Yield and agronomic performance of released Tef [Eragrostis tef (Zucc.) Trotter] varieties under irrigation at Dembia, Northweastrn, Ethiopia

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Abstract: Tef is the major staple cereal crop in Ethiopia, mainly grown under rainfed condition but not very common under irrigation. Field experiment was conducted to select well adapted and high yielder tef varieties on vertisoil (blacks soil), at Dembia North weastrn Amhara, Ethiopia during 2017/2018 and 2018/2019 irrigation season. The experiment was arranged in a randomized complete block design with three replications having 36 tef varieties including local check with recommended water dept and intervals for each treatments. A seed rate of 15 kg ha−1 was drilled in a row. The combined analysis over years showed that significant difference (p < 0.01) was observed among the varieties for most of the measured traits including grain yield over the farmer local vareities. Moreover, the combined analysis of variance over years indicated that three varieties, namely Dukem, Gibe and Gola, gave the highest grain yield (3079.7, 2993.2 and 2868.8 kg ha−1, respectively), with yield advantage of 36%, 34.2% and 31.3% over the local check yield (1969.7 kg ha−1), respectively. Therefore, we concluded that based on grain yield and other important traits, Dukem, Gibe and Gola varieties can be recommended for Dembia district and similar areas where irrigation is available.

Keywords: Dembia; grain yield; irrigation; tef varieties

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PUBLIC INTEREST STATEMENT
In recent years, tef is receiving global attention among cash crops and has been attracting an export market due to attention for its nutritional and health-related benefits due to the absence of gluten, a cause for celiac disease. Drought is one of the main challenges world agriculture is facing, but its effects may vary from region to region. Ethiopia is one of the sub-Saharan African countries facing recurrent droughts leading to low crop productivity or crop failure and food insufficiency. In addition, yield reduction of up to 77% has been reported to have occurred as a result of drought at the anthesis stage of tef. Therefore, produce tef both rainfed and irrigation season to alleviate food insecurity for Ethiopian Farmers in the study area.
1. Introduction
Tef [Eragrostis tef (Zucc.) Trotter] is an indigenous staple cereal crop of Ethiopia, occupying about 2.6 million hectares (23% of the grain crop area) of land, which is more than any other major cereals such as maize (16%), sorghum (14%) and wheat (13%) (Central Statistical Agency [CSA], 2008). Ethiopians are the first domesticator of this unique cereal in the world. Ethiopia is the center of origin and diversity for tef (Seyfu, 1997). According to Seyfu (1997), it can be grown from sea level up to 2,800 m.a.s.l, under various rainfalls, temperature and soil regimes. However, he emphasized that for better performance, it requires an altitude of 1,800–2,100 m.a.s.l, annual rainfall of 750–850 mm, and a temperature range of 10–27°C. It is predominantly cultivated on sandy loam to black clay soils.

In recent years, tef is receiving global attention among the cash crops and has been attracting an export market due to attention for its nutritional and health-related benefits (Provost & Jobson, 2014), especially due to the absence of gluten, a cause for celiac disease, in its grain (Fikadu et al., 2019; Seyfu, 1997; Spaenij-Dekking et al., 2005). Most of Ethiopian farmers are motivated to cultivate tef because of its relative merits over the other cereals with respect to husbandry, utilization and economic benefits (Assefa et al., 2011). Moreover, a much higher content of fiber and other nutrients such as minerals, vitamins and bioactive phenolic compounds than most other cereals (Gebremariam et al., 2014).

Tef in Ethiopia is mainly used to make a traditional fermented-circular soft bread called injera or flat bread (Tatham et al., 1996); the cultivated food crops grown in Ethiopia, tef ranks first, with an estimated production area of 2730272.95 ha and a mean productivity of 1.38 t ha\(^{-1}\) (CSA, 2013). Tef has the genetic potential to yield up to 6 t ha\(^{-1}\) (Seyfu, 1993). In North Gondar, it was covered an estimated total land area of 124473.41 ha and 2093570.75 ton with average productivity was 1.68 t ha\(^{-1}\) which is less than the national average productivity of 1.97 t ha\(^{-1}\) in 2015/2016 cropping season (CSA, 2016). Currently, tef is mainly cultivated under rainfed agriculture with very low (1.7 t ha\(^{-1}\)) yield (CSA, 2016) compared to productivity under irrigation (3.3 t ha\(^{-1}\)) (Yenesew, 2015). The low productivity of tef in Ethiopia is mainly attributed to its susceptibility to lodging, its small seed size, poor pre- and post-harvest agronomic management practices, and moisture stresses (Seyfu, 1997). Similarly, Haileselassie et al. (2011) studied tef production constraints in Tigray Region of northern Ethiopia, and found that in the highlands, poor soil fertility, and in the lowlands, low moisture stress, were the major constraints affecting tef production. Drought is one of the main challenges facing world agriculture, but its effects may vary from region to region. Ethiopia is one of the sub-Saharan African countries facing recurrent droughts leading to low crop productivity or crop failure and food insufficiency (Deressa & Hassan, 2009). Declining levels and high variability of rainfall is among the main causes for low crop productivity in different parts of Ethiopia (Tilahun, 2006). Yield losses of tef due to low moisture are estimated to reach up to 40% during severe stress (Ayele, 1993). Furthermore, yield reduction of up to 77% has been reported to have occurred as a result of drought at the anthesis stage of tef (Takele, 2001). Most regions of Ethiopia are suffering from insufficient and unreliable rainfall. Thus food insecurity has remained the major problem that is a great concern to the country. Therefore, the objective of this study was to evaluate, select, recommend best performing tef varieties for irrigation at Northern Gondar Amhara and similar areas.

2. Material and methods

2.1. Description of the study area
The experiment was conducted in a region where tef production was dominantly cultivated at Dembia, Northweastrn Gondar, Ethiopia, for a continuous two years of 2017/18 and 2018/19 irrigation season to select best adaptive and high yielder tef varieties. Dembia irrigation scheme is located Northweastrn Gondar, Ethiopia, 40 km to Gondar town and 220 km to Bahir Dar city at
12°17'42.18" Northing and 37° 13' 25.39" Easting, an altitude of 1856 masl with an average annual rain fall of 1,095 mm. The soil type of the study area is characterized by well-drained verti-soil. The average maximum and minimum temperature is 29°C and 13°C, respectively with an average annual rainfall of about 1,067 mm (Akalu et al., 2009). The area is characterized as mild altitude agro-ecology.

2.2. Experimental setup
A total of 36 varieties including the local check (Table 1) were evaluated in a randomized complete block design (RCBD) with three replications having 2 m length. The seed rate was used for the experiment was 15 kg ha\(^{-1}\) and the spacing between row was 20 cm and sowing was drilled in a row. All agronomic practices including weeding, pesticide and insecticide were done equally for all treatments. Fertilizer was applied at the rate of 41/46 kg ha\(^{-1}\) N and P\(_2\)O\(_5\) in the form of urea and DAP, respectively. Half of the total nitrogen and total phosphorus was applied at planting while the remaining nitrogen was applied at tillering (Deckers et al., 1998). Irrigation water was applied every three days interval for the first initial stage, five days interval at vegetative stage and eight days interval after heading to early maturity with furrow irrigation method (Savva & Frenke, 2002). Grass hopper and shoot fly were found the most challenging pests on the trial, and controlled by spraying the recommended chemical (diazinon 60%). Important agronomic practices such as plowing and weeding were performed as per the recommendation.

2.3. Data collection
Days to flowering: the number of days from 50% of the plots showing seedling emergence up to 50% of the plants in the plot flower. Days to maturity: the number of days from 50% of the plots showing seedling emergence up to 50% of the plants in the plot reaching phonological maturity stage (as evidenced by eye-ball judgment of the plant stands when the color is changed from green to color of straw). Plant height (cm): measured as the distance from the base of the stem of the main tiller to the tip of the panicle at maturity. Panicle length (cm): the length from the node where the first panicle branch starts up to the tip of the main panicle at maturity. Total biomass (t ha\(^{-1}\)): the weight of all the harvestable area including tillers harvested at the level of the ground. Grain yield (kg ha\(^{-1}\)): the weight of grain yield for all the harvestable area of plot.

2.4. Data analysis
All the collected data on yield and yield parameters were analyzed for variance as suggested by (Gomez & Gomez, 1984) using SAS software Version 9.0 (SAS Institute, 2002). Combined analysis of variance over years were carried out and Duncan’s Multiple Range Test (DMRT) test was used to compare the mean separations at 5% significance level.

3. Results and discussion

3.1. Analysis of variance
The combined analysis variance genotypes by year interaction showed highly significant (\(p < 0.01\)) difference for biomass yield, whereas significant for days to flowering, plant height and grain yield. However, the interaction exhibited also non-significant for days to maturity and panicle length while highly significant differences (\(p < 0.05\)) were observed among tasted genotypes for days to heading, days to maturity, plant height panicle length and grain yield and significant (\(p < 0.05\)) difference was observed for biomass yield (Table 2). Such considerable variations would provide a good opportunity for yield selection and improvement. Bakala et al. (2018) also conducted performance evaluation and adaptation trial of tef genotypes for moisture stress areas of Borena, Southern Oromia. They reported considerable variation in the days to flowering, plant height and grain yield of different tef varieties when planted over years. Moreover, similar result reported by Girma et al. (2019), genotypes by year interaction showed highly significant (\(P < 0.01\)) difference for days to heading, plant height and grain yield. While the interaction exhibited also non-significant for traits days to maturity and panicle length at Raya valley, Northern Ethiopia under irrigation season. They also reported that highly significant differences (\(P < 0.01\)) were observed
| No. | Variety       | Year of release | Releasing research center | Altitude (masl) | Annual rainfall (mm) | Days to maturity | Productivity (t ha\(^{-1}\)) under rainfed conditions |
|-----|---------------|-----------------|---------------------------|-----------------|----------------------|-----------------|-------------------------------------------------------|
|     |               |                 |                           |                 |                      |                 | On farm | At research station |
| 1   | DZ-01-99 (Asgori) | 1970            | Debre Zeit                | 1,500–2,400     | 300–700              | 80–130          | 1.7–2.2 | 2.4–3 |
| 2   | DZ-01-196 (Magna) | 1970            | Debre Zeit                | 1,500–2,400     | 300–700              | 80–113          | 1.4–1.6 | 1.8–2.2 |
| 3   | DZ-01-354 (Entit) | 1970            | Debre Zeit                | 1,600–2,400     | 300–700              | 85–130          | 1.7–2.2 | 2.4–3.2 |
| 4   | DZ-01-787 (Walankomi) | 1978           | Debre Zeit                | 2,800–2,500     | 400–700              | 90–130          | 1.7–2.2 | 2.4–3.0 |
| 5   | DZ-01-354 (Enatit) | 1982            | Debre Zeit                | 1,800–2,500     | 400–700              | 125–140         | 1.4–1.9 | 1.8–2.8 |
| 6   | DZ-01-787 (Melko) | 1982            | Debre Zeit                | 1,600–2,400     | 300–700              | 76–138          | 1.7–2.2 | 2.4–3.5 |
| 7   | DZ-01-787 (Tseday) | 1998            | Holetta                   | 1,900–2,700     | 700–800              | 124–140         | 1.6–2.4 | 2.1–3.6 |
| 8   | DZ-01-787 (Gibe) | 1999            | Holetta                   | 2,200–2,400     | 700–800              | 125–140         | 2.5     | 3.4 |
| 9   | DZ-01-787 (Ziqala) | 2002            | Debre Zeit                | 1,850–600       | >600                 | 73–95           | 1.6–2.0 | 2.0–2.2 |
| 10  | DZ-01-787 (Gerada) | 2002            | Debre Zeit                | 1,900–2,200     | 300–700              | 104–118         | 1.8–2.5 | 2.4–3.6 |
| 11  | DZ-01-787 (Kay teke) | 2002           | Debreti Zeit              | 1,600–1,900     | 300–500              | 84–93           | 1.6–2.0 | 2.0–2.2 |
| 12  | DZ-01-1278 (Ambo toke) | 2003           | Sirinka                   | 1,450–1,850     | 660–1,025            | 68–100          | 1.6     | 1.1 |
| 13  | DZ-01-1254 (Gola) | 2003            | Sirinka                   | 1,450–1,850     | 660–1,025            | 85–110          | 1.0–1.4 | 1.0–1.5 |
| 14  | DZ-01-1287 (Ajora) | 2004            | Areaka                    | Low-medium      | 900–1,200            | 85–110          | 1.6–2.0 | 1.8–2.8 |
| 15  | DZ-01-1291 (Yilman) | 2005            | Debreti Zeit              | 1,800–2,500     | 997–1,200            | 112–123         | 1.0     | 1.7 |
| 16  | DZ-01-1294 (Dima) | 2005            | Adet                      | 2,000–2,600     | >600                 | 105             | 1.6     | 2.46 |
| 17  | DZ-01-1295 (Genete) | 2005           | Sirinka                   | 1,450–1,850     | 660–1,025            | 78–85           | 1.5     | 2.17 |
| 18  | DZ-01-1296 (Zobel) | 2005            | Sirinka                   | 1,450–1,850     | 660–1,025            | 78–85           | 1.51    | 2.07 |

(Continued)
| No. | Variety                              | Year of release | Releasing center | Altitude (masl) | Annual rainfall (mm) | Days to maturity | Productivity (t ha$^{-1}$) under rainfed conditions |  |
|-----|--------------------------------------|-----------------|------------------|-----------------|----------------------|------------------|--------------------------------------------------|-----|
|     |                                      |                 |                  |                 |                      |                  | On farm | At research station |  |
| 23  | Ho-cr-136 (Amarach)                  | 2006            | Debre Zeit       | 1,600–1,700     | 500–850              | 63–87            | 1.2     | 1.3                |  |
| 24  | DZ-Cr-387/RIL-355 (Quncho)          | 2006            | Debre Zeit       | 1,500–2,500     | 300–700              | 80–113           | 2.0–2.2 | 2.4–2.8            |  |
| 25  | Dz-01-1880 (Guduru)                 | 2006            | Bako             | 1,850–2,500     | 1,000–1,200          | 132              | 1.4–2.0 | 1.5–2.3            |  |
| 26  | Acc.205953 (Mechere)                | 2007            | Sirinka          | 1,450–1,850     | 660–1,025            | 79               | 1.79    | 2.06               |  |
| 27  | Dz-cr-387 RIL#127 (Gamechis)        | 2007            | Melkassa         | 1,450–1,695     | 690–965              | 62–83            | 1–1.4   | 1.3–2.0            |  |
| 28  | Dz-01-3186 (Etsub)                  | 2008            | Adet             | 1,800–2,600     | 1,230                | 92–117           | 1.6–2.2 | 1.9–2.7            |  |
| 29  | DZ-01-899 (Gimbichu)                | 2005            | Debre Zeit       | 2,000–2,500     | 2,000–2,500          | −118–137         | 1.6–1.8 | 1.8–2.0            |  |
| 30  | 23-tafi-adi-72 (Kena)               | 2008            | Bako             | 1,850–2,400     | 1,000–1,200          | 110–134          | 1.3–2.3 | 1.7–2.7            |  |
| 31  | Dz-Cr-385 RIL295 (Simada)           | 2009            | Debre Zeit       | Low             | 300–700              | 88               | 1.7–2.0 | 1.8–2.2            |  |
| 32  | SR-RIL-273 (Laketch)                | 2009            | Sirinka          | 1,450–1,850     | 660–1,025            | 90               | 1.3–1.8 | 2.24               |  |
| 33  | DZ-Cr-409/RIL50d (Boset)            | 2012            | Debre Zeit       | 1,500–1,750     | 500–900              | 75–86            | 1.6–2.0 | 1.9–2.8            |  |
| 34  | Dz-Cr-438 (Kora)                    | 2014            | Debre Zeit       | 1,700–2,400     | 700–1,200            | −110–117         | 18–22   | 25–28              |  |
| 35  | Acc. 21476A (Workiye)               | 2014            | Sirinka          | 1,450–2,220     | 505–1,025            | 94               | 16      | −22.2              |  |
| 36  | Local                                |                 |                  |                 |                      |                  | -       | -                  |  |
among genotypes for panicle length and grain yield and significant \( P < 0.05 \) difference were observed for days to heading, days to maturity and shoot biomass. Furthermore, this result is inline with different findings for the presence of significant variation among tef varieties for the traits days to heading, days to maturity, plant height, panicle length and grain yield (Basha et al., 2018). However, this result is in disagreement based on interaction significant difference for days to maturity and spike length were observed by Molla et al. (2012).

### 3.2. Mean performance of genotypes phenological characters

#### 3.2.1. Days to heading

In days to flowering, significant difference was observed in 2017 and 2018 irrigation seasons. The variation among varieties for days to heading ranged from 50.1 to 61.5 days. About 91.7% genotypes had mean performances lower than the local check for character days to heading, indicating those genotypes were early heading as compared to the others while two new varieties, namely Quncho and lakech, showed late heading over the others for days to heading (Table 3). This implied that the higher chance of selecting early varieties which can escape the terminal moisture stress which is one of the tef production problems in the study area. The longest (61.5) days to heading was recorded on local variety while the shortest/early (50.1 days) was recorded on Simada varieties (Table 3). Molla et al. (2012) also reported significant difference among the tested varieties for days to flowering in East Belessa, north western Ethiopia. Similarly, Girma et al. (2019)
Table 2. Combined mean squares of days to heading, days to maturity, plant height, panicle length, grain yield and dry shoot biomass yield in Dembia district in 2017/18 and 2018/19 under irrigated seasons

| Source of variation | DF  | Days to heading | Days to maturity | Plant height (cm) | Panicle length (cm) | Grain yield (kg ha\(^{-1}\)) | Drybiomass(t ha\(^{-1}\)) |
|---------------------|-----|-----------------|------------------|-------------------|---------------------|-----------------------------|--------------------------|
| Variety (V)         | 35  | 34.64**         | 46.55**          | 326.03**          | 51.01**             | 79273.3**                   | 11.30**                  |
| Replication         | 2   | 4.31ns          | 3.35ns           | 537.12**          | 1741**              | 17059.2**                   | 51.52*                   |
| Year (Y)            | 1   | 133.80**        | 1628.0**         | 2699.47**         | 1059.57*            | 1045584.3**                 | 3182.36**                |
| V*Y                 | 35  | 9.23*           | 12.55m           | 38.46*            | 1094m               | 327126.9**                  | 5.36*                    |
| Error               | 140 | 5.05            | 11.14            | 20.44             | 8.25                | 10625.5                     | 3.55                     |

Where, ns: non-significant, * and **: significant and highly significant, respectively.
reported that significant difference among the tested tef varieties for days to flowering at Raya Valley, Northern, Ethiopia.

### 3.2.2. Days to maturity
As the study result indicates, significant difference was observed among the tested genotypes for days to maturity, but it was non-significant difference for the interaction over year. The tasted varieties variation for days to maturity ranged from 83.7 to 96.8 days. The varieties Simada (83.7 days) had short period for maturity while local variety (96.8 days followed by Lakech (96.3 days) had long period for maturity. As compared to the overall varieties days to maturity, among 36 varieties, 35 exhibited lower days to maturity while as compared to the late maturing local check variety. This suggested that the higher chance of selecting early varieties for future breeding (Table 3). These results are in harmony with working on germplasm evaluation; Kebebew et al. (1999) and Girma et al. (2019) reported that days to maturity ranged from about 87 to 113 at Raya valley, Northern Ethiopia under Irrigation season.

### 3.2.3. Plant height
Plant height is an important feature that positively contribute to yield. The variation of tasted varieties for plant height ranged from 66.13.2 to 104.8 cm. Variety Guduru (104.8 cm) was recorded the highest plant height while the lowest plant height was recorded on variety Simada (61.13 cm) (Table 3). This finding in line with Girma et al. (2019) reported that highly significant differences ($P < 0.01$) among tasted varieties for plant height at Raya valley, Northern Ethiopia under Irrigation season. Moreover, this results in line with Abel (2005) reported that plant height varied from 41 to 95 cm. While this finding is not in line with Molla et al. (2012), which reported non-significant difference in plant height among tef varieties over years.

### 3.2.4. Panicle length
Variety Guduru (38.8 cm) shows maximum panicle length followed by varieties Quunco (37.9 cm) and Dukem (37.23 cm), whereas variety Simada (25.2 cm) shows minimum panicle length (Table 3). This results in line with Abel (2005) reported that panicle length varied from 17 to 42 cm. Similar result was also reported by Aliyi et al. (2016) who observed the tasted tef varieties for panicle length across the study locations, which was ranged from 29.56 to 41.18. Moreover, Girma et al. (2019) studied that tasted tef genotypes for panicle length ranged from 22.7 to 39.5 cm at Raya valley, Northern Ethiopia under irrigation season.

### 3.3. Yield and yield component

#### 3.3.1. Shoot biomass yield
The highest shoot biomass tone per hectare were recorded at variety Gola (12.57 t ha$^{-1}$), Degetaef (12.03 t ha$^{-1}$), Dukem (11.887 t ha$^{-1}$) and Kora (11.7 t ha$^{-1}$) while the lowest shoot biomass was recorded at variety Simada (7.22 t ha$^{-1}$) (Table 3). This result in line with Girma et al. (2019) studied that, among tasted tef genotypes for biomass yield ranged from 8.0 to 14.25 ton per hectare at Raya valley, Northern Ethiopia under irrigation season and significant difference among tasted genotypes.

#### 3.3.2. Grain yield
Variation in grain yield tone per hectare among genotypes extrapolated from yield per hectare is presented in Table 3. Accordingly, highly significant variability was observed among varieties for grain yield, which ranged from 1558 to 3078 kg ha$^{-1}$ with the mean value of 2261 kg ha$^{-1}$ and coefficient of variation of 14.4%. Based on the mean performances, varieties such as Dukem (3078 kg ha$^{-1}$), Gibe (2990.2 kg ha$^{-1}$) and Kora (2868 kg ha$^{-1}$) had mean performances higher than the local check variety (1969.7 kg ha$^{-1}$) for grain yield (Table 3). In addition, these varieties (Dukem, Gibe and Gola) showed yield advantage of 36.05%, 34.4% and 31%, respectively, over the local check (Table 3). This result in line with Molla et al. (2012) who studied farm performance evaluation of improved tef varieties in East Belessa, north western Ethiopia during main
Table 3. Combined mean performance of released tef varieties for grain yield and other agronomic traits in Dembia district over 2017 and 2018 irrigation seasons

| Variety       | Days to heading | Days to maturity | Plant height (cm) | Panicle length (cm) | Grain yield (kg ha⁻¹) | Dry shoot biomass (t ha⁻¹) |
|---------------|-----------------|------------------|-------------------|---------------------|------------------------|---------------------------|
| Enatit        | 57.5c-e         | 94.670a-e        | 88.07f-j          | 35.67a-h           | 2360.1d-i             | 10.76a-f                  |
| Asgori        | 59a-e           | 90.83c-h         | 81.47m            | 33.25c-i           | 2184.5e-i             | 9.48b-i                   |
| Walankomi     | 58.5a-e         | 90.76d-e         | 94.70a-e          | 37.27d-c           | 2627.6e-a             | 11.88abc                  |
| Magna         | 57.33r-g        | 93.830-e         | 92.20c-g          | 32.80k-h           | 1948.2r-n             | 10.18b-n                  |
| Menagesha     | 58.83a-e        | 94.57f-f         | 90.90g-f          | 36.40a-f           | 1876.4d-n             | 9.06d-f                   |
| Melka         | 56.55h          | 94.330-f         | 86.43b-h          | 33.33c-h           | 1796.2r-n             | 10.80c-f                  |
| Gibe          | 56.33a-h        | 95.17d-d         | 90.73c-g          | 34.60d-i           | 2993.3ab              | 10.25g                    |
| Dukem         | 61.17ab         | 95a-d            | 96.07bc           | 37.23d-c           | 3079.7g               | 11.85abc                  |
| Ziqala        | 60.83ab         | 91.83b-g         | 86.19a-k          | 32.77d-k           | 1726.2mn              | 7.59b                      |
| Kaye          | 57.33r-g        | 93a-d            | 82.44k            | 32.90d             | 1961.9n               | 9.35c                      |
| Quncho        | 60.33abc        | 93+7             | 99.73ab           | 37.83a-d          | 2164.2r-m             | 10.35+9                   |
| Tseday        | 53j             | 86.67f           | 75.37m            | 30.30m             | 1555.3f               | 7.5133f                   |
| Gerado        | 57.17ef         | 95.17b-f         | 86.07h-k          | 33.53j-f           | 2523.1j               | 11.46a-b                  |
| Kaytana       | 57.17c-g        | 92.50g-d         | 82.61l            | 32.70k             | 2109.7m-l             | 8.495j                    |
| Kora          | 60a-d           | 90.17b-g         | 99.77ab           | 37.07d-d          | 2484.7h-l             | 11.70d-d                  |
| Simada        | 50.17j          | 81.67i           | 66.13m            | 25.2n              | 2071.3m-d             | 7.22                      |
| Boset         | 54.59k          | 88.17g           | 83.91h-i          | 31.17m             | 2619.7b-f             | 8.88e                      |
| Gimbichu      | 56.17a-n        | 94.670a-e        | 86.58a            | 33.63c-j           | 2653.3bcd             | 10.38ag                    |
| Amarach       | 55.17gf         | 89.83f-g         | 79.97m            | 32.33m-f           | 2225d-l               | 9.38b                      |
| Holeta Key    | 57.67c-t        | 91.67b-g         | 79.07h            | 29.48k-m          | 2109.7b-m             | 9.59g                      |
| Ambotoke      | 58.83a-e        | 95.17d-f         | 86.03h-k          | 33.07d-k           | 2368a-l               | 9.40e                      |
| Gamechis      | 57.17gq         | 91.17c-g         | 95.37hcd          | 35.33b-n           | 2394.8d-l             | 11.15e-d                   |
| Gola          | 58.67a-e        | 94.170-c         | 93.07f-f          | 37.03d-g           | 2868.8abc             | 12.57g                    |
| Genete        | 57.59g          | 94.330-f         | 89.83h-h          | 36.10g             | 2533.9c-g             | 11.15f                    |
| Zobel         | 59a-e           | 95.17abc         | 88.63e-i          | 34.43b-i           | 2210.4s-t             | 10.39g                    |
| Mechare       | 57d-h           | 96.330-c         | 89.17h-h          | 35.6a-h            | 2247.1s-k             | 11.66e-d                   |
| Lakech        | 61.17ab         | 96.33b          | 93.03f-f          | 33.27c-k           | 2541.1f-g             | 11.79c-e                   |
| Yilmanu       | 57.33c-g        | 95.67abc         | 84.33h-l          | 32.39m             | 1961.7n               | 10.07+j                    |
| Etsub         | 58.17g-f        | 940-f            | 93.97h-f          | 36.47e-o           | 2619.8h-f             | 11.83g-c                   |
| Dima          | 57.55g          | 91.330-c         | 82.21j            | 28.83m             | 1978.5n               | 8.05f                      |
| Guduru         | 59a-e           | 94.50-f          | 104.83g           | 38.87m             | 1781.8n               | 9.84h                      |
| Kena          | 60.83ab         | 94.57f           | 88.11f            | 31.77m             | 1828.9n               | 10.59g-g                   |
| Ajora         | 54i             | 92.670-g         | 88.03j            | 33.5c-j            | 22573f-j              | 9.74k                      |
| Degatet       | 56.67a-h        | 94.170-f         | 90.57j            | 34.83b-i          | 2392.3d-i             | 12.07ab                    |
| Workiye       | 55.83a-e        | 93.830-d         | 91.43-g           | 36.4a-f           | 2479.6c-h             | 9.52b-j                    |
| Local         | 61.56          | 96.830           | 79.67m           | 29.07f-m          | 1969.7r-n             | 10.61a-d                   |
| Mean          | 57.62           | 93.07           | 87.95            | 33.8             | 2263                 | 10.18                      |
| CV (%)        | 3.9             | 3.59            | 5.14             | 8.5             | 14.4                 | 18.51                      |

R-square(%): 70 70.02 85.06 73.56 76.7 88.32

Where, treatments (varieties) with the same letters are not significantly different.
cropping season (July–September), and reported the stable and high yielding performance of Dukem variety. They also reported that significant grain yield among different tef varieties. Moreover, this result in line with Girma et al. (2019) studied that, among tasted tef genotypes for biomass yield ranged from 1.65 to 3.4 ton per hectare at Raya valley, Northern Ethiopia under irrigation season and significant difference among tasted genotypes. This finding was not in line with Aliyi et al. (2016), who observed that among the tested varieties across the testing locations for grain yield t/ha, which was ranged from 1.04 to 1.58 t ha\(^{-1}\) with the mean value of 1.32 t ha\(^{-1}\) under rain feed condition.

4. Conclusion and recommendations

From this study, the combined analysis of variance revealed that were observed that each of the tested varieties shows different performance for different characters such as, days to heading, days to maturity, panicle length, plant height and grain yield. Grain yield is an important trait to be emphasized for genotype selection to address the objective of the conducted activity. Despite the difference in performance of varieties for different parameters across years, varieties, namely Dukem, Gibe and Gola, had consistent performance for grain yield and gave yield advantage of 36.0%, 34.4% and 31% over the local check, respectively. Generally, the cultivation of improved tef varieties using both rainfed and irrigation seasons is unquestionable solution for food security and income for farmers by enhanced tef production and productivity, crop yield as compared to farmer local varieites. Therefore, these three varieties can be recommended for Dembia district and similar areas under irrigated production system.

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Competing Interests

The authors declares no competing interests.

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correction

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