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Research Article

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Evaluation of selected semi-dwarf Tef (*Eragrostis tef* (Zucc.) Trotter) genotypes for yield and yield related traits

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ABSTRACT

Tef is the major staple food crop for Ethiopia which is cultivated by more than 6.7 million smallholder farmers. As an indigenous cereal, it is well adapted to diverse climatic and soil conditions; however, its productivity is very low mainly due to susceptibility to lodging. The objective of this study was to identify stable, high yielding and lodging tolerant tef genotypes for moisture stress areas of the country. A total of twenty genotypes including standard and local checks were tested. The field experiment was conducted using a 2m x 2m area with a completely randomized block design at six locations (Debre Zeit, Minjar, Alemtena, Melkassa, Sirinka and Axum) during the 2019 and 2020 main cropping seasons. Data were taken on plot and individual plant basis on eight pheno-agro-morphological characters including days to heading, days to maturity, grain filling period, plant height, panicle length, lodging index, above-ground shoot biomass and grain yield. The combined analysis of variance showed that the mean squares due to genotypes, locations and genotype interactions were highly significant ($P<0.01$) for the tested eight agronomical and morphological traits evaluated. Based on the current result, 39% of the tested genotypes had a higher yield advantage over the standard check *Boset* variety. On the other hand, 44% of the genotypes showed higher yields than the local check. Therefore, the promising genotype for lodging tolerance needs further testing in the variety verification trial and those genotypes are used as representative materials to develop varieties, especially for lodging tolerance.

Keywords: Genotypes, Inbred Lines, lodging, Semi-dwarf, Traits

INTRODUCTION

Tef, *Eragrostis tef* (Zucc.) Trotter is an annual self-pollinated grass species of the family Poaceae, subfamily Chloridoideae. Tef is an allotetraploid, with $2n=4x = 40$ chromosomes (Tavassoli, 1986) and Ethiopia is the place where tef originated and diversified (Vavilov, 1951). Previous reports done on the morphological study of tef showed that five possible progenitors for this cereal were suggested, namely: *Eragrostis pilosa* (L.) (Hackel, 1890; Rozhevits, 1928), *Eragrostis aethiopica* or *Eragrostis pseudo-tef* (Trotter, 1938) *Eragrostis macilenta* (Chevalier, 1940) and *Eragrostis longifolia* (Porteres, 1958). Of these, *Eragrostis pilosa and Eragrostis aethiopica* morphologically look like tef more than the remaining three (Clayton, 1974). In the case of molecular study, thousands of SNPs were identified genome-wide from the germplasm panel. Genetic diversity, population structure, phylogenetic relationships and sequence similarity and/or divergence were assessed by those identified SNPs. Mapping individual reads to the tef reference genome revealed that of the 40 wild *Eragrostis* species included in this study, *Eragrostis pilosa*, *Eragrostis aethiopica*, *Eragrostis obtusa*, *Eragrostis ferruginea*, *Eragrostis lugens*, and *Eragrostis lehmanniana* had 92% of their sequences represented in the tef reference genome (Girma *et al*., 2018). According to Ketema (1997) and Chanyalew *et al*. (2019), adaptation under varied climatic conditions, tolerance to both drought and water-logging conditions; suitability for various cropping systems and crop rotation schemes, low-risk catch crops, and little vulnerability to epidemics of pests and diseases are the most important agronomic advantages of the crop.

Over 6.7 million smallholder farmers in Ethiopia have cultivated it. While its health benefits and nutrition contents, tef is now growing in different countries as food and forage grass including the United States, Israel, the Netherlands, Spain, South Africa, India, Australia, and Kenya (Ketema, 1997; Assefa *et al.*, 2011). Comparatively to other cereal crops, the productivity of tef is significantly low. The national average yield in Ethiopia for tef is 1.6 t ha^{-1} while those of maize and wheat are 3.4 and 2.5 t ha^{-1} respectively (CSA, 2015). Lodging is one of the serious problems in tef production causing an estimated average yield loss of 15 to 45% (Ketema, 1993; Zhu *et al.*, 2012). It has been challenging to develop resistant varieties for lodging from the existing germplasm mainly because of the lack of variation for lodging resistance within the available germplasm (Assefa *et al.*, 2010). Agronomic practices like the application of increased amounts of nitrogen fertilizer to boost the yield results in severe lodging (Assefa *et al.*, 2015). Various types of lodging were reported for tef, root lodging was dominant over stem lodging (van Delden *et al.*, 2010). The introduction of semi-dwarf varieties of rice and wheat during the green revolution greatly reduced culm bending-type lodging and increased productivity (Hedden, 2003; Hirano *et al.*, 2017). Nevertheless, due to the high economic value of the tef straw as livestock feed, breeding for a substantial reduction in plant height might have little acceptance by the farmers (Yami, 2013). Both the grain yield and quality of tef can be affected by lodging depending on the weather condition and the inherent nature of the variety (Zhu *et al.*, 2012). Therefore, lodging is a crucial problem in tef production that needs to be addressed as long as tef production and research are concerned. Although various attempts have been made by the research community to develop lodging-resistant tef cultivars (Assefa *et al.*, 2011; Tadele & Assefa, 2012), *kegne* is the only semi-dwarf tef cultivar resistance for lodging which was achieved using inhibitors of gibberellic acid biosynthesis especially paclobutrazol (Gebre *et al.*, 2012; Plaza-Wüthrich *et al.*, 2016).

Many efforts were taken in the past to implement different techniques and tools in order to improve tef. The inter-specific crossing was made between tef (*Eragrostis tef*) and *Eragrostis curvula* in an effort to transfer the lodging tolerant trait of *Eragrostis curvula* to tef (Berhe *et al.*, 2011). However, so far, no viable hybrid obtained from the crosses. Some efforts were also made to develop double haploids using the gynogenesis technique and some promising tef lines were obtained (Gugsa *et al.*, 2006). Through many struggles about 51 improved varieties were released to the farming communities (MoARD, 2020). However, improvement of high yielding and lodging tolerant tef varieties, and adapting to the changing climate remain to be the primary focus of tef research (Chanyalew, 2009; Chanyalew *et al.*, 2013). Therefore, the present study was designed to evaluate some selected semi-dwarf tef genotypes for yield and yield related characteristics.

MATERIALS AND METHODS

Plant Materials

The experimental plant materials comprised 20 semi-dwarf tef recombinant inbred lines including local and standard checks. These included 18 recombinant inbred lines (RIL) derived from the crosses of DZ-01-192 X GA-10-3, the two parents (pure lines), and one standard and local check. The crossing combinations and names of recombinant inbred lines as well as control materials used in the study are shown in Table 1. The RILs are offspring of the intra-specific cross through continuous maintenance of progenies up to the seventh filial generation (F7) through selfing using the F2-derived single-seed-descent breeding method. The tef cultivar DZ-01-192 is late maturing, thick culmed, tall, and has loose panicles and white seed color. GA-10-3 is a mutant line developed through mutation breeding by using Ethyl methane sulphonate (EMS) assisted by the Targeted Induced Local Lesions In Genomes (TILLING) method and introduced from University of Bern (Switzerland).

Description of Experimental Sites

The field experiment was carried out at six locations (Debre Zeit, Minjar, Melkassa, Alemtena, Sirinka and Axum) during the 2019 and 2020 main cropping seasons. The geographical location and climatic conditions of the testing sites were discussed in Table 2.

Experimental Design and Management

A Randomized Complete Block Design (RCBD), with four replications used in each testing site, a plot size of 2 x 2 m with a spacing of 1 m between plots. Sowing was done at the recommended period. At some of the locations such as Debre Zeit and Minjar, low moisture stress was simulated by

Table 1: List of twenty experimental tef genotypes

Code	Lines	Parents
1	(RIL.No. 137)	DZ-01-192 X GA-10-3
2	(RIL.No. 158)	DZ-01-192 X GA-10-3
3	(RIL.No. 185)	DZ-01-192 X GA-10-3
4	(RIL.No. 198)	DZ-01-192 X GA-10-3
5	(RIL.No. 208)	DZ-01-192 X GA-10-3
6	(RIL.No. 218)	DZ-01-192 X GA-10-3
7	(RIL.No. 223)	DZ-01-192 X GA-10-3
8	(RIL.No. 238)	DZ-01-192 X GA-10-3
9	(RIL.No. 252)	DZ-01-192 X GA-10-3
10	(RIL.No. 259)	DZ-01-192 X GA-10-3
11	(RIL.No. 260)	DZ-01-192 X GA-10-3
12	(RIL.No. 264)	DZ-01-192 X GA-10-3
13	(RIL.No. 210)	DZ-01-192 X GA-10-3
14	(RIL.No. 235)	DZ-01-192 X GA-10-3
15	(RIL.No. 262)	DZ-01-192 X GA-10-3
16	(RIL.No. 91)	DZ-01-192 X GA-10-3
17	(RIL.No. 68)	DZ-01-192 X GA-10-3
18	(RIL.No. 63)	DZ-01-192 X GA-10-3
19	DZ-Cr-409 (Boset)	Standard check
20	Local Check	Farmer's variety

Table 2: Geographical location and climatic condition of the study sites

Site	Latitude° N	Longitude° E	Temperature (Max and Min/°C)	Rain fall (Ave/mm)	Altitude (m)
Debre Zeit	8° 44	38° 58	8.9–28.3	851	1900
Alemtena	8° 30	38° 95	12.3 –28.8	706.3	1611
Melkassa	8° 24	39° 32	26 – 30	791	1550
Minjar	9° 09	39° 19	15.9 – 28.4	903.4	1040
Sirinka	11° 75	39° 61	18 – 27	1200	1861
Axum	14° 06	38° 36	12.2 – 26.8	613.92	2200

late sowing in addition to the light-textured soils of low water holding capacity. The rate of 10 kg ha^{-1} from each genotype seed was drilled along the 10 rows of each plot. The recommended amounts of fertilizers were applied for each location (60 kg ha-1 P_2O_5 and 60 kg ha-1 N at Debre Zeit and Minjar and 60 kg ha-1 P_2O_5 and 40 kg ha-1 N at Alemtena, Melkassa, Sirinka and Axum. The recommended amount of P_2O_5 was applied at planting whereas nitrogen (N) fertilizer was applied two times, during the planting and tillering stage (after 30 - 40 days of planting) in the form of urea. Important agronomic practices were employed as per the recommendations of the respective test locations.

Data Collection

Data was collected from eight quantitative pheno-agro-morphological traits including six traits taken on a plot basis and two traits assessed on randomly taken five plants of tef from the central rows of each plot. For individual plant traits sampled, averages of data from the five random samples of plants per plot are used for statistical analyses.

The following data have been taken from plot basis:

Days to heading/panicle emergence (DH): Number of days from seedling emergence to the appearance of the tips (about 5 cm) of the main shoot panicle on 50% of the plants in a plot. Note that tef panicle appears without showing the booting stage, which is unlike the other small cereals like wheat and barley, but similar to that in rice.

Days to maturity (DM): Number of days from seedling emergence to physiological maturity as judged by the change to the straw color of the vegetative parts on 75% of the plants in the plot.

Grain filling period (GFP): This is computed as the difference between the days to panicle emergence and that to maturity.

Above ground biomass yield (ABM): The total dry weight in kilogram of the above ground biomass per plot before threshing

Grain yield (GY): The entire plot of grains weight in kilograms after threshing and sun drying.

Lodging index (LI): lodging assessment was performed as suggested by Caldicott and Nuttall (1979) as follows:

$$\mathrm{LI} = \frac{\mathrm{Sum(Lodging\,scores * Percentage\,of\,area\,lodged)}}{5}$$

The lodging score was recorded on a 0-5 scale as the degree of leaning from the upright position and whereby zero= completely upright non-lodged plants and five=completely flat on the ground. The severity of lodging for each degree is assessed as the proportion in percent of plants in a plot manifesting each degree of lodging. Finally, the lodging index for each plot was computed as the average of the product sum of each degree of lodging and the corresponding severity as indicated in the formula above.

The following observations have been recorded based on measurements made on five randomly taken and pre-tagged plants from the three central rows of each plot.

Plant height (PH): The length of the plant in centimeters from ground level to the tip of the panicle.

Panicle length (PL): The length in centimeters from the node where the first panicle branch starts to the tip of the panicle.

Statistical Analyses

All data were subjected to analysis of variance (ANOVA) for RCBD, as described by Gomez and Gomez (1984), using SAS version 9 (SAS, 2011). For the combined analysis of variance over locations, the homogeneity of error variance was tested using the F-max test method of Hartley (1950), which requires independent random samples of the same size from normally distributed populations (Ott & Longnecker, 2015). It is based on the ratio of the larger mean square of error (MSE) from the separate analysis of variance to the smaller mean square of error given by the following formula:

$$\mathrm{Fmax} = \frac{\mathrm{Largest\,MSE}}{\mathrm{Smallest\,MSE}}$$

If the calculated value of Fmax was less than three, it means that the ratio of the highest error mean square is not threefold larger than the smallest error means square, and this indicates that the variance was considered homogenous thereby making it to possible to proceed with the combined analysis of variance (Gomez & Gomez, 1984).

RESULTS AND DISCUSSION

Analysis of Variance

The combined analysis of variance over six locations (Table 3), grain yield was highly significantly ($P<0.01$) affected by genotypes, location, year and year genotype and location interaction. In the same way, genotypes by environment (G×E) interaction effects showed significant ($P<0.05$) on grain yield indicating that the tested genotypes performed differently across the test environments. This implies that the genotypes tested exhibit differential adaptation to specific environments. The significant variability of genotype traits shown in the present study for different traits of tef genotypes was in agreement with the previous report by different authors for genotype variability (Jifar *et al*., 2017; Kebede *et al*., 2020). The considerable difference was observed among the genotypes in grain yield performance pooled across all environments. The average grain yield of DZ-01-192 X GA-10-3 (RIL 185) was 2260 kg ha^{-1} (Table 4) which was the maximum grain yield recorded among tested genotypes across pooled environments. Correspondingly, the current result is in close agreement with that of Jifar *et al.* (2017).

The genotype DZ-01-192 X GA-10-3 (RIL 185) showed 241.7 kg ha^{-1} and 358.2 kg ha^{-1} grain yield advantage over the standard (*Boset*) and local checks respectively. On the opposite, better yielder genotypes have been observed from the study of Fikre *et al.* (2020) report conducted under irrigation conditions on semi-dwarf tef. The multi-location trial on two consecutive years, DZ-01-192 X GA-10-3 (RIL 185), DZ-01-192 X GA-10-3 (RIL 262) and DZ-01-192 X GA-10-3 (RIL 252), were exhibited the highest grain yield performance among the tested genotypes. The standard check (*Boset*) showed better performance for lodging resistance followed by DZ-01-192 X GA-10-3 (RIL 137) and DZ-01-192 X GA-10-3 (RIL 185) with 76%, 80% and 82% respectively. However, no genotypes tested were significantly superior in lodging tolerance characters to the standard checks. A similar range of lodging index was reported from previous work of Jifar *et al.* (2017), conducted on semi-dwarf tef genotypes on multi-location trials at Holeta, Debre Zeit and Alem Tena.

Table 3: Mean squares from the combined analysis of variance for eight agronomical and morphological related traits of 20 tef genotypes

Source	DF	Sum square	Mean square	F Value	Pr>F
Loc	5	80805805.85	16161161.	86.97	0.0001
Loc (Rep)	18	9116796.66	506488.70	2.73	0.0002
Year	1	12596391.01	12596391.01	67.79	0.0001
Genotype	19	12820082.12	674741.16	3.63	0.0001
Loc* Genotype	95	23105452.44	243215.29	1.31	0.0364
Year* Genotype	19	5441283.31	286383.33	1.54	0.0668
Year*Loc* Genotype	40	35325707.00	883142.67	4.75	0.0001
Error	522	96999444.5	185822.7		
Total	719	291481806.4			

Ranges of Traits

The mean, minimum and maximum values for the eight traits of the tef genotypes were computed based on combined analyses over six locations and showed the existence of a significant amount of variability among the test genotypes for all the studied traits (Table 4). DZ-01-192 X GA-10-3 (RIL 137), exhibited the longest days to maturity (92.67) and days to heading (49.39). Correspondingly, most of the genotypes having similar values for panicle length are in line with the result of (Jifar *et al*., 2017). The results of the current study have a broader range for aboveground shoot biomass and grain yield that showed discrepancies from those reported based on a review of several studies by Assefa *et al.* (2001). However, DZ-01-192 X GA-10-3 (RIL 262) had the shortest plant height. On the other hand, RIL 158 gave the highest yield and shortest. In the same way, RIL 235 gave the shortest days to maturity

Table 4: Mean of eight agronomical traits of 20 tef genotypes evaluated at Debre Zeit, Minjar, Melkassa, Alemtena, Sirinka and Axum

No.	Genotypes	DTH	DTM	GFP	PH	PL	LI	SBM kg/ha	GY kg/ha
1	DZ-01-192 X GA-10-3 (RIL. 137)	49.39	92.67	43.94	114.81	45.57	80.94	10820.49	2180.02
2	DZ-01-192 X GA-10-3 (RIL. 158)	43.11	90.92	47.91	107.57	42.38	86.89	9128.57	2217.29
3	DZ-01-192 X GA-10-3 (RIL. 185)	46.31	92.36	44.25	105.15	38.74	82.71	10380.56	2260.31
4	DZ-01-192 X GA-10-3 (RIL. 198)	46.42	88.31	43.56	107.84	43.29	90.88	8992.01	2054.47
5	DZ-01-192 X GA-10-3 (RIL. 208)	49.17	90.33	42.53	111.09	43.24	88.49	9263.19	1817.45
6	DZ-01-192 X GA-10-3 (RIL. 210)	47.53	89.39	43.41	104.82	40.04	88.80	8991.67	1960.61
7	DZ-01-192 X GA-10-3 (RIL. 218)	45.28	92.28	46.25	109.88	43.12	84.59	9817.71	2138.77
8	DZ-01-192 X GA-10-3 (RIL. 223)	45.75	88.25	43.78	109.83	39.33	85.55	8310.76	2067.39
9	DZ-01-192 X GA-10-3 (RIL. 235)	44.58	87.72	43.97	101.02	37.57	91.98	8406.94	1960.21
10	DZ-01-192 X GA-10-3 (RIL. 238)	44.19	89.58	45.84	102.86	40.47	86.43	8606.35	2021.73
11	DZ-01-192 X GA-10-3 (RIL. 252)	46.06	90.31	45.94	105.42	39.03	90.68	8872.81	2241.88
12	DZ-01-192 X GA-10-3 (RIL. 259)	46.14	89.58	44.28	102.19	40.53	90.64	9151.04	2016.01
13	DZ-01-192 X GA-10-3 (RIL. 260)	45.36	91.81	47.97	103.00	41.34	95.23	8531.94	1968.74
14	DZ-01-192 X GA-10-3 (RIL. 262)	45.75	90.11	45.69	96.03	37.66	91.78	8206.25	2254.51
15	DZ-01-192 X GA-10-3 (RIL. 264)	47.44	89.42	43.88	106.72	39.71	90.01	8699.86	1788.55
16	DZ-01-192 X GA-10-3 (RIL. 63)	44.97	88.47	42.50	101.71	39.87	89.23	8524.60	1900.12
17	DZ-01-192 X GA-10-3 (RIL. 68)	43.61	90.11	47.31	104.07	39.90	92.15	8240.49	1942.68
18	DZ-01-192 X GA-10-3 (RIL. 91)	44.00	91.56	46.72	99.21	39.18	92.51	8944.79	2102.12
19	DZ-Cr-409 (Boset)	47.92	90.22	42.50	103.28	38.81	76.30	9128.13	2018.58
20	Local Check	48.64	92.64	43.56	106.64	40.02	85.60	9730.21	1902.14
	Grand Total	*46.08*	*90.30*	*44.79*	*105.16*	*40.49*	*88.07*	*9037.42*	*2040.68*
	R^2	*0.88*	*0.84*	*0.82*	*0.53*	*0.60*	*0.80*	*0.65*	*0.66*
	CV (0.05)	*3.73*	*3.49*	*6.95*	*8.69*	*8.46*	*8.25*	*19.22*	*21.12*
	LSD	**	**	**	**	**	**	**	**

DTH=days to heading, DTM=days to maturity, GFP=grain filling period, PH=plant height, PL=panicle length, LI=lodging index, SBM=Shoot biomass (kg/ha), GY=grain yield (kg/ha) and panicle length. The range of, days to heading, grain filling period and days to maturity were 43-49, 42-47and 88-93 days, respectively. Similarly, wide ranges were also noted for all the traits assessed. The shortest plant height (96.03) was scored by RIL 262. RIL 185 and RIL 68 showed the highest aboveground shoot biomass following RIL-137. The lowest and highest lodging index was 76.30 and 95.23 respectively scored by the standard check (*Boset*) and RIL 260. Additionally, RIL 262 and RIL 252 were among the high yielding genotypes and RIL 264 scored the lowest (1788.55 kg ha^{-1}) grain yield. RIL-260 gave the longest and RIL 63 and *Boset* showed the shortest grain filling period. Currently, straw also has a comparable economic value to grain yield. Thus, as mentioned by Fikre *et al*. (2020), using the right genotype at the right location plays a fundamental role in increasing the production and productivity of tef.

In general, the existence of considerable variations for all traits of the test genotypes has been detected. Thus, the genotype RIL-137 has a significantly longer panicle, the longest days to maturity and the highest aboveground shoot biomass. Besides, RIL-68 and RIL-158 both have the smallest days to heading. Based on this result, 50% and 80 % of the tested genotypes had higher yields over the standard (*Boset*) and local checks respectively. Evaluation of the mean performances of each trait at the six environments clearly showed that some locations were good enough for the accomplishment of the same traits; while others were moderate or even the least for the performance of the same traits (Table 4 & 5).

Genotypes Performance

The mean grain yield performance of the tested tef genotypes during two years (2019 and 2020) exhibited different yields. The average grain yield of DZ-01-192 X GA-10-3 (RIL. 262) was 2155.5 kg ha^{-1} (Table 4) which was the maximum grain yield recorded among the tested genotypes across pooled environments during the 2019 cropping season whereas, DZ-01-192 X GA-10-3 (RIL. 185) gave 2601.3 kg ha^{-1} during 2020

Table 5: Mean grain yield performance of twenty semi-dwarf tef genotypes evaluated in the national variety trial over two years during main cropping season

Genotypes	2019						2020					Over all 2019 and 2020
	Axum	Debre Zeit	Melkassa	Minjar	Sirinka	2019 Total	Alemtena	Debre Zeit	Minjar	Sirinka	2020 Total	
DZ-01-192 X GA-10-3 (RIL. 137)	1712.0	1326.6	1389.4	2625.0	2213.1	1853.2	1855.0	2477.5	2358.8	3662.9	2588.5	2180.0
DZ-01-192 X GA-10-3 (RIL. 158)	1773.7	1584.4	1716.9	3131.9	2015.6	2044.5	2359.4	1953.1	2259.4	3161.3	2433.3	2217.3
DZ-01-192 X GA-10-3 (RIL. 185)	1715.6	1303.9	1465.0	2937.5	2515.6	1987.5	2419.4	2270.6	2947.5	2767.6	2601.3	2260.3
DZ-01-192 X GA-10-3 (RIL. 198)	1704.5	1342.2	1630.0	2589.4	2240.6	1901.3	2043.8	2088.1	2190.0	2661.8	2245.9	2054.5
DZ-01-192 X GA-10-3 (RIL. 208)	1062.0	939.1	1611.9	2558.8	2077.5	1649.8	1683.8	1675.0	2125.6	2623.5	2027.0	1817.4
DZ-01-192 X GA-10-3 (RIL. 210)	2084.1	1255.5	1516.9	2200.6	1855.6	1782.5	1907.5	1964.4	2171.3	2689.8	2183.2	1960.6
DZ-01-192 X GA-10-3 (RIL. 218)	1948.2	1780.5	1635.0	2723.8	1840.0	1985.5	2281.3	1645.0	2462.5	2932.8	2330.4	2138.8
DZ-01-192 X GA-10-3 (RIL. 223)	2325.1	1444.5	1395.6	2197.5	2258.1	1924.2	2158.1	2171.3	2054.4	2601.9	2246.4	2067.4
DZ-01-192 X GA-10-3 (RIL. 235)	2117.6	1496.1	1470.0	2258.1	2050.6	1878.5	1721.9	2168.1	2003.8	2355.8	2062.4	1960.2
DZ-01-192 X GA-10-3 (RIL. 238)	1803.5	1317.2	1423.1	2879.4	2415.6	1967.8	1924.4	1901.3	2164.4	2366.8	2089.2	2021.7
DZ-01-192 X GA-10-3 (RIL. 252)	1588.3	1556.3	1863.8	3012.5	2000.6	2004.3	2316.3	2293.1	2576.3	2969.9	2538.9	2241.9
DZ-01-192 X GA-10-3 (RIL. 259)	2009.6	1335.2	1478.1	2670.6	1939.4	1886.6	1992.5	1934.4	2119.4	2665.0	2177.8	2016.0
DZ-01-192 X GA-10-3 (RIL. 260)	1492.2	1442.2	1458.8	2793.8	2016.3	1840.6	1863.8	2408.8	2030.6	2212.4	2128.9	1968.7
DZ-01-192 X GA-10-3 (RIL. 262)	2638.3	1707.8	1525.6	2598.8	2306.9	2155.5	1795.6	2380.0	2611.9	2725.8	2378.3	2254.5
DZ-01-192 X GA-10-3 (RIL.264)	1806.8	919.5	1325.6	2600.6	1865.0	1703.5	1656.9	1879.4	2045.6	1997.5	1894.8	1788.6
DZ-01-192 X GA-10-3 (RIL. 63)	1921.7	1189.8	1426.3	2509.4	1776.9	1764.8	1735.0	1844.4	1941.9	2755.8	2069.3	1900.1
DZ-01-192 X GA-10-3 (RIL. 68)	1751.7	1446.9	1455.6	2730.6	1801.9	1837.3	1930.0	1768.8	2340.0	2258.6	2074.3	1942.7
DZ-01-192 X GA-10-3 (RIL. 91)	1465.7	1656.3	1178.1	2792.5	2139.4	1846.4	2200.6	2003.8	2703.1	2779.6	2421.8	2102.1
DZ-Cr-409(Boset)	1340.9	1524.2	1445.6	2745.0	2016.3	1814.4	2080.0	1912.5	2475.6	2627.1	2273.8	2018.6
Local Check	1610.8	1024.2	1250.0	2061.9	1765.6	1542.5	1783.8	1953.8	2181.3	3488.0	2351.7	1902.1
Grand Total	1793.6	1379.6	1483.1	2630.9	2055.5	1868.5	1985.4	2034.7	2288.2	2715.2	2255.9	2040.7

cropping season (Table 5). During the 2019 cropping season 2638.3 kg ha^{-1} grain yield was recorded by genotype DZ-01-192 X GA-10-3 (RIL. 262) from the Axum testing site which was the second higher result next to Minjar 3131.9 kg ha^{-1}. In the next cropping season (2020), DZ-01-192 X GA-10-3 (RIL. 185) gave 2419.4 kg ha^{-1} grain yield at Alem Tena followed by genotype DZ-01-192 X GA-10-3 (RIL.137) 3662.9 kg ha^{-1} at Sirinka. This inconsistency may be due to the variation in the experimental locations and genotypes. The comparison of the RILs with the standard checks *Boset* variety showed the excelling grain yield performances of some RILs (Table 5). This lowest yield at Debre Zeit is the highest at Minjar. The lowest yield at Debre Zeit may be due to environmental factors that hinder the genotype performance for that specific season because in the next year those genotypes gave comparable yield with the other genotypes tested.

Based on two years of multi-location trial, the genotype DZ-01-192 X GA-10-3 (RIL. 185) and DZ-01-192 X GA-10-3 (RIL. 262) were given a higher grain yield performance of 2260.3 kg ha^{-1} and 2254.5 kg ha^{-1} respectively. However, no single genotype exhibits consistent superiority for grain yields across locations. However, DZ-01-192 X GA-10-3 (RIL. 185) and DZ-01-192 X GA-10-3 (RIL. 262) had better yield performance among the tested tef genotypes and they excelled the standard check varieties *Boset* significantly. Consequently, the promising genotype for yield performance will be further tested in the variety verification trial and it would be advisable to use those genotypes as a parental line for future breeding work for the development of semi-dwarf variety.

CONCLUSION

The current experiment was carried out on 20 semi-dwarf tef recombinant inbred lines that were selected from DZ-01- 192 X GA-10-3 crosses of F7 single seed descent developed inbred lines. Analysis of variance combined over six environments showed highly significant differences among genotypes, location, year and year genotype and location interaction for grain yield. The substantial inconsistency among the tef genotypes for several agronomic and morphological traits could be due to gene recombination or reshuffling resulting from mutagenesis and subsequent crossings. Furthermore, the highly significant genotype by environment interaction effects revealed differential performances of the test genotypes across the locations. Hence, further evaluation of the genotypes in the environment where they perform well will enable their recommendation for the specific release. About 50% of the tested genotypes had higher yield performance over the standard check *Boset* and 80% of the tested genotypes were yielder than the local check. The genotype DZ-01-192 X GA-10-3 (RIL. 185) showed 241.7 kg ha^{-1} and 358.2 kg ha^{-1} grain yield advantage over the standard (*Boset*) and local check, respectively. This proves that continuous crossing, breeding and exploitation of natural diversity plays a crucial role in the development of improved varieties like lodging resistant. The genotype DZ-01-192 X GA-10-3 (RIL. 185) scored 2260 kg ha^{-1} (Table 4) which was the maximum grain yield recorded among tested genotypes across pooled environments. From the current study, we can conclude that genotypes identified with better grain yield related traits and reasonable lodging tolerance require further evaluation and eventual release to the farming communities in tef growing environments in the country.

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