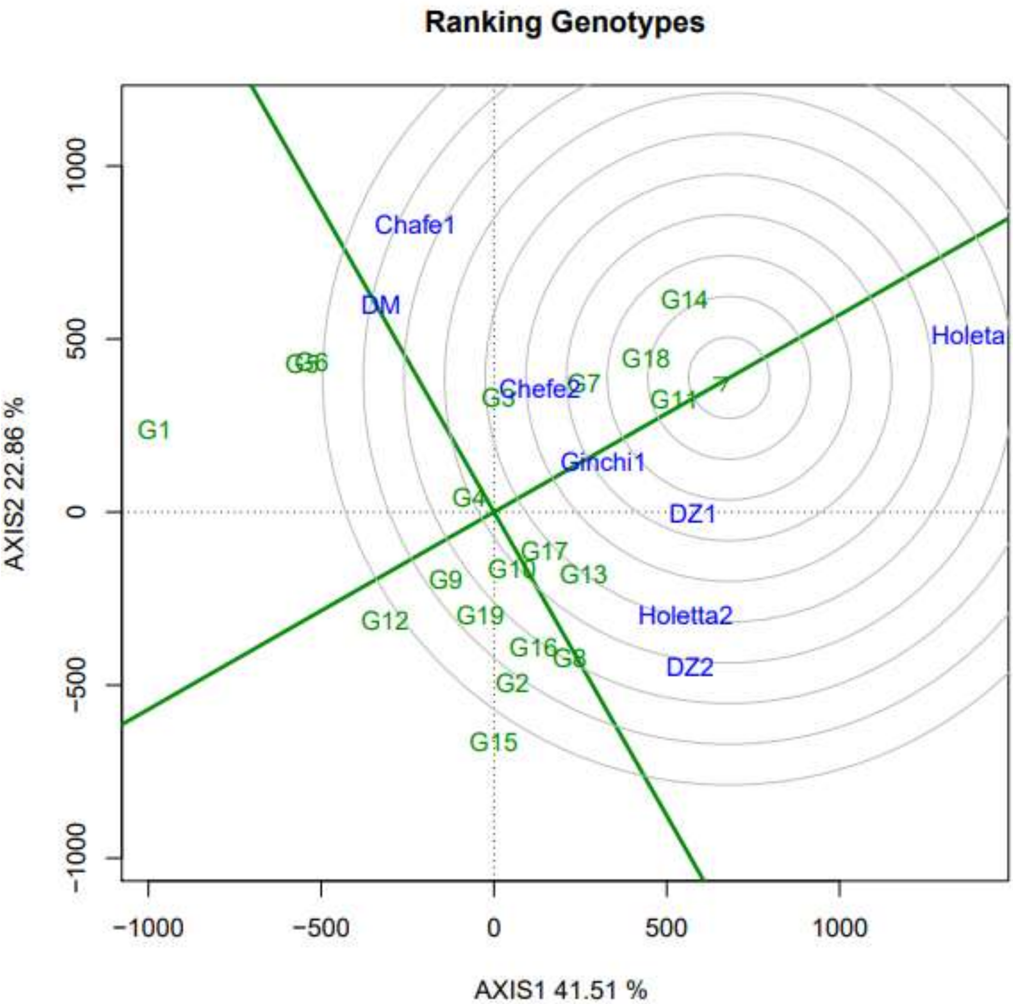

Figure 3. A graph showing the ranking of genotypes relative to the best genotype. DZ1= Debre Zeit 2019, DZ2= Debre Zeit 2020, Holetta1= Holetta 2019, Holetta2= Holetta 202, DM=Debre Markos, Chefe1= Chefe 2019, Chefe2= Chefe 2020, Ginchi1= Ginchi 2019.

Description of Kulle Tef Variety

Description of the new tef variety **Kulle** which include its pedigree, vernacular name, adaptations and other distinguishing agro-morphological features are given in Table 6. DZ-Cr-387 X DZ-01-99 (RIL 106) is designated by the breeder as DZ-Cr-542 (RIL 106). It was developed through crossing of DZ-Cr-387 (Quncho) with DZ-01-99 (Asgori) in 2014 to develop a stable, high yielding, and farmers and consumers preferred brown seeded tef varieties for the high rainfall high potential areas of the country. In this crossing, brown seeded varieties with better yield, thicker culm and quality compared to *Felagot* was targeted. DZ-Cr-387 was selected as a female parent for its high yielding ability and thicker culm while DZ-01-99 was selected as a pollen (male) parent for its brown seed colour. The designation DZ-Cr-542 (RIL 106) shows that this variety was obtained from the 542nd crosses made at Debre Zeit Agricultural Research Center while RIL106 (Recombinant Inbred Line number 106) is a designation of the homozygous line among those inbred lines tested at F_7. A vernacular name *Kulle* meaning “beautiful” in Afaan Oromo language was given to it after its official release to express its deep brown colour that most consumers prefer.

Table 6. Agronomic and Morphological characteristics of Kulle

No.	Parameters	Description
1	Breeders Name	DZ-Cr-542 (RIL106)
2	Pedigree	DZ-Cr-387 X DZ-01-99 (RIL 106)
3	Vernacular name	Kulle
4	Days to heading (days)	56-68
5	Days to maturity (days)	115-130
6	Plant Height (cm)	95-115
7	Panicle length (cm)	38-47
8	Panicle form	Loose
9	Lemma colour	variegated
10	Anther colour	Yellowish white
11	Caryopsis colour	Brown
12	1000 seed weight (g)	0.29-0.33
13	Grain yield	
	• Research Station (Kg ha^{-1})	2200-2700
	• on farm (Kg ha^{-1})	2000-2300
14	Dried above ground biomass yield (Kg ha^{-1})	85000-10500
15	Adaptation Area	High and optimum tef growing areas
16	Altitude (m.a.s.l.)	1700-2600
17	Rainfall (mm)	700-1300
18	Crop Pest Reaction	Not significant
19	Year of Release	2022
20	Releasing Center/ maintainer	Debre Zeit Agricultural Research Center

Conclusions and Recommendations

Subsequent selection and field testing of desirable genotypes is essential to develop suitable tef varieties for various growing environments. In this study, DZ-Cr-387 X DZ-01-99 (169) followed by DZ-Cr-387 X DZ-01-99 (106) gave the higher grain yield of 2385.9 kg/ha and 2339.5 kg/ha, respectively. However, the later was found to be most stable across environments, gave above average grain yield at about 70% of the test environments and showed 23.7% biomass yield and 20.1% panicle length advantage over the standard check. With this yield advantage and other merits, therefore, DZ-Cr-387 X DZ-01-99 (106) was proposed for verification in 2021 and has got approval of release by the technical committee of the national variety release in 2022. Hence, DZ-Cr-387 X DZ-01-99 (106) or DZ-Cr-542 (RIL 106) was officially released for commercial production in the high potential tef growing environments of Ethiopia with a simple and unique name called *Kulle*.

Author Contributions

This article is the result of a collaborative research among all authors. Habte Jifar designed the study, performed the statistical analysis, wrote the protocol and the first draft of the manuscript. Worku Kebede, Tsion Fikire, Kidist Tolessa, Solomon Chanyalew, Kebebew Assefa, Yazachew Genet, Mahlet Tadesse, Girma Ashe and others managed the literature searches. All authors read and approved the final manuscript.

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