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Effect of Sowing Date on the Performance of Drought Tolerant Tef *(Eragrostis tef (Zucc.)Trotter)* Genotype in the Central Rift Valley of Ethiopia

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Abstract: **Tef [Eragrostis tef (Zucc.)Trotter] productivity in Ethiopia is relatively low as compared to other cereals. Its production is constrained, mainly by drought and climate variability, coupled with lack of appropriate sowing time. Therefore, the study was conducted to elucidate, pinpoint and recommend the response of ten selected recombinant inbred lines and two early maturing standard check tef varieties during 2017/18 and 2018/19 main season at Alem Tena and Melkassa Research center that represented the drought prone area in the central rift valley of Ethiopia. The experiment was laid out in split plot design with three replication. The treatments consisted of three sowing date (June 30, 10 July and 20 July) as main factors and 10 genotype as sub factors and two standard checks have included. The result reveled early sowing on June 30 mean grain yield was 2.317 t ha $^{-1}$, the normal sowing date July10 the mean grain yield were 2.319 t ha $^{-1}$ and the late sowing date 20 July was 2.71 t ha $^{-1}$. The combined analysis of the two years variance over locations revealed highly significant variation (P≤0.01) among both sowing times, and tef genotypes for the 5 traits evaluated. The seasonal rainfall distribution was with about 73% of the annual rainfall received in the five months of June to October 2017/18-2019, thus, even the latest third planting date of 20 July 2019 was successful, showing high grain yield record than the other sowing dates. Consequently, the dates that ranged July 10 to July 20 are recommendable as appropriate time of sowing.**

Keywords: **genotype, grain yield, rainfall, sowing dates, traits.**

1. INTRODUCTION

Tef [*Eragrostis tef* (Zucc.) Trotter] is an allotetraploid (2n=4x=40), small cereal grain crop that belongs to the family Poacea, sub-family Eragrostoideae, tribe Eragrostidae and genus *Eragrostis* (Ketema, 1997). Its origin and diversity is in Ethiopia [1]. Tef is the most important cereal crop in Ethiopia for its largest area coverage and its high value for food, feed, but with low grain yield of 1.85 t ha^{-1} [2] Drought is one of the main contributing factors for its low yield level. Tef is also known to be tolerant to extreme climatic and soil conditions; hence, it is a favorite crop in the semi-arid areas with moisture limitations [3] However, about 25.5 to 51% grain yield reductions have been reported for tef due to moisture stress [4] [5] Drought is a complex quantitative trait controlled by many genes and affected by the environment and genotype by environment interactions [6] . Breeding for drought tolerance depends on the accumulation of additive genes, a controlled stress screening environment and high throughput selection methods to maximize selection gains [7]. Developing moisture stress tolerant varieties with high yield potential is one of the main goals of the national tef breeding program [8]Assefa et al., (2011). A tef variety locally referred to as Tseday (DZ-Cr-37), released in 1983, and is the most widely grown improved variety in the moisture stressed areas. Summaries of the farmer-preferred traits of tef across four drought-prone districts of Tigray Region described that high grain yield is the first preferred trait, followed by a long panicle length and high straw yield [9] .

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In most of the tef growing regions, including the areas that receive sufficient annual rainfall, tef suffers from moisture stress at different stages of the growth. In the central highlands, terminal moisture stress is very important due to late planting time. Studies made to investigate the ability of tef to response to changes in the photoperiod using four tef cultivars showed differential genotype responses [9]. Hence, it would be imperative to examine the phenologic plasticity, and to evaluate different tef genotype characters and the response of planting time under rain fed condition in central rift valley environment of Ethiopia to attempt towards combating the problem of drought in tef.

2. MATERIALS AND METHODS

Experimental Sites Description

The field experiment was carried out at two terminal drought-prone locations (Melkassa Agricultural Research Center and Alem Tena sub-station of Debre Zeit Agricultural Research Center) during the 2017/18 and 2018/19 main cropping season. Melkassa is located in East Shewa Zone of Oromiya, about 115 km South East of Addis Ababa. Alem Tena is also located in East Shewa Zone of Oromiya about 112 km south-south east of Addis Ababa. It is located at 8° 18'27" N latitude and 38° 20 ' 6" E longitude with elevation of 1653 masl (Table 1). It receives annual total rainfall of 689 mm with maximum and minimum mean daily temperatures of 29.49 ^{0}C and 15.29 ^{0}C, respectively.

Table 1: Geographical coordinates and weather data of the test locations

Location	Latitude (N)	Longitude (E)	Altitude (masl)	Rainfall (mm)	Mean temperature (^{0}C)		Soil type
					maximum	minimum	
Melkassa	8°23'52"	39°20'6"	1539	591	28.56	16.07	"*Nitosols*"
Alem Tena	8°18'27"	38°20'6"	1575	589	29.49	15.29	"*Nitosols*"

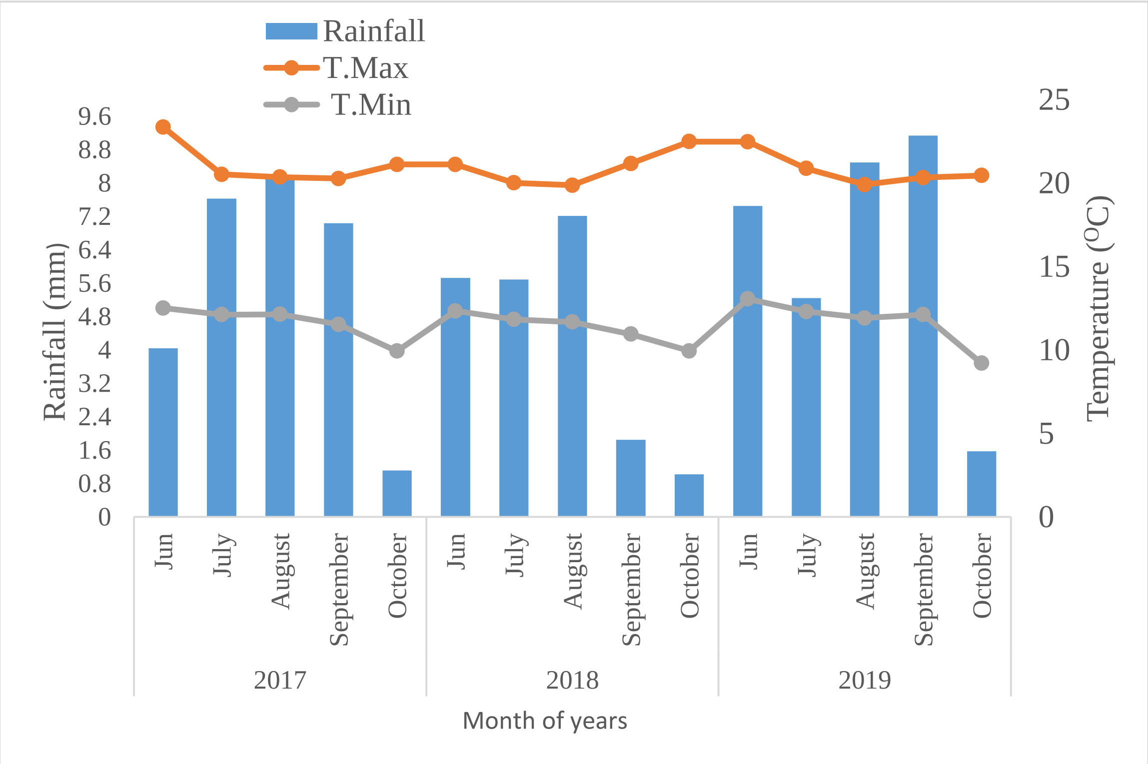

Figure 1: Mean monthly annual rainfall and max, min temperature distribution of Melkassa sub-station (based on data from 2017 to 2019)

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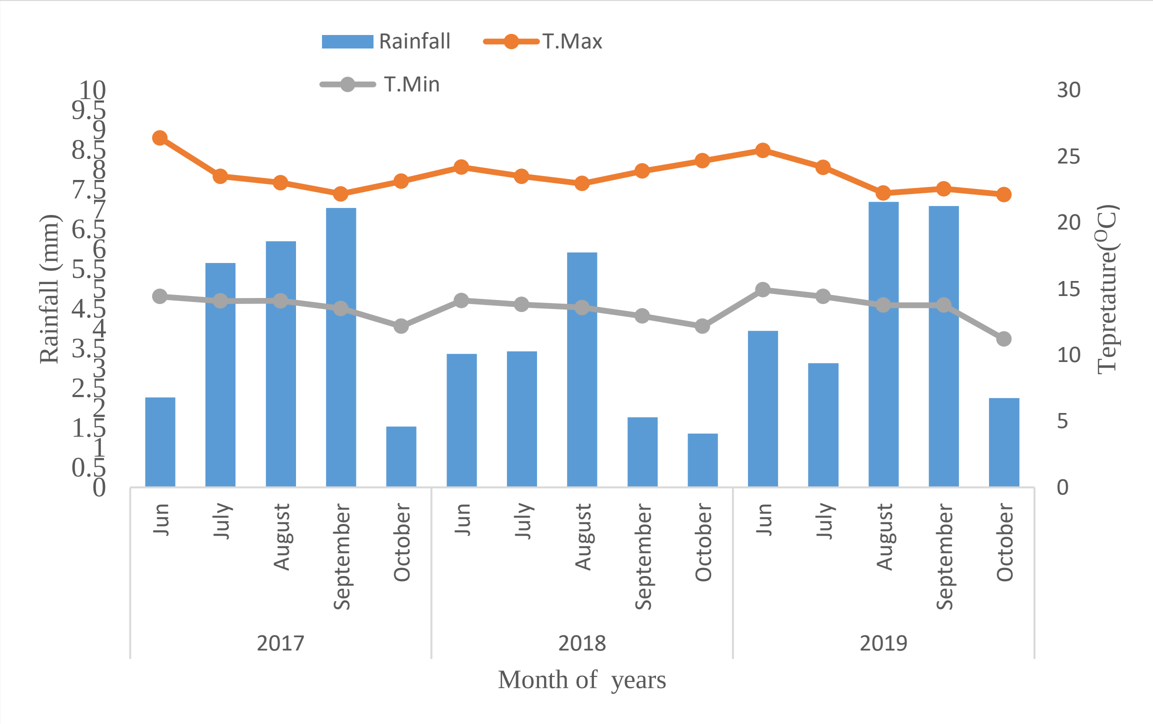

Figure 2: Mean monthly annual rainfall and max, min temperature distribution of Almetena sub-station (based on data from 2017 to 2019

Experimental Design and Management

The field experiment consisted of 36 entire factorial treatment combinations of three sowing dates and twelve tef genotypes including two standards check varieties. It was carried out in three replications of split plot design with three sowing dates [June 30, 10 July and 30 July (considering early, normal and late planting, respectively)] as main plots and genotypes as sub-plots. The size of the main plots was 23m x27m and the sub-plots 2m x1m (2 m^2). The total number of rows per sub plot was five and the spacing's were 0.2 m between rows, and 1.5 m and 1 m between blocks and plots, respectively. As per the research recommendations 15 kg ha^{-1} (3 g $plot^{-1}$) of seeds was hand broadcast on the surfaces of each row. Fertilizers used were 40 kg N and 60 kg P_2O_5 per hectare as recommended for "Nitosols" (light soils) by [10]. DAP was applied all at planting, while urea was applied three weeks after sowing and top dressed at tillering stage. Hand weeding was made two times during the crop growth stages (i.e. early and late tillering) depending on the weed infestation. All other pre-and post-stand establishment management practices were performed as per the recommended cultural practices of the specific test locations.

Experimental Planting Materials

Ten selected recombinant inbred lines (RILs) and two early maturing standard check varieties were used (Table 2). The RILs have been developed at DZARC by the National Tef Improvement Program, the parents of the RILS were developed through TILLING (Target Induced Local Lesions in Genomes) and they were relatively early maturing types selected based on their high grain and biomass yield in the moisture stress environments of the rift valley areas of Ethiopia in earlier observation nurseries. The seed color of all the test genotypes were white.

Table 2: Description of the tef genotypes used in the field experiment

No.	Genotypes	Panicle form	Lemma Color (Immature)	Phenology	
				Days to heading	Days to maturity
1	Dtt_2 X Dtt_{13}RIL182	Loose	Variegated (purple and yellow)	35	78

2	Dtt_2 X Dtt_{13}RIL78	Loose	Yellowish green	34	78
3	Dtt_2 X Dtt_{13}RIL270	Very loose	Yellowish green	35	77
4	Dtt_2 X Dtt_{13}RIL128	Very loose	Variegated (purple and yellow)	35	76
5	Dtt_2 X Dtt_{13}RIL96	Loose	Yellowish green	33	78
6	Dtt_2 X Dtt_{13}RIL37	Loose	Yellowish green	38	78
7	Dtt_2 X Dtt_{13}RIL101	Very Loose	Yellowish green	35	79
8	Dtt_2 X Dtt_{13}RIL70	Loose	Yellowish green	34	78
9	Dtt_2 (Parental line)	Very loose	Yellowish green	35	76
10	Dtt_{13} (Parental line)	Very loose	Yellowish green	35	78
11	Boset(DZ-Cr-409) (Standard check)	Fairly loose	Variegated (red and yellowish)	37	78
12	Simada (DZ-Cr-385) (Standard check)	Fairly loose	Yellowish green	34	76

Dtt refers to “drought tolerant”.

Data Collection

Data on plant maturity and panicle length were taken randomly from the three central row per plot, while shoot biomass and grain yield was recorded on plot basis. Grain filling period was calculated by subtracting the date of physiological maturity period to the date of panicle emergence. ,

Data Analysis

All measured variables were subjected to analyses of variance (ANOVA) on individual location basis using the standard procedure for split plot design in randomized complete blocks as described by [11]. Homogeneity of error variance was checked using the method of F-max test method of [12], which 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. Combined analysis of variance over locations and year was done after getting positive results from the testing for homogeneity of error variances using SAS statistical package [13]

3. RESULTS AND DISCUSSION

Agronomic traits

Days to physiological maturity

The analysis variance showed ($p<0.0001$) differences among genotype over years and locations for physiological maturity, main effect of sowing date and sub effect of genotypes (Table 3), while the interaction affect as well as and the main effect and genotype Dtt_2X Dtt_{13} RIL37 recorded the mean of days to maturity 78 days and this genotype was high yielder. The least maturity date was showed by Dtt_2X Dtt_{13} RIL27-0 which has a record of 70 days. Flowering and maturity period are two easily measured traits to be considered in screening trials. Some research have been investigated that the numbers of days to flowering and maturity have a positive correlation with yield while under moisture stress the correlation is negative. Therefore, selection should be targeted for early flowering and maturity genotypes [14], [7], [15] and Tef Cultivars: Morphology and Classification have been reported.

Grain filling period

The main effects of sowing dates and sub effect genotype was revealed highly significant difference ($p<0.0001$) among genotype over year, location and sowing time the result showed on planting date on July 20 the overall mean of 38 days was reported, which is the least of the other sowing date (Table 3). The short grain filling period helps the plant to escape the water tense during the moisture stress period.

Panicle length

The present study combined analysis of variance, panicle length depicted significant (P≤0.05) effects the combined analysis of variance, while the effects of sowing dates and the interaction effects of sowing dates and genotypes were exhibited (Table 3).In these study planting date of July 20 genotype Dtt2 X Dtt13 RIL101 substantial variation in panicle length of the genotypes can be attributed to their inherent genetic resulted the panicle length of 41.10cm which is the highest, followed by Dtt2 X Dtt13 RIL37(40.65 cm). Which are in the loose panicle form types ranged from 33.74-42.14 cm. Farmers in all the districts described that high grain yield is the first preferred trait, followed by a long panicle length [9]. The result is in agreement with Ebba [16].

Table 3: Interaction effect of dates of sowing and genotype over year and location on DTM, PAL and GFP value at Alem Tena and Melkassa, 2017/18-2019

No	Genotype	Planting Date Jun 30			Planting date July 10			Planting Date July 20		
		DTM	PAL	GFP	DTM	PAL	GFP	DTM	PAL	GFP
1	Dtt2XDtt13RIL182	83.58^{c-e}	36.61^{b-e}	45.41^{d-f}	79.66^{de}	37.81^{ab}	44.33^{cd}	71.91^{ab}	35.28^{c}	37.75^{a-c}
2	Dtt2XDtt13RIL78	84.58^{b-d}	36.26^{ced}	48.00^{ab}	80.91^{a-d}	35.48^{b}	46.00^{a-d}	72.25^{a}	37.03^{a-c}	37.00^{a-c}
3	Dtt2XDtt13RIL27-0	83.00^{d-f}	37.63^{bcd}	43.58^{f}	80.08^{c-e}	35.66^{b}	45.33^{a-d}	70.83^{a-c}	35.81^{c}	37.16^{a}-^{c}
4	Dtt2XDtt13RIL128	82.00^{e-g}	38.51^{bc}	43.91^{ef}	81.00^{a-d}	38.67^{ab}	45.75^{a-d}	70.50^{bc}	35.21^{c}	36.25^{bc}
5	Dtt2XDtt13RIL 96	83.33^{de}	36.41^{b-d}	47.58^{a-c}	82.33^{a}	36.38^{b}	47.16^{a}	71.16^{a-c}	39.25^{a-c}	39.25^{a}
6	Dtt2 XDtt13RIL37	76.58^{h}	41.65^{a}	43.67^{f}	74.41^{f}	41.75^{a}	40.83^{e}	70.91^{a-c}	40.65^{ab}	35.16^{c}
7	Dtt2 XDtt13RIL101	85.17^{bc}	38.03^{bcd}	48.08^{ab}	81.83^{ab}	39.26^{ab}	46.83^{ab}	72.41^{a}	41.10^{a}	38.16^{ab}
8	Dtt2 XDtt13 RIL70	87.17^{a}	37.48^{b-e}	49.41^{a}	79.33e	37.31^{ab}	44.66^{b-d}	72.33^{a}	39.25^{bc}	39.25^{a}
9	Dtt2 (Parental line)	81.25^{g}	35.58^{de}	43.75^{ef}	80.91^{a-d}	36.80^{b}	45.16^{a-d}	72.50^{a}	39.00^{ab}	39.00^{a}
10	Dtt13 (Parental line)	84.58^{b-d}	36.90^{b-d}	46.66^{b-d}	81.08^{a-d}	35.93^{b}	46.50^{a-c}	72.08^{ab}	35.63^{c}	37.33^{a-c}
11	Boset (DZ-Cr-409) (Stan. check)	85.25^{b}	38.91^{b}	45.83^{c-e}	81.50^{a-c}	37.85^{ab}	43.91^{d}	71.75^{ab}	38.67^{a-c}	38.25^{ab}
12	Simada (DZ-Cr-385) (Stan. check)	82.00^{fg}	34.91^{e}	45.08^{d-f}	80.50^{c-e}	36.43^{b}	45.75^{a-d}	70.00^{c}	35.60^{c}	36.83^{a-c}
	LSD (0.05)	1.63	2.64	2.20	1.54	4.83	2.48	1.67	4.81	2.62
	Overall mean$^{\delta}$	83.13	37.41	45.91	80.29	37.44	45.18	71.47	37.28	37.61
	Pr >F	<.0001	0.0609	0.0006	<.0001	0.0002	<.0001	0.0993	0.0043	0.0104
	CV (%)	5.45	9.15	10.79	2.60	8.54	5.25	3.59	11.97	7.34

Shoot Biomass

The analysis of variance showed that above-ground dry shoot biomass was highly significantly (P≤0.05) affected by sowing date as well as genotypes, while at each of the individual test locations of Alem Tena as well as on the average over these two locations, and over year the means for above-ground dry tef shoot biomass yield for the first sowing date were significantly lower than those of the second and third sowing dates which exhibited statistically comparable means; substantial genotype differences in above-ground dry shoot biomass yield the combined analysis of variance over locations and year revealed planted on July 20 has 15761.46 kg ha^{-1} (Table 4). Some research study reported that the effect of genotypes was significant for days to maturity, grain yield, and shoot biomass and plant height Some research study investigated that descriptive statistical values for phenological traits, components of plant height, shoot biomass [17] [4].

Analysis of 10 RILs and two standard check varieties by sowing time tested at two location and years is presented in Figure 3. Axis 1 abscissa and ordinate is the single arrow pointed that found ordinate genotype code 6 (Dtt2 XDtt1337 and the abscissa date 3 planted July 20 while consistently the single arrowed lined and pointed and obtained higher mean yield, the analysis of variance do the same (Table-5) Consistently, Yan [18] reported that the mean grain yield and stability of genotypes the abscissa and ordinate passes through the origin of the plot and is perpendicular to the MET abscissa and points to greater uncertainty in axis.

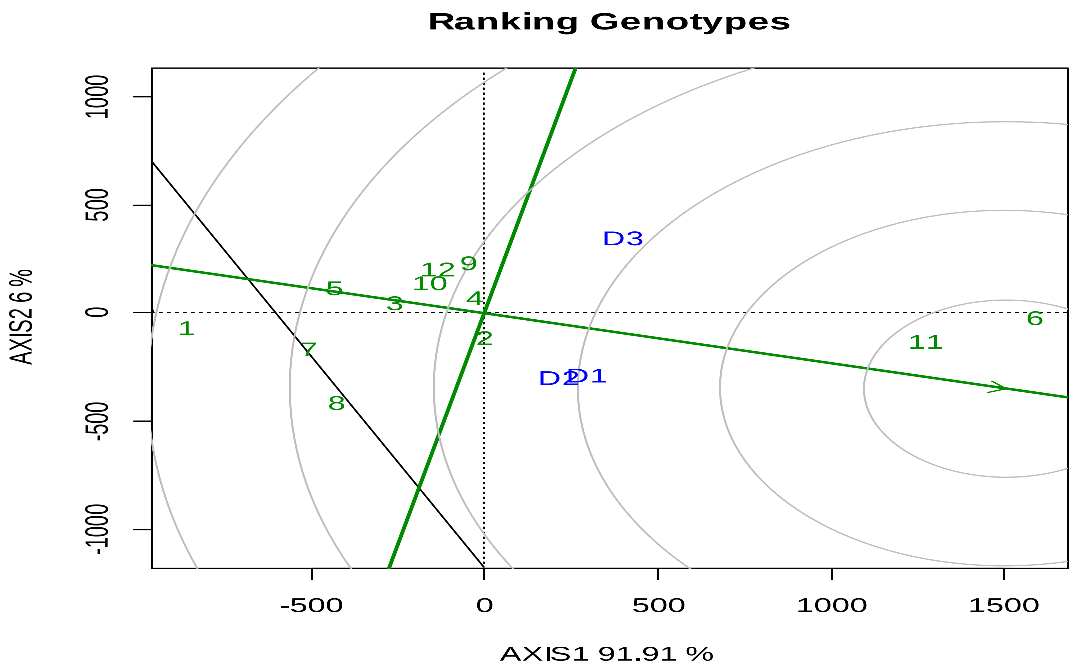

Figure 3: Analysis of 10 RILs and two standard check varieties by sowing time tested at two location and years

Table 4: Interaction effect of dates of sowing and genotype over year and location on shoot biomass and grain yield value at Alem Tena and Melkassa, 2017/18-2019

No	Traits	**Means of Sowing date (over all genotype)** June 30	July 10	July 20	LSD (0.05)	(Pr> F)
	Shootbiomass kg ha^{-1}	14508.3^{b}	14927.1^{b}	15761.5^{a}	675.05	<.0001
	Grain yield kg ha-^{1}	2317.08^{b}	2319.72^{b}	2710.97^{a}	327.17	<.0001

No	Genotype	Shoot bio-mass kg ha^{-1}	Grain yield kg ha^{-1}	Shoot biomassKg ha^{-1}	Grain yield kg ha^{-1}	Shoot bio mass kg ha^{-1}	Grain yield kg ha^{-1}
1	Dtt2XDtt13RIL182)	13020.8^{d}	1862.5^{b}	14437.5^{c-e}	2034.6^{b}	15125.0de	2034.6^{e}
2	Dtt2XDtt13 RIL78)	14250.0^{bc}	2373.3^{b}	13875.0^{e}	2370.0^{b}	15212.5^{c-e}	2639.2^{cd}
3	Dtt2XDtt13 RIL 27-0)	13625.0^{cd}	2286.7^{b}	14083.3^{e}	2033.8^{b}	15645.8^{cd}	2536.7^{b-e}
4	Dtt2XDtt13RIL128)	14291.7^{bc}	2292.5^{b}	15583.3ab	2230.4^{b}	14437.5^{e}	2735.0^{bc}
5	Dtt2XDtt13RIL 96)	14166.7^{bc}	1924.2^{b}	14333.3^{de}	2185.0^{b}	15895.8^{cd}	2483.8^{c-e}
6	Dtt2 XDtt13RIL37)	16541.7^{a}	3106.7^{a}	16208.3^{a}	3037.1^{a}	18029.2^{a}	3890.8^{a}
7	Dtt2 XDtt13RIL101)	14170.8^{bc}	2017.5^{b}	15145.8^{b-d}	2318.3^{b}	15250.0^{c-e}	2242.1^{de}
8	Dtt2 XDtt13 RIL70)	14187.5^{bc}	2337.5^{b}	14437.5^{c-e}	2322.1^{b}	15520.8^{cd}	2120.8^{de}
9	Dtt2 (Parental line)	14312.5^{bc}	2149.6^{b}	15000.0^{b-d}	2190.0^{b}	15541.7^{cd}	2840.8^{b}
10	Dtt13 (Parental line)	14645.8^{b}	2125.8^{b}	15250.0^{bc}	2212.1^{b}	15437.5^{cd}	2697.5^{bc}
11	Boset (DZ-Cr-409) (Stan. check)	16416.7^{a}	3117.5^{a}	16270.8^{a}	2832.9^{a}	16958.3^{b}	3567.5^{a}
12	Simada (DZ-Cr-385) (Stan. check)	14470.8^{bc}	2211.3^{b}	14500.0^{c-e}	2070.4^{b}	16083.3^{bc}	2742.9^{bc}
	LSD	906.55	678.72	871.11	339	946.86	525.77
	Overall mean$^{\delta}$	14508.3	2317.08	14927.8	2319.71	15761.46	2710.97
	Pr >F	<.0001	<.0001	0.0012	0.0012	<.0001	<.0001
	CV (%)	8.37	26.79	10.30	26.11	8.56	22.86

4. CONCLUSION AND RECOMMENDATION

Based on the result, sowing date and genotypes had a significant effect on grain yield and shoot biomass of tef. The Dtt2 XDtt13 RIL37 revealed highest grain yield of 3890.8 kg ha^{-1} and out performed in most of the traits studied. In line with this Dtt2 X Dtt_{13} RIL 37 has been identified for variety verification trail during main cropping season of 2020. This line showed better drought escaping ability than the other genotypes tested even to the standard check Boset (DZ-Cr-409). Consequently, the dates that ranged from July 10to July 20 are recommendable as appropriate time of sowing. Hence, this study demonstrated the need to evaluate genotypes and appropriate sowing time in the moisture-stressed environment helps to select varieties with either high grain yield potential or yield stability in the drought-prone areas.

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REFERENCES

[1] Vavilov NI (1951). The origin, variation, immunity and breeding of cultivated plants, Translated from the Russian by K S. Chester, Ronald Press, Co., New York, USA.

[2] CSA (Central statistics Agency) (2020). Report on Area and Production of Major Crops (private peasant holdings, Meher season). Vol I, Statistical Bulletin 587, Addis Ababa, Ethiopia.

[3] Zerihun Tadele; Assefa, Kebebew. 2012. "Increasing Food Production in Africa by Boosting the Productivity of Understudied Crops" Agronomy 2, no. 4: 240-283. https://doi.org/10.3390/agronomy2040240

[4] Admas, S.,and G. Belay. 2011. Drought-resistance traits variability in Eragrostis tef X Eragrostis pilosa recombinant inbred lines. African Journal of Agricultural Research 6:3755-3761.

[5] Shiferaw, Wondwesen & Balcha, Alemayehu & Mohammed, Hussen. (2012). Genetic Variation for Grain Yield and Yield Related Traits in Tef [Eragrostis tef (Zucc.)Trotter] under Moisture Stress and Non-Stress Environments. Am. J. Plant Sci. 3.

[6] H. Tefera, G. Belay, and M. Sorrels (eds), Narrowing The Rift: Tef Research and Development. Proceedings of the International Workshop on Tef Genetics and Improvement. Debre-Zeit, Ethiopia, 16-19 October, 2000. Ethiopian Agricultural Research Organization. Debre-Zeit, Ethiopia. P.3-7.

[7] Blum, A. 2011. Plant Breeding for Water-limited Environments. Springer, New York, USA. 28

[8] Assefa K, Ketema S, Tefera H, Hundera F, Kefyalew T (2001). Genetic diversity for agronomic traits in tef. Hailu Tefera, Getachew Belay and Mark Sorrells (eds.), Narrowing the Rift: Tef Research and Development, Proceedings of the International Workshop on Tef Genetics and Improvement, 16-19 October (2000), Addis Ababa, Ethiopia pp. 33-48.

[9] Abraha, M.T., H. Shimelis, M. Laing, and K. Assefa. 2016. Diagnostic assessment of the production status, constraints and farmer-preferred traits of tef [Eragrostis Tef (Zucc.) Trotter] under drought-prone environments. Transylvanian Review 24:926-939

[10] van de Wouw MJ, Kik C, van Hintum TJL, van Treuren R, Visser L (2010). Genetic erosion in crops: concept, research results and challenges. Plant Genetic Resources 8(1):1-15.

[11] Mamo T, Richter C, Heiligtag B (2002). Phosphorus Availability Studies on Ten Ethiopian Vertisols, Journal of Agriculture and Rural Development in the Tropics and Sub-tropics 103:177-183.

[12] Gomez KA, Gomez AA (1984). Statistical Procedures for Agricultural Research.2ndedition, John Wiley and Sons Incorporated New York, USA.

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Vol. 8, Issue 2, pp: (20-28), Month: March - April 2021, Available at: www.noveltyjournals.com

[13] Hartley, H.O. (1950). The Use of Range in Analysis of Variance. Biometrika, 37, 271-280.http://dx.doi.org/ 10.1093/biomet/37.3-4.271

[14] SAS Institute (2002). SAS/STAT Guide for Personal Computers, Version 9.00 editions. Cary, N.C., SAS Institute Inc.

[15] KILIÇ, H., & YAĞBASANLAR, T. (2010). The Effect of Drought Stress on Grain Yield, Yield Components and Some Quality Traits of Durum Wheat (Triticum turgidum ssp. durum) Cultivars. Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 38(1), 164-170.

[16] Ebba T (1975). Tef (Eragrostis tef) Cultivars: Morphology and Classification, Part II. Experiment Station Bulletin 66, Addis Ababa University, College of Agriculture, Dire Dawa, Ethiopia

[17] Ketema S (1993). Tef (Eragrostis tef): Breeding, Genetic Resources, Agronomy, Utilization and Role in Ethiopian Agriculture. Institute of Agricultural Research, Addis Ababa, Ethiopia.

[18] Yan, W. et Tinker, N. A. 2006. Biplot analysis of multi-environment trial data: Principles and applications. Can. J. Plant Sci. 86: 623–645.

[19] Admas, S.,and G. Belay. 2011. Drought-resistance traits variability in Eragrostis tef X Eragrostis pilosa recombinant inbred lines. African Journal of Agricultural Research 6:3755-3761.

[20] Assefa K, Ketema S, Tefera H, Hundera F, Kefyalew T (2001). Genetic diversity for agronomic traits in tef. Hailu Tefera, Getachew Belay and Mark Sorrells (eds.), Narrowing the Rift: Tef Research and Development, Proceedings of the International Workshop on Tef Genetics and Improvement, 16-19 October (2000), Addis Ababa, Ethiopia pp. 33-48.

[21] Assefa, K., Yu, J. K., Zeid, M., Belay, G., Tefera, H., & Sorrells, M. E. (2011). Breeding tef [Eragrostis tef (Zucc.) trotter]: conventional and molecular approaches. Plant Breeding, 130(1), 1-9. Bultosa Beri, G. (2006).

[22] Assefa K, Yu JK, Zeid M, Belay G, Tefera H, Sorrells ME (2011b). Breeding tef [Eragrostis tef (Zucc.) Trotter]: conventional & molecular approaches, Plant Breeding 130:1-9.

[23] Assefa K, J.K. Yu, M. Zeid, G. Belay, H. Tefera, and M.E. Sorrells. 2011. Breeding tef [Eragrostis tef (Zucc.) Trotter]: conventional and molecular approaches. Plant Breeding 130:1-9.

[24] Ayele M, Ketema S (1995). Potentials of physiological traits in breeding of tef (Eragrostis tef) for drought resistance with emphasis on excised-leaf water loss, Proceedings of the Sixth Annual Conference of the Crop Science Society of Ethiopia, Addis Ababa, Ethiopia.

[25] Birhanu A, Degenet Y, Tahir Z (2020). Yield and agronomic performance of released Tef [Eragrostis tef (Zucc.) Trotter] varieties under irrigation at Dembia, Northweastrn, Ethiopia. Cogent Food and Agriculture 6:1

[26] Bultosa G, Hall AN, Taylor JRN (2002). Physico-chemical characterization of grain tef [Eragrostis tef (Zucc.) Trotter] starch, Starch-Starke 54:461-468.

[27] Blum, A. 2011. Plant Breeding for Water-limited Environments. Springer, New York, USA. 28

[28] Cannarozzi, G. 2015. Whole genome sequencing of Eragrostis tef. Presented at Plant and Animal Genome XXIII Conference, San Diego, USA, January 10 - 14, 2015.

[29] Caldicott JJB, Nuttall AM (1979). A method for the assessment of lodging in cereal crops. Journal of the National Institute of Agricultural Botany 15:88-91.

[30] Central Statistical Agency (CSA) (2018). Agricultural sample survey for 2018. Addis Ababa, Ethiopia. Statistical Bulletin 1:586.

[31] CSA (Central statistics Agency) (2020). Report on Area and Production of Major Crops (private peasant holdings, Meher season). Vol I, Statistical Bulletin 587, Addis Ababa, Ethiopia.

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Vol. 8, Issue 2, pp: (20-28), Month: March - April 2021, Available at: www.noveltyjournals.com

[32] Ebba T (1975). Tef (Eragrostis tef) Cultivars: Morphology and Classification, Part II. Experiment Station Bulletin 66, Addis Ababa University, College of Agriculture, Dire Dawa, Ethiopia

[33] Gomez KA, Gomez AA (1984). Statistical Procedures for Agricultural Research.2ndedition, John Wiley and Sons Incorporated New York, USA.

[34] Hartley, H.O. (1950) The Use of Range in Analysis of Variance. Biometrika, 37, 271-280.http://dx.doi.org/10.1093/biomet/37.3-4.271

[35] Ketema S (1993). Tef (Eragrostis tef): Breeding, Genetic Resources, Agronomy, Utilization and Role in Ethiopian Agriculture. Institute of Agricultural Research, Addis Ababa, Ethiopia.

[36] Ketema S (1997). Promoting the Conservation and use of underutilized and neglected Crop ISBN 92-9043-304 via dell sett Chiese 142 00145 Roma Italy International Plant Genetic Resource Institute.

[37] Legesse A (2004). Response of tef [Eragrostis tef (Zucc.)Trotter] to applied nitrogen and phosphorus in Sirinka, North Eastern Ethiopia. MSc Thesis, Haramaya University, Haramaya, Ethiopia.

[38] Mamo T, Richter C, Heiligtag B (2002). Phosphorus Availability Studies on Ten Ethiopian Vertisols, Journal of Agriculture and Rural Development in the Tropics and Sub-tropics 103:177-183.

[39] Richards RA, Rebetzke GJ, Condon AG, van Herwaarden AF (2002). Breeding Opportunities for Increasing the Efficiency of Water Use and Crop Yield in Temperate Cereals Crop Science 42(1):111-121

[40] SAS Institute (2002). SAS/STAT Guide for Personal Computers, Version 9.00 editions. Cary, N.C., SAS Institute Inc.

[41] Tekele A (2001). Canopy temperatures and excised leaf water loss of tef [Eragrostis tef (Zucc.) Trotter] cultivars under water deficit conditions at anthesis. Acta Agronomica Hungarica 49(2):109-117.

[42] Yan, W. et Tinker, N. A. 2006. Biplot analysis of multi-environment trial data: Principles and applications. Can. J. Plant Sci. 86: 623–645.

[43] van de Wouw MJ, Kik C, van Hintum TJL, van Treuren R, Visser L (2010). Genetic erosion in crops: concept, research results and challenges. Plant Genetic Resources 8(1):1-15.

[44] Vavilov NI (1951). The origin, variation, immunity and breeding of cultivated plants, Translated from the Russian by K S. Chester, Ronald Press, Co., New York, USA.