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Nationally Released Tef Variety Adaptation Trial in North Western Tigray, North Ethiopia, 2018

Hailegebrial K., Chekole N., Redae W., and W/gerima G.

Plant Breeder, Shire-Maitsebri Agricultural Research Center. Corresponding Author email: hailatkinfe@gmail.com

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Nowadays tef (Eragrostis tef (Zucc.) Totter) is becoming the most preferred crop both for consumption and market value. However, its production and productivity is still very low due to traditional agronomic practices, nutrient deficiencies, and lack of improved varieties and susceptibility of the crop to lodging. So, the current trial was carried out during 2017 and 2018 cropping seasons in Medebay zana district at on station with twenty eight nationally released tef varieties including standard and local check were evaluated with the objective of selecting adaptable and best performing tef variety/ies. Alpha lattice experimental design with three (3) replications was used on plot size of 2mx2m. The data recorded were days to 50% heading and 75% physiological maturity, plant height, panicle length, grain yield, biomass yield and harvest index. The data was analyzed using Genestat software and means were separated using Duncan multiple range test (DMRT). The combined two years data analysis showed that varieties varied significantly for most studied traits at ($P\leq0.01$ and ($P\leq0.05$). Based on the obtained result, one improved tef varieties namely; 'Niguse' shown to be high yielder variety followed by the varieties Tesfa and Guduru with the values of 1880.0, 1769.0 and 1692.0 kg ha-1, respectively, greater than 20% yield increment than local variety . The varieties Guduru, Wollenkomi and Magna were found to be having high biomass with the values of 9599.0, 9166.0 and 9139.0 kg ha-1, respectively. So, Niguse was superior in almost all the agronomic traits evaluated while the local variety of Abat tef and was out performed by most of the improved varieties of teff tested. Therefore, based on objectively measured traits, the variety Niguse was found most promising having the potential to increase the average yield of tef in Medebay zana district and is therefore recommended for general cultivation through demonstration and pre extension popularization activity as alternative tef variety for production at the testing and similar sites.

Keywords: Variety, Adaptation, Grain Yield, Teff

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INTRODUCTION

Tef (*Eragrostis tef* (Zucc.) Totter) is a tetra ploid 2n=40 plant, C4 self-pollinated, annual, warm season cereal crop; believed to have originated in Ethiopia and have been domesticated and used throughout the world due to its excellent nutritional value as grains for human consumption and as forage for livestock (Miller, 2010). The vast range of varieties is estimated to be 4000 worldwide (Davison *et al*., 2011) with great genetic diversity (Ayalew *et al*., 2011 and Ayalneh *et al*., 2012), thus leading to increased opportunity to develop cultivars that could be suitably adapted to any country that would invest in teff production.

Based on report of Vavilov (1951) Ethiopia is not only the origin of tef, but also the center of diversity where it contribute great role towards sustaining food security.

Five major cereals namely Teff, wheat, maize, sorghum and barley are the core of Ethiopia's agriculture and food economy, accounting for about three-quarters of total area cultivated (Alemayehu *et al*., 2011). Out of 10.14 million hectares of land occupied by cereals, tef the single dominant cereal took up 3.01 hectares annually and the production is about 47.5 million quintals (CSA,2014).

Research has also shown that teff is free of gluten (Miller, 2010) and the grain of teff in Ethiopia country is mainly adopted for food after baking the ground flour into pancake-like soft and sour bread, "injera", which forms the major component of the most favorite national traditional dish. It is also consumed in the form of porridge, and somewhat fermented or un-fermented non-raised breads ("kita" and "anebabero"), native beer, "talla", and more alcoholic cottage liquor,"katikalla" or " arakie" (Assefa *et al*, 2015).

However, its productivity is not comparable with other major cereal crops growing in the country. This reduction of tef crop productivity could be resulted from a complex interaction among the environment, crop genetics, and management, biotic and abiotic stress that could occur across the average national yield. Tef as well as many field crops, is greatly influenced by seasonal and environmental fluctuations. Therefore, G X E interaction and genotypic stability are important whereas plant breeders prefer the varieties, which are distinguished with high yield, good quality and more adapted for range of environments. Generally, Plant breeders agree on the importance of good phenotypic stability, but there is much less agree on the most appropriate definition of stability and a statistical measure of stability in yield trails (Becker,1981 and Shrief, 2003). An information on genotype x environment interaction leads to successful evaluation of stable genotype, which could be used for general cultivation. Yield is a complex quantitative character and is greatly influenced by environmental fluctuations; hence, the selection for superior genotypes based on yield per se at a single location in a year may not be very effective. Thus, evaluation of genotypes for stability of performance under varying environmental conditions for yield has become an essential part of any breeding programme. An understanding of the causes of genotype x environment interaction can help in identifying traits and environments for better cultivar evaluation. So, development of improved tef varieties with high yield and desirable grain quality for different environments is one of the exciting research leads to successful evaluation of stable genotype, which could be used for general cultivation.

Despite the aforementioned importance and large area, coverage, good prioritize, its productivity is very low i.e the average national yield of tef is about 1.74 tons per ha (CSA, 2018) and this low as compared to other cereals grown in Ethiopia (CSA, 2018) due to hinder factors of low soil fertility and suboptimal use of fertilizers, weeds, and erratic rainfall distribution and drought particularly in the areas of low altitude, lack of high yielding cultivars, lodging and water-logging (Ermias *et al*., 2007).

But, it is possible to increase its grain-yield up to 4 tons/ha by using improved varieties and good management practices under non-lodging condition (Hailu and Seyfu, 2001). So, since the national and regional research institutions in the country have released many varieties adaptable to a wide range of environment for commercial production, specifically in the current testing site Medebay zana district, quncho and kora are under production. Therefore, the present study was conducted to get an alternative stable potential variety/ies in addition to the few existed tef varieties through evaluating and selecting adaptable, high yielding, early maturing and diseases resistant improved tef varieties for Medebay zana district and other similar mid altitude agro ecologies.

OBJECTIVES

- ✓ To evaluate and select the best stable, high yielder, early maturing and major diseases and insect pest resistant tef variety/ites

MATERIALS USED (METHODOLOGY)

The study was conducted at Medebay zana district, Selekleka research site, in Tigray Regional State in Northern Ethiopia in the 2017 and 2018 cropping seasons which is located at the distance of 1065 km north of Addis Ababa. The experimental site is situated at the latitude of 14°6′43″ N, longitude of 38°27′50″E, and at the altitude of 1951 m above sea level (Wikipedia, 2016). The mean annual rainfall is 680 mm. The soil textural class is clay loam with pH of 7.2. The experimental material comprised of twenty eight nationally released varieties including one standard check and one local check obtained from Debrezeit Agricultural Research Center. The genotypes were planted during the main rainy season of 2017 & 2018 in a well prepared soil under alpha lattice design with three replications. Row planting with spacing of 0.2m between rows was used on a plot size of 2m x 2m with a gross area of 4 m2. Ten rows of tef per plot were planted and the middle eight rows were used for data collection and analysis. Spacing of 1m and 1.5m between plot and block respectively was used. Planting was done in row by drilling at seed rate of 15kg ha-1 and fertilizers rate of 100kg/ha Urea and 100kg/ha DAP. Half of the Urea was applied at the time of sowing and the rest half was applied at tillering stage (top-dressing). Standard cultural practices were

Table 1. Combined mean yield and yield related traits performance of released tef varieties at north western Tigray, Medebay zana district in 2017 & 2018

SN	Varieties	DH	DM	PL(cm)	PHt(cm)	BY kg/ha	GY kg ha^{-1}	HI	Lodging(1-5)
1	DZ-01-196(Asgori)	53.33	98	39.4	103.19	8093	1269	0.16	2.8
2	DZ-01-354(Enatit)	57.83	101.17	41.47	104.79	7832	1223	0.16	2.7
3	DZ-01-196(Magna)	58.5	100.5	40.82	105.17	9139	1414	0.16	3.3
4	DZ-01-787(Wellenkomi)	59.33	99.67	43.27	104.61	9166	1299	0.15	2.5
5	DZ-cr-44(Menagesha)	57.33	99	38	103.07	8790	1351	0.17	2.8
6	DZ-cr-82(Melko)	57.33	99.67	39.57	101.52	8126	1390	0.18	2.7
7	DZ-cr-255(Gibe)	57.33	101	41.3	104.56	7189	1175	0.17	2.8
8	DZ-cr-358(Ziquala)	57	100.5	40	106.86	8073	1427	0.18	3.3
9	DZ-01-974(Dukem)	58.5	99.67	45.7	112.16	9047	1582	0.18	2.8
10	DZ-01-1281(Gerado)	57	98.17	41.27	104.84	7778	1116	0.15	3.3
11	DZ-01-1285(Keye)	53	98.83	43.5	105.38	8215	1377	0.17	3.0
12	DZ-01-1681(KEyTena)	54.5	98.5	39.9	99.28	7529	1166	0.16	3.2
13	DZ-01-899(Gimbichu)	57.83	100.5	41.9	104.67	8447	1151	0.15	3.2
14	DZ-01-2675(Dega Tef)	55	99.67	46.17	112.95	7743	982	0.14	2.8
15	DZ-cr-387 RIL 355 Quncho	61.67	98.67	45.3	118.93	9073	1517	0.19	3.2
16	DZ-01-2053(Holetta Key)	52.17	98.33	35.8	88.29	6609	1075	0.16	3.8
17	DZ-01-1278(Ambo Toke)	57.17	100.83	41.77	103.53	7426	972	0.14	2.8
18	DZ-01-2054(Gola)	56.17	98.67	44.83	107.47	8256	1397	0.18	2.7
19	DZ-01-1821(Zobel)	54.83	100	42.73	101.83	7459	1013	0.15	3.5
20	DZ-01-1868(Yilmana)	57.17	100.33	41.73	102.14	6365	1068	0.2	2.7
21	DZ-01-2423(Dima)	53.83	100.67	43.47	108.03	7949	1334	0.17	2.8
22	DZ-01-3186(Etsub)	58.67	100.83	43.7	111.51	8722	1377	0.17	3.2
23	DZ-01-1880(Guduru)	56.5	100.83	46.43	110.38	9599	1692	0.19	3.2
24	PGRC/E 205396(Ajora)	55.5	100.17	41.9	105.96	7880	1451	0.19	3.5
25	Local Check	56.33	99.67	37.77	103.29	6884	1454	0.27	2.5
26	Kora	61.33	100.67	45.8	115.48	8729	1661	0.2	2.7
27	Dagim	60.17	98.83	36.93	108.13	8329	1419	0.18	2.3
28	Tesfa	59.67	97.17	42	105.52	7303	1769	0.29	2.5
29	Flagote	54.17	98.83	40.13	102.28	7817	1314	0.18	2.7
30	Dz-cr-429(RIL#125)Nigusse	57	100.5	41.93	102.19	8648	1880	0.22	2.7
	Grand Mean	56.87	99.66	41.82	105.6	8074	1344	0.18	2.9
	CV	4.5	1.7	7.5	5.1	13	14.8	18	17.3
Lsd	Genotype	2.894**	1.92**	3.59**	6.12**	1199.4*	227.1**	0.04**	0.58**
	Year	0.75**	0.25**	0.93**	1.58ns	309.7**	58.6**	0.01**	0.15**
	Gene * Year (Envit)	4.092**	2.71**	5.08**	8.66**	1696.2**	321.2**	0.05**	0.82*

Key: DH- Days to 50% heading, DM- Days to 75% physiological maturity, PHt- plant height, PL-panicle length, GY- grain yield per hectar in kg, BY- biomass yield per hectar in kg, HI-harvest index followed from sowing till harvesting during the entire crop season. Data was recorded based on plot and individual plant basis for phonological, yield and yield related. The data were subject to the analysis of variance of techniques using Genestat software packages (Genestat 18th edition) where in means were compared using Duncan multiple rage test (DMRT) at 5% levels.

RESULT AND DISCUSSIONS

Agronomic Performance of Tef Varieties

The result of combined analysis of variance was done and showed presence of significant difference among the tested varieties for phonological, growth, yield and yield related characters (Table 1). This study also in agreement with the finding of previous studies of Genotype x environment on 22 tef genotypes at four locations in Southern regions of Ethiopia which indicated significant variations in grain yield and most yield related traits among the tested genotypes (Ashamo and Belay, 2012).

Date of 50% heading: There is a significance differences between varieties for the character days to 50% heading. Early heading was recorded by variety Holetta Key followed by Keye. However, variety Dagim exerts late heading followed by kora. while selecting varieties for early maturing, considering early heading varieties could be imperative. Fentie *et al*., (2012) and Plaza-Wuthrich et *al*.,(2014) also reported significant difference among the tested varieties for date of heading.

Days to maturity: Identification of genotypes of different days to flowering and maturity is useful in adjusting sowing time in order to avoid adverse climatic conditions such as severe frost or extreme heat in summer, particularly during flowering and grain filling. Moreover planting teff genotype with the appropriate growing period allows effective use of seasonal rainfall. So, the current tef genetic materials rely early maturing groups. As this study result indicates, significant difference is observed among the tested variety for date of maturity across the location. Similar result was also reported by Fentie *et al*., (2012). considering this character for variety selection is very critical in order to select early maturing varieties for different agro ecologies. Accordingly, variety Tesfa followed by Asgori and Holleta key were early maturing as compared to local check and other varieties. Further observation indicated that genotypes that can fit different length of growth period could be identified the varieties under study for each year.

Plant height: Plant height and peduncle length (PL) of teff are important features that positively contribute to yield on the one hand and negatively to lodging on the other hand. Since lodging is a major problem in teff crop and can affect grain yield (Delden *et al*., 2010). Among the tested varieties, Quncho shows the longest height followed by kora with figure of 118.9cm and 115.5 whereas variety Holleta key and Key Tena exerted the shortest height. Considering this character for variety evaluation is very crucial as it help for selecting varieties that can able to withstand lodging problems. But, this study result is in contrast to Fentie *et al*., (2012) finding.

Panicle length: From the study result, significant difference was observed at ($P \leq 0.05$) among the tested varieties for panicle length across the study locations which was ranged from 35.8 (Holleta key) to 46.18(Guduru). Accordingly, variety Guduru shows maximum panicle length whereas variety Holleta key followed by Dagim shows minimum panicle length. Late set varieties were produced longer panicles i.e Dega tef and Guduru and this study also confirmed with previous studies which indicated late maturing varieties have long plant and panicle height. Many studies have indicated the presence of substantial variation among tef genotypes for different traits of tef. Habte *et al*. (2011) reported highly significant genotype variation for days to panicle emergence and maturity, plant height, panicle length, shoot biomass and grain yield, harvest index, lodging index and thousand seed weight. Similarly, highly significant genotype differences for days to panicle emergence, lodging percentage, thousands kernel weight, grain yield per plant and grain yield per hectare were also reported by Ayalneh *et al.* (2012).

Harvest index (HI): Harvest index is important yield parameters in various grain crops including tef. The more harvest index showed more grain yield over biological yield and vice versa. A significant difference was depicted among the varieties across the years for the character HI which was ranged from 0.14 to 0.29. Maximum HI was exerted by variety Tesfa followed by local check. Low HI was revealed by variety Dega tef (Table 1).

Lodging Index (LI): From the studied genotypes the lowest lodging index were recorded to varieties Wollenkomi and Tesfa with value of 2.5 and 2.5 respectively and those varieties preferable due to their lodging resistant traits.

Grain yield (GY): Grain yield is an important character for plant breeders to be considered for variety selection to address the objective of the conducted activity. Grain yield being complex trait is highly influenced by various environmental factors including biotic and a biotic factors. It is also interplay of various morphological characters which either favor or worsen the final yield. In present investigations grain yield in kg ha-1was found to be highly significantly different ($p \leq 0.01$) due to different tef genotypes (Table 1). Variation in yield shows a diverse genetic background of genotypes studied under these conditions. The possible reasons for the observed difference could be variation in their genetic makeup and As (Dagnachew *et al* (2014) finding indicated the varietal stability could be challenged not only due to the change in the test environment but also due to change in growing season per environment A genotype is stable if at a given location or plant population exhibits very little fluctuation in seed quality from year to year. Superior grain yield across environment is the main goal of teff breeders. Significant variability was observed among the tested varieties across the testing locations for grain yield qt/ha, which was ranged from 9.72 to 18.80 qt/ha with the mean value of 13.44qt/ha. The highest grain yield (18.80) and (17.69 qt/ha) was recorded for Niguse and Tesfa variety respectively. But, low yield of 9.72 qt/ha was obtained from variety Ambo Toke (table 1).

Biomass yield (kg/ha): Biomass production (kg ha-1) was significantly different among the genotypes, years and genotype * environment interactions. The variety Guduru superseded all the genotypes with highest biomass yield of 9599.0 kg ha-1. It was followed by the varieties Wellenkomi and Quncho with biomass yield of 9166.0 and 9073.0 kg ha -1, respectively. The genotype Yilmana showed poor performance in this experiment producing only 6365.0 kg ha-1.This also in line with the finding of (Daniel *et al*, 2016) who studied with released fourteen released tef varieties. It was further observed that the variety Niguse remained superior in term of both grain and biomass yield as well as in other important yield components (Table 1). It is, therefore suggested that this variety must be brought forward for testing across the various ecological areas of the studied district in a couple of years. The possible reason for the observed differences for all the traits recorded could be because of variation in the genetic makeup of the studied varieties. In support of this finding, different researchers have reported significant amount of variability in different tef populations studied.

Environmental effect on teff yield and yield related traits

The test environments (testing years) has showed substantial effects on all the traits studied except plant height for days to heading, days to physiological maturity, grain yield, shoot biomass, panicle length etc.) indicating that the years were adequately diverse to reveal the performance of the teff genotypes (Habte *et al*., 2015). Substantial genotype by environment interactions for all traits evaluated indicating that the test genotypes had differential performance at diverse years due different in amount and distribution of received rain fall, temperature, humidity (weather variability) etc.

Depending up on the magnitude of the interactions or the differential genotypic response to environments, the varietal ranking can differ greatly across environments. The performance of a genotype is not necessarily under diverse agro- ecological zones. Therefore, crop performance depends on the genotype, the environment in which it grows and the interaction between them. According to Eberhart & Russell (1966), information on the interaction of genotypes with environment is crucial in developing new cultivars for production in diverse environments. Such information guides the breeder in choice of selection methods and to test locations for optimal character expression. When analyzed, a performance test of genotypes over a series of environments gives information on genotype-environment interactions. So, since the current study anova result showed significant difference among the genotypes in genotype by environment interaction and it need further stability analysis to test the repeatability performance of the winner genotypes across the environment and to ensured whether the interaction is cross or non cross over interaction.

GGE-biplot analysis

Which-won-where pattern analysis

In the which-won-where concept of GGE biplot, genotype markers furthest from the biplot origin are connected with straight lines to form a polygon such that markers of all other genotypes are contained in the polygon. The polygon view of a GGE biplot clearly displays the which-won-where pattern, and hence it arranged the genotypes in such a way that some of them were on the vertexes while the rest were inside the polygon. A given genotype which relies at the vertex for each sector is the winner genotype at the given testing environments included in that sector. According to the biplot in Figure 1, the vertex genotypes were G30, G28, G14, G11 and G12 and those genotypes are the most responsive and these genotypes were the best or the poorest genotypes in some or all of the environments because they were farthest from the origin of the biplot (Yan and Kang, 2003). In this biplot, environments are also divided into two sectors. The first sector represents E1 with genotype G30 as the best yielder genotype and the second sector represents E2 with genotype G28 as the most winner genotype. The other vertex genotype, G14 which was located far away from all of test environments, implied that it did not yielding well on both environments which attained such temperature, rainfall, humidity and other agronomic practice (Figure 1).

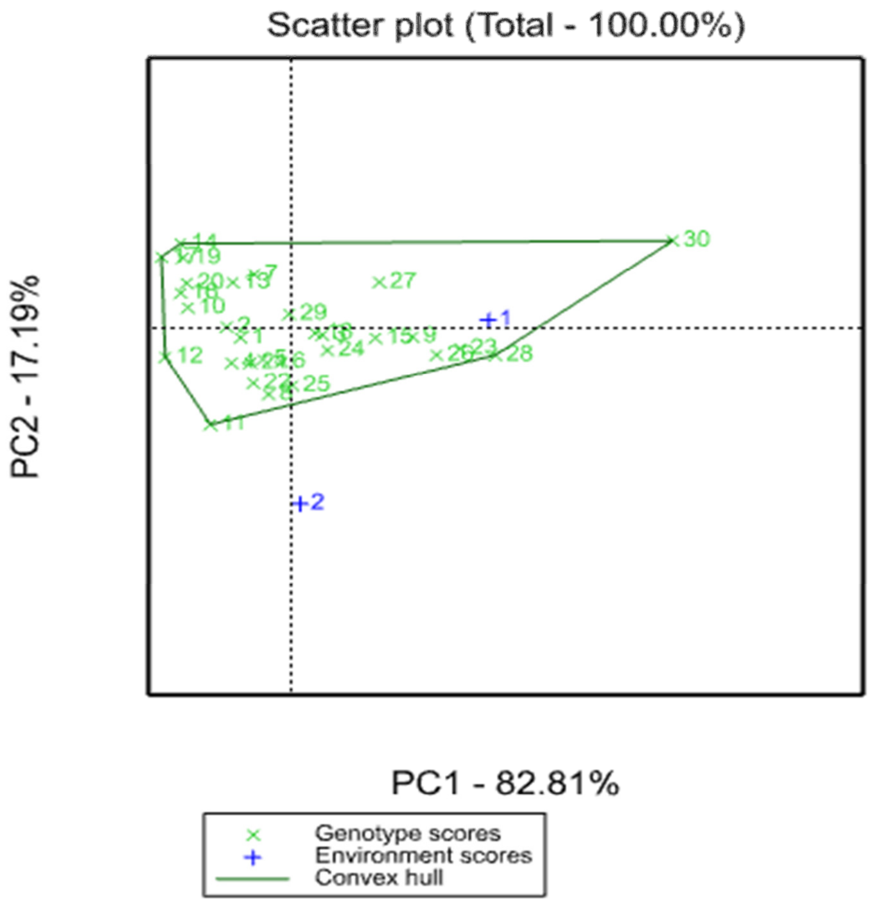

Figure 1: performance of genotypes across environment (Polygon view of the GGE biplot based on yield data)

Mean performance and stability analysis

Ranking of thirty tef genotypes based on mean yield performance and stability is presented in Figure 2. The single arrow line passing through the biplot origin and the average environment indicated by the small circle is the average environments coordinate (AEC) axis, which is defined by the average PC1 and PC2 scores of all environments (Yan and Kang, 2003). This line points towards higher mean yield across environments. As Yan *et al* (2002) reported that AEC abscissa has a one directional arrow which is important for approximating the mean yield performance of the genotypes. Hence, in the present biplot, G30 produced the highest mean yield while genotypes G28, G20, and G23 were the next high yielding genotypes in that order. However, the remaining genotypes had bellow average mean yield (Figure 2). The line which passes through the biplot origin and perpendicular to the AEC axis shows measure of stability. Either direction away from the biplot origin, on this axis, indicates greater genotype by environment interaction and poor stability or vice versa (Kaya *et al.*, 2006). A genotype which has shorter absolute length of projection in either of the two directions of AEC ordinate (located closer to AEC abscissa), represents a smaller tendency of GEI, which means it is the most stable genotype across different environments or vice versa. Thus, the genotypes with the highest yield performance and relatively better stability were G23, G20 and G9. Conversely, genotypes G25, G6, G13, G7, G14, G17 and G19 were not only low yielding but also less stable (Figure 2).

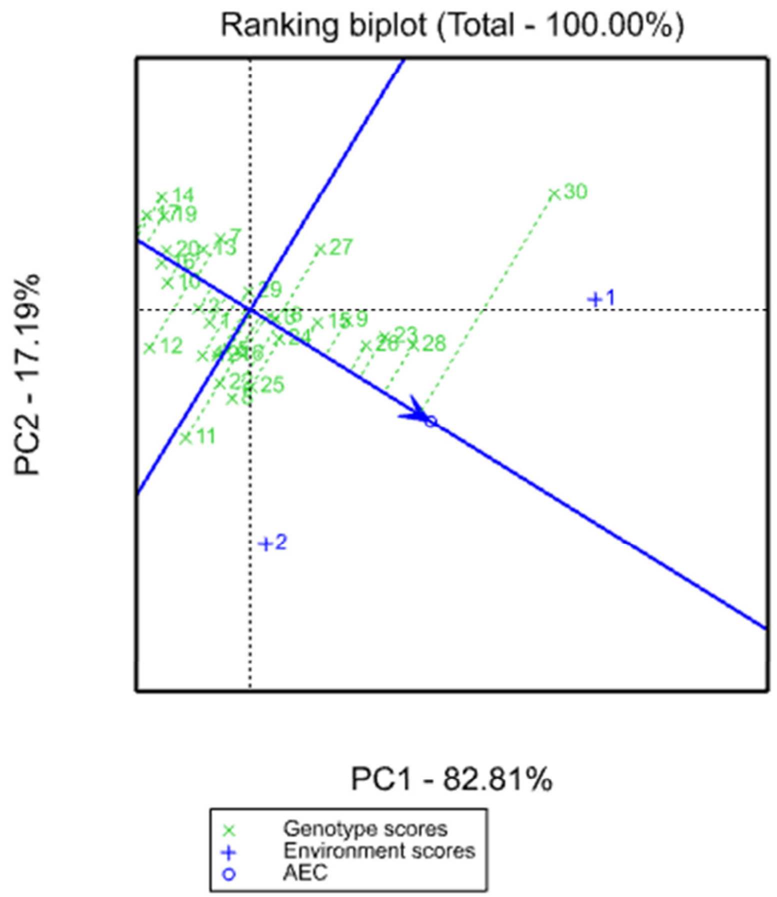

Figure 1: mean yield performance of genotypes across average environment coordination(AEC)

CONCLUSION

The present investigation was conducted at Medebay zana district during 2017 and 2018 cropping season using twenty eight nationally released testing varieties including comparable standard & local checks with the objective of selecting adaptable and best performing tef variety/ies. Different agronomic traits like plant height, panicle length, lodging and grain and biomass yield were considered by the researchers as evaluation criteria. Based on the analysis of variance, the varieties at the given location in both years exhibited significant variation for most traits studied except plant height, which showed non-significant variation at ($p \leq 0.05$) across years and indicated there is considerable amount of diversity among the tested varities which could be manipulated for further improvement in tef breeding. Niguse variety gave highest grain yield (18.80 qt/ha) relative to the rest varieties in both years' at the given district followed by Tesfa (17.89 qt/ha) yield performance and this variety also relatively stable variety. On the contrary, Ambo Toke gave lower yield than the local check in both testing years of the trial location. Finally, in order to avail the accessibility of improved tef varieties to the area these varieties need to be demonstrated to users along with their improved production packages for their further extension and scaling up.

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