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Research paper

Performance evaluation of tef varieties for yield and yield related traits in east Gojam zone of Amhara region

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Tef is the only cereal cultivated for human consumption in the genus *Eragrostis.* Compared to other cereal crops tef is resilient and able to withstand adverse weather conditions. The major problems for adaptation of tef are lack of diversified alternative improved varieties adapted to the study area and limited availability of varieties. This study was carried out to recommend best adapted and high yielder tef varieties in the study area. A total of twelve released tef varieties were used in the experiment. Randomized Complete Block Design (RCBD) with three replications was used to execute this research activity. The analysis of variance showed that the genotypes differed significantly ($p< 0.05$) for harvest index, and lodging, and were highly significant ($p<0.001$) for days to heading, plant height and panicle length. Heritability estimate was moderately high for panicle length followed by plant height and days to 50% heading. Panicle length and plant height showed moderately high heritability with a high genetic advance as a percent of the mean. Grain yield showed a positive and highly significant ($P < 0.001$) correlation with biomass yield (0.97), lodging index (0.84) and plant height (0.82). To alleviate the limited access of improved tef varieties to study area these selected varieties need to be demonstration and popularized to farmers with their full production package to enhance the productivity of tef crop.

Key words: *Adaptation, gluten-free, grain yield, lodging index, panicle length, Tef, variability*

INTRODUCTION

Teff (*Eragrostis tef* (Zucc.) Trotter), commonly referred to as teff, is an annual self-pollinated, allotetraploid ($2n = 4x = 40$) warm-season crop belonging to the Poaceae (grass) family (Assefa, 2015). Tef [*Eragrostis tef* (Zucc.) Trotter], a cereal crop that adapts to extreme climatic and soil conditions is extensively cultivated in the Horn of Africa (Chanyalew et al., 2019). It is also considered a nutritious and lifestyle crop due to its richness in essential nutrients and health-related benefits. It is the only cereal cultivated for human consumption in the genus *Eragrostis* (Tefera et al., 2003). The importance of tef in Ethiopia is mainly due to its preference by both farmers and consumers. Farmers, above all, grow tef due to its tolerance to several biotic and abiotic stresses especially to the poorly drained vertisols, a dominant soil type in the central highlands where other cereals can hardly survive without the use of a proper drainage system (Jifar et al., 2015). Tef is grown by more than 7.1 a million households with area coverage of 3.1 million hectares of land (CSA, 2020). It grows in various agro-climatic conditions from sea level to 3000 meters above sea level and different types of edaphic factors thus from light sandy to heavy clay soil in variable fertility but grown suitably at middle elevations between 1800 and 2200 meters above sea level and in regions where there is adequate rainfall. These characteristics, together with it being easy to store, seemingly explain the sustained importance of tef in Ethiopia (Bachewe et al., 2019).

Tef in Ethiopia stands first in area coverage and second in total annual production next to maize, and ranks the lowest yield compared with other cereals grown in Ethiopia (CSA, 2020). Amhara region is the second largest tef producer in the country next to Oromia region. Tef is the most dominant cereal crop in East Gojam zone accounting for nearly 23% of the total food grain production while covering about 30% of the total food grain cultivated land. (Setotaw et al., 2020). The tef crop in Amhara region is produced by 2,659,496 small scale farmers with area coverage of 1,156,131.09 hectares of land and about 2.2 million tone with average productivity of 1.9 tone /ha grain produced in 2019/20 cropping season. From these East gojam zone covers 494,368 small scale farmers with area coverage of 268,691.31 hectares of land and produced 557,843.8 tone with an average productivity of 2.07 tone / ha. (CSA,2020).

East Gojjam is the leading zone in Tef production constituting more than 10 percent of the national annual Tef production (Flaishman et al., 1997). Although the actual production of Teff is 2.29 ton/ha, the report of national Tef research commodity strategy 2016-2030, shows that the productivity of Tef can be increased by 4.34 ton/ha if farmers could adopt agricultural technologies (such as improved seed, row planting, herbicide and fertilizer) (Demelash et al., 2020). The major problems for adaptation of tef are lack of diversified alternative improved varieties of crops adapted to different agro-ecologies of the zone in quality and quantity, limited availability of varieties, wide-scale use of traditional and unimproved cultural practices, susceptible to lodging, inadequate seed supply system, changing rainfall patterns. Due to the above reasons, current cultivars of tef in this area were not giving the intended amount of yield. Hence this research activity was initiated to recommend best adapted and high yielder tef varieties in the study area of East Gojam Zone.

MATERIALS AND METHODS

Study area

The experiment was carried out by crop research process from July 2019 to January 2020 at Awable district and Debre-Markos Agricultural Research centre, which is located in the East Gojam zone of the Amhara Regional State. The elevation ranges between 2530 and 2470 m above sea level. The rainfall in the zone is unimodal and it varies from 900 - 1800 mm. The average temperature ranges between 7.5 and 27^{0}C. East Gojjam is dominated by low-input subsistence agriculture, with cultivation extending from the Blue Nile gorge up to the summit of the Choke Mountain.

Experimental Materials

A total of twelve recently released tef varieties were used in the experiment. These improved Tef varieties namely, DZ-Cr-438 (RIL 91A) (Dagiem), DZ-Cr-429(Neguse), DZ-Cr-457 (Tesfa), DZ-Cr-442 (Flagot), DZ-Cr-419 (Hiberland), DZ-Cr-438 (RIL 7) (Abola), Areka-1,DZ-Cr-458 (RIL-18) (Ebba),DZ-Cr-453 (RIL-120B) ,DZ-Cr-429 (RII 29) (Washera), DZ-01-256(Jitu),DZ-Cr-428(Mena)were brought from Debre Zeit Agricultural Research Center, which is the national tef research coordinating center.

Experimental Design and Procedures

The experiment was conducted in Randomized Complete Block Design (RCBD) with three replications. Each experimental plot had 10 rows at a spacing `of 20cm, having a plot length of 2 m and a width of 2 m. Fertilizer was applied according to the recommendation of the trial location at a rate of 100 kg NPS/ha and 160kg urea/ha. Sowing was done by hand drilling at the seed rate of 15 kg/ha. Other agronomic practices recommended for tef were done to ensure normal plant growth and development in the experimental field.

Data collection: Data was collected on plant and plot bases on yield and yield-related traits. Plant Height (cm), panicle length was recorded on the plant base. Whereas data like days to 50% emergence, days to 50% heading, days to 50% maturity, lodging index, shoot biomass, grain yield and harvest index were recorded on plot base

Data analysis: Analysis of variance (ANOVA) was carried out on the data to assess the genotypic effects and their interaction using general linear model (GLM) procedure for randomized complete blocks design (RCBD) using SAS software; version 9.4 . Mean comparisons among treatment means were conducted by the least significant difference (LSD) test at 5% levels of significance..

RESULTS AND DISCUSSION

The analysis of variance showed the presence of significant differences among the tested varieties for characters considered, indicating the existence of variability among the tested varieties. The analysis of variance showed that the genotypes differed significantly ($p < 0.05$) for harvest index, and lodging, and were highly significant ($p < 0.001$) for days to heading, plant height and panicle length. But Days to maturity biomass yield and grain yield per plot showed a non-significant variation on the tested genotypes (Table 1).

Based on this research; Dagim, Araka-1 and Niguse scored the highest grain yield 5.27 tone, 5.12 tone and 5.09 tons ha^{-1} respectively at the Ydabena site but statistically, there is no significant difference observed, on the contrary varieties showed significant difference ($p<0.05$) for grain yield at Debre Markos on the station, hence Filagot, Areka-1 and DZ-Cr-453

(RIL- 120B) comparatively scored maximum grain yield 1350, 1166.77 and 1129.17 kg ha^{-1} respectively (Table 2). In this research activity, all varieties scored maximum grain yield above two-fold of the national average of tef productivity 1850 kg ha-1 and regional tef productivity1894 kg ha^{-1}. From two locations the highest grain yield was obtained at the Ydabena

Table 1. The mean squares for different sources of variation for 8 Traits of 12 genotypes and the corresponding CV in percentage

Source of variation	df	Mean Square							
		DH	**DM**	**PH**	**PL**	**BMY**	**GY**	**HI**	**LOD**
Replication	2	19.680Ns	38.089Ns	13.383Ns	11.278Ns	3982639Ns	754552.2Ns	0.0034Ns	0.222Ns
Variety	11	125.619***	53.862Ns	345.336***	104.596***	2229798Ns	239215.9Ns	0.00602**	1.074**
location	1	4720.68***	1540.12**	18400.01**	65.26***	334834722***	271037403.1**	0.03***	70.01**
Variety x location	11	264.48Ns	34.30Ns	94.68**	11.73**	2612374Ns	171982.3Ns	0.002**	0.65**
Error	57	19.329	39.307	44.028	5.817	2143026	204692.3	0.00116	0.36

*Where; "**, *** Indicate significance at 0.05 and 0.01 probability levels' = non-Significant*

Where: GY = grain yield, DH = number of days to heading, DM = number of days to mature, PL = panicle length, PH = plant height, BMY = biomass yield, HI = harvest index, LOD =lodging index

Table 2. Mean value of different agronomic traits for tef varieties grown at DMARC on station

	Variety Name	DH	DM	PH	PL	BM	GY	HI	LOD
1	DZ-Cr-438 (RIL 91A) (Dagiem)	76.33	119.67	85.87	34.87	3666.67	991.67	0.27	1.00
2	DZ-Cr-429 (Neguse)	68.33	120.33	87.13	36.17	3833.33	941.67	0.24	1.00
3	DZ-Cr-457 (Tesfa),	75.33	125.00	83.80	34.53	3166.67	741.67	0.24	1.00
4	DZ-Cr-442 (Filagot)	72.00	112.67	86.27	32.00	4500.00	1350.00	0.30	2.33
5	DZ-Cr-419 (Hiberland	76.33	120.67	90.27	38.87	3833.33	995.83	0.25	1.00
6	DZ-Cr-438 (RIL 7) (Abola)	83.67	117.67	85.27	35.67	3166.67	600.00	0.19	1.00
7	Areka-1	61.67	120.00	81.27	33.07	3833.33	1166.67	0.30	1.33
8	DZ-Cr-458 (RIL- 18) (Ebba),	73.00	120.00	83.87	36.60	3333.33	825.00	0.24	1.00
9	DZ-Cr-453 (RIL- 120B)	69.67	116.67	89.20	37.53	4333.33	1129.17	0.26	2.33
10	DZ-Cr-429 (RII 29)(Washera)	73.67	116.33	92.07	39.37	3666.67	675.00	0.18	1.00
11	DZ-01-256(Jitu)	79.67	125.33	99.53	47.47	3666.67	600.00	0.16	1.00
12	DZ-Cr-428(Mena)	74.33	119.33	87.87	39.47	3833.33	725.00	0.19	1.00
Mean		73.67	119.47	87.70	37.13	3736.11	895.14	0.23	1.25
C.V		7.68	4.75	5.07	4.30	14.05	23.08	13.04	31.13
LSD		13.033	13.16	10.24	3.67	1208.9	475.59	0.07	0.89
P-value		**	Ns	**	***	Ns	**	***	**

*Where; "**, *** Indicate significance at 0.05 and 0.01 probability levels' =non-Significant*

Where: GY= grain yield, DH= number of days to heading, DM= number of days to mature, PL= panicle length, PH= plant height, BMY= biomass yield, HI= harvest index, LOD =lodging index

Table 3. Mean value of different agronomic traits for tef varieties grown at the Yedabena site

No	Variety Name	DH	DM	PH	PL	BM	GY	HI	LOD
1	DZ-Cr-438 (RIL 91A) (Dagiem)	59.00	109.67	122.27	38.87	17666.67	**5275.83**	0.30	3.00
2	DZ-Cr-429 (Neguse)	54.67	117.00	111.93	34.38	16666.67	5094.17	0.31	3.33
3	DZ-Cr-457 (Tesfa),	56.00	107.67	109.87	36.40	16000.00	4581.67	0.29	3.33
4	DZ-Cr-442 (Flagot)	50.67	104.33	105.80	32.00	16333.33	4444.17	0.27	2.67
5	DZ-Cr-419 (Hiberland	59.67	111.33	121.87	41.87	16666.67	4755.83	0.29	2.00
6	DZ-Cr-438 (RIL 7) (Abola)	62.33	111.00	117.40	40.57	20000.00	4678.33	0.23	3.67
7	Areka-1	50.33	104.33	105.27	32.80	16000.00	**5125.83**	0.32	3.33
8	DZ-Cr-458 (RIL- 18) (Ebba),	56.00	117.33	119.47	38.07	16833.33	4494.17	0.26	3.00
9	DZ-Cr-453 (RIL- 120B)	62.33	111.67	137.67	45.80	18833.33	4680.83	0.25	4.33
10	DZ-Cr-429 (RII 29)(Washera)	58.33	110.00	124.67	41.17	17666.67	4574.17	0.26	3.33
11	DZ-01-256(Jitu)	63.67	111.33	140.67	47.37	17833.33	4567.50	0.26	3.33
12	DZ-Cr-428(Mena)	56.67	107.00	119.20	39.17	18000.00	5034.17	0.28	3.33
Mean		**57.47**	**110.22**	**119.67**	**39.04**	**17375.00**	**4775.56**	**0.28**	**3.22**
C.V		**3.80**	**5.78**	**4.03**	**5.76**	**10.60**	**12.80**	**10.68**	**20.68**
LSD		**5.03**	**14.67**	**11.11**	**5.17**	**4241.2**	**1407.8**	**0.06**	**1.53**
P-value		***	**Ns**	***	***	**NS**	**Ns**	**	**Ns**

*Where; "**, *** Indicate significance at 0.05 and 0.01 probability levels' =non-Significant*

Where: GY= grain yield, DH= number of days to heading, DM= number of days to mature, PL= panicle length, PH= plant height, BMY= biomass yield, HI= harvest index, LOD =lodging index site which is characterized by heavy black soil that suffers from water logging with moderate drainage capacity. in contrast, Debre Markos on the station is mainly characterized by light Nitosols which is affected by soil acidity problem; hence yield reduction was observed due to the mentioned problem. The mean value of each quantitative trait over the two locations was computed at which the tested tef varieties showed a significant variation in all measured quantitative traits at Debre-Markos on the station but a non-significant variation on their grain yield potential in the Yedabna site which resulted in the over-all non-significant difference for grain yield over location for tested varieties (Table 2 & 3). The combined mean result revealed that highly significant (p <0.001) difference was observed for days to heading, plant height and panicle length and differed significantly (p < 0.05) for harvest index, and lodging, But Days to maturity biomass yield and grain yield per plot showed a non-significant difference on the tested genotypes (Table 4).

Phonological Characters

Days to heading: Highly significant differences in days to 50% heading was observed among genotypes ranging from 56.00 to 73.00 days. The highest days to heading was recorded for variety DZ-Cr-438 (RIL 7 (Abola) (73 days) followed by variety DZ-01-256 (Jitu) 71 days and variety DZ-Cr-419 (Hiberland) 68.00 days. in contrast variety, Areka1 showed an early heading date (56 days) followed by DZ-Cr-442 (Filagot) 56.33 days. (Chondie and Bekele, 2017) also reported similar results for days to 50% heading for tested varieties

(Tesfa) and DZ-Cr-429 (Neguse) showed the shortest plant height. Varieties that recorded the shortest plant height showed higher grain yield than those that scored higher plant height. (Bakala *et al*., 2018) reported significant plant height among different tef varieties. (Asaye Demelash, 2017) reported that Plant height is an important trait that positively contributes to yield directly and negatively to lodging on the other hand.

Panicle length: The analysis of variance showed a highly significant difference (*P<0.001*) for panicle length in different genotypes with a range of 32.93 - 47. 42 cm. Maximum panicle length (47.42 cm) was noted in variety DZ-01-256 (Jitu) followed by variety DZ-Cr-453 (RIL- 120B) DZ-Cr-419 (Hiberland) and DZ-Cr-429 (RII 29) (Washera). It was interestingly observed that genotypes showing tall plants had also shown long panicles and vice versa. This might be attributed due to the positive association between plant height and panicle length., (Chekole et al., 2020) reported similar findings with this research findings. The shortest plant height and panicle length were recorded by variety Areka-1 which scored maximum grain yield in this research.

Lodging index: Lodging significantly reduces the yield and quality of tef seed. Merga & Dachassa (2021) reported that lodging is not only affecting yield but also potentially deteriorating the quality of tef straw which is important feed source for livestoc. Significant differences were observed for lodging index among varieties across locations ranged from 1.5 to 3.3. The maximum lodging index was detected for

Table 4. Combine means for different traits of tef varieties for multi-location trial

	Variety Name	DH	DM	PH	PL	BM	GY	HI	LOD
1	DZ-Cr-438 (RIL 91A) (Dagiem)	67.67	114.67	104.07	36.87	10666.67	3133.75	0.29	2.00
2	DZ-Cr-429 (Neguse)	61.50	118.67	99.53	35.28	10250.00	3017.92	0.27	2.17
3	DZ-Cr-457 (Tesfa),	65.67	116.33	96.83	35.47	9583.33	2661.67	0.26	2.17
4	DZ-Cr-442 (Flagot)	56.33	108.50	96.03	32.00	10416.67	2897.08	0.29	2.50
5	DZ-Cr-419 (Hiberland)	68.00	116.00	106.07	40.37	10250.00	2875.83	0.27	1.50
6	DZ-Cr-438 (RIL 7) (Abola)	73.00	114.33	101.33	38.12	11583.33	2639.17	0.21	2.33
7	Areka-1	56.00	112.17	93.27	32.93	9916.67	3146.25	0.31	2.33
8	DZ-Cr-458 (RIL- 18) (Ebba),	64.50	118.67	101.67	37.33	10083.33	2659.58	0.25	2.00
9	DZ-Cr-453 (RIL- 120B)	66.00	114.17	113.43	41.67	11583.33	2905.00	0.25	3.33
10	DZ-Cr-429 (RII 29)(Washera)	66.00	113.17	108.37	40.27	10666.67	2624.58	0.22	2.17
11	DZ-01-256(Jitu)	71.67	118.33	120.10	47.42	10750.00	2583.75	0.21	2.17
12	DZ-Cr-428(Mena)	65.50	113.17	103.53	39.32	10916.67	2879.58	0.23	2.17
Mean		**65.56**	**114.84**	**103.68**	**38.08**	**10555.56**	**2835.34**	**0.225**	**2.236**
C.V		**6.705**	**5.45**	**6.39**	**6.33**	**13.88**	**15.95**	**13.36**	**26.98**
LSD		**6.764**	**9.646**	**10.209**	**3.711**	**2254.9**	**696.09**	**0.052**	**0.927**
LSD at 5%		***	**Ns**	***	***	**Ns**	**Ns**	**	**

*Where; "**, *** Indicate significance at 0.05 and 0.01 probability levels' =non-Significant*
Where: GY= grain yield, DH= number of days to heading, DM= number of days to mature, PL= panicle length, PH= plant height, BMY= biomass yield, HI= harvest index, LOD =lodging index

Plant height: Plant height which has a direct relation with lodging index showed a highly significant difference among tested varieties that ranged from 93.27to to 120.10 cm. Maximum plant height was recorded in variety DZ-01-256 (Jitu) 120.10 cm followed by variety DZ-Cr-453 (RIL- 120B) 113.43 cm and variety DZ-Cr-429 (RII 29) (Washera) 108. 37cm. The genotype Areka-1, DZ-Cr-442 (Flagot), DZ-Cr-457

variety DZ-Cr-453 (RIL- 120B) whereas the lowest lodging index was noted for variety DZ-Cr-419 (Hiberland).

Yield and yield-related traits

Biomass yield: The combined mean result revealed that a non-significant difference among the varieties was observed,

Table 5. Estimates of mean, standard deviation, range, variance components and coefficients of variability, heritability and genetic advance of the 8 characters studied

Traits	Means $\pm$ SD	Range	σ^2_g	σ^2_p	σ^2_e	GCV (%)	PCV (%)	h^2_b	EGA (k=5%)	GAM (K=5%)
DH	65.56$\pm$10.101	50.0 -84.0	35.43	54.75	19.32	9.07	11.28	0.64	9.77	14.90
DM	114.84$\pm$7.916	104.0-143.0	4.85	44.15	39.30	1.91	5.78	0.1	1.37	1.19
PH	103.68$\pm$18.665	77.8-145.8	100.43	144.46	44.02	9.72	11.59	0.70	17.23	16.62
PL	38.08$\pm$4.702	31.4-49.6	32.92	38.73	5.82	15.07	16.34	0.85	10.91	28.65
BMY	10556$\pm$7024	2500.0-20000.0	28924	2171950	2143026.00	274.02	20576.36	0.013	40.49	0.38
GY	2835$\pm$2010	450.0-5898.0	11507.87	216200.17	204692.30	405.87	7625.19	0.053	50.98	1.79
HI	0.256$\pm$0.049	0.1-0.4	0.002	0.003	0.001	15.78	20.677	0.583	0.06	28.13
LoD	2.236$\pm$1.204	1.0-5.0	0.23	0.60	0.36	21.76	34.648	0.395	0.630	28.17

SD = standard deviation, σ^2g = Genotypic variance, σ^2e = Environmental variance, σ^2ph = Phenotypic variance, GCV= Genotypic coefficient of variation, PCV= Phenotypic coefficient of variation, h^2b = Broad sense heritability, EGA= Expected Genetic Advance, GAM= Genetic advance as percent of mean and K =Selection intensity GY= grain yield, DH= number of days to head, DM= number of days to mature, PL= panicle length, PH= plant height, BY= biomass yield

Table 6. The correlation coefficient of the traits

Traits	DH	DM	PH	PL	BM	GY	HI	LOD
DH	1	0.53***	-0.57***	0.12	-0.77***	-0.82***	-0.6	-0.69***
DM		1	-0.45***	-0.02	-0.57***	-0.58***	-0.33***	-0.51***
PH			1	0.60***	0.87***	0.82***	0.25	0.75***
PL				1	0.23	0.14	-0.33*	0.15
BM					1	0.97***	0.39*	0.86***
GY						1	0.55***	0.84***
HI							1	0.43***
LOD								1

but a highly significant difference was observed for biomass yield across locations. The highest biomass yield was recorded by variety DZ-Cr-453 (RIL- 120B) and DZ-Cr-438 (RIL 7) (Abola) 11.58 t ha^{-1}, As (Esuyawkal et al., 2019) reported variety DZ-Cr-438 (RIL 7) (Abola) recorded the highest biomass yield result, While the lowest biomass yield was recorded by variety DZ-Cr-457 (Tesfa) and Areka-1which is 9.5 t ha^{-1} and 9.9 t ha^{-1} respectively.

Harvest index: A significant difference in harvest index was observed among varieties ranging from 0.21to 0.31. The highest harvest index result was recorded from variety Areka-1and the lowest harvest index was recorded from variety DZ-01-256(Jitu) and DZ-Cr-438 (RIL 7) (Abola).

Grain yield: The combined mean value of grain yield over the two locations was computed at which the tested tef varieties showed a non-significant variation on their grain yield potential; the variety Areka-1produce the highest grain yield 3146.25 kg ha^{-1} followed by DZ-Cr-438 (RIL 91A) (Dagiem) 3133.75 kg ha^{-1} and DZ-Cr-429 (Neguse) 3017.92 kg ha^{-1}, but not significantly different from the variety DZ-01-256(Jitu) which produce the lowest grain yield 2583.75 kg ha^{-1}.

Estimation of genetic parameters

The phenotypic variance was higher than the genotypic variances for all the characters indicating the influence of the environmental factors on these traits. The higher phenotypic and genotypic variance were obtained from plant height (100.43), days to heading (35.43) and panicle length (32.92) indicating the high influence of the environment on the traits. Plant height, Days to maturity and days to heading had high phenotypic variance (PV) values. The PCV values, for the Lodging index, harvest index and panicle length were higher, on the other hand, days to maturity had low values. The characters lodging, harvest index and panicle length gave a comparatively higher value of the genotypic coefficient of variation. The high level of genotypic and phenotypic coefficients of variation was also recorded for traits like lodging index, harvest index and panicle length. In contrast, low estimates of genotypic and phenotypic coefficients of variation were estimated for days to maturity. In the present study, phenotypic coefficients of variation were slightly higher than the genotypic coefficients of variation for all the traits studied. This indicates the presence of slight environmental influence to some degree in the phenotypic expression of the characters. (Bitew et al., 2018) also observed similar findings on rice.

Estimation of broad-sense heritability

In this study estimate of heritability in a broad sense ranged from 10% for Days to maturity to 85% for panicle length. Heritability estimate was moderately high for panicle length followed by plant height; days to 50% heading and harvest index, it was low < 40%) for days to maturity and lodging in this study. Very low heritability indicates a greater role of the environment on the expression of the trait.

Genetic advance as percent of mean

The genetic advance as the percentage of the mean (GAM) at 5% selection intensity is presented in (Table 5). Estimated genetic advance as percent of mean ranged from 0.38 for biomass yield per plot to 28.65 for panicle length. A relatively higher genetic advance was observed for panicle length, harvest index and lodging index. Likewise, estimates of genetic advance as percent of the mean for plant height and day's to50% heading was also considerably high. Panicle length and plant height showed moderately high heritability with a high genetic advance in percent of the mean. Therefore, selection based on this character might be effective for increasing grain yield. Medium heritability and genetic advance were recorded for days to 50% heading and harvest index. This suggests that these traits are primarily under genetic control and selection for them can be achieved through their phenotypic performance. Very low heritability and genetic advance for biomass yield were observed due to non-additive gene action and great influence of the environment on the trait as reported by (Akinwale et al., 2011) on rice.

Correlations of grain yield and yield-related traits

Grain yield, being a quantitative trait is a complex character of any crop. Various morphological and physiological plant characters contribute to yield. These yield-contributing components are interrelated with each other showing a complex chain of relationship and highly influenced by the environmental conditions (Prasad *et al*., 2001). Biomass yield, plant height, lodging index, harvest index and panicle length were positively correlated with grain yield. Grain yield showed a positive and highly significant ($P < 0.001$) correlation with biomass yield (0.97), lodging index (0.84) and plant height (0.82).Similar result was reported by (Asaye Demelash, 2017) positive and significant correlation of biomass yield (0.97) and plant height (0.82) for grain yield Plant height showed positive and strongly correlated with biomass yield (0.87), grain yield (0.82), lodging index (0.75) and panicle length (0.60) (Table 6). Days to 50% heading was a positive association with days to maturity but strongly and negatively correlated with grain yield, biomass yield, lodging index and plant height such negative correlations arise primarily from competition for a common possibility such as nutrient supply. If one component gets an advantage over the other; a negative correlation may arise (Adams and Grafius, 1971). Days to maturity was a negative correlation with all traits analyzed except for days to 50% heading. The strong positive correlations of biomass yield, plant height, lodging index and harvest index indicate that these characters might be utilized as selection criteria for improving grain yield in tef. The overall mean results of the varieties indicated that Dagim, Araka-1 and Niguse could be recommended for areas where heavy black soil (Vertisols) is dominant; whereas varieties Filagot, Areka-1 and DZ-cr-543(RIL-120B) could be recommended for those areas characterized by light red soil (Nitosols). Therefore; these varieties necessitate demonstration and popularisation to farmers with their full production package. This study was carried out from July 2019 to January 2020 to recommend the best adapted and high yielder tef varieties in the study area of East Gojam Zone. Hence different yield-related characters are important to recommend best-adapted technologies to the study area, the priority should be given to the major objective of the research studied.

CONCLUSION

Grain yield is an important trait to be given high emphasis during variety selection. The combined analysis of variance showed that there is no significant variation for grain yield per plot for the tested genotypes. Even though the tested varieties showed non-significant variation; all tested varieties scored maximum grain yield above two-fold of the national average of tef productivity (1850 kg ha^{-1} and regional tef productivity 1894 kg ha^{-1}) at the Ydabena site. To alleviate the limited access of improved tef varieties to study area these selected varieties need to demonstrate and popularized to farmers with their full production package to enhance the productivity of tef crop.

AUTHOR CONTRIBUTIONS

Mulugeta Bitew: Execute the experiment, data organization, formal analysis and wrote the manuscript, seriously edited the manuscript. **Alehign Worekie:** design the experiment, methodology, collect data, help with manuscript preparation, edited the manuscript, authors read and approved the final manuscript.

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COMPETING INTERESTS

The Authors have declared that no conflict of interest exists.

ETHICS APPROVAL

Not applicable

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