

Original Research Article

Performance of Tef [*Eragrostis tef* (Zucc) Trotter] Varieties Influenced by Soil Compaction and Sowing Dates on Yield and Yield Components of in Ethiopia

Comment [B1]: Influence of Soil Compaction and Sowing Date on Yield and Yield Components of Tef [*Eragrostis tef* (Zucc) Trotter]. I suggest this modification

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ABSTRACT

Tef is the most cultivated crop in terms of area and second most produced crop after maize in Ethiopia. Soil compaction, inaccurate sowing date and shortage of high-yielding varieties are crucial problems in the study area. Therefore, this experiment was carried-out during the main cropping season of 2021 to study the effect of soil compaction, sowing dates and tef varieties on yield and yield components of tef in Toke Kutaye district. The treatments included soil compaction (compacted and un-compacted soil), three sowing dates such as (1st sowing date on 15/2021, 2nd on July 22/2021 and 3rd on July 29/2021, respectively) and three tef varieties such as [Dedefe (as standard check), Quncho and Dagim]. Treatments were factorially arranged and laid out in randomized complete block design with three replications. Analysis of the data indicated that days to 50% emergence, days to 50% panicle emergence, days to 90% physiological maturity, and number of productive tillers of tef were significantly ($P < 0.05$) influenced by main effect of soil compaction, sowing dates and varieties. Plant height, panicle length, number of total tillers, above ground biomass yield, grain yield and straw yield of tef were significantly affected by the interaction of three factors. Highest plant height (124.26 cm), panicle length (36.26 cm), above ground biomass yield (7.47 t ha^{-1}) and grain yield (2.8 t ha^{-1}) were recorded from un-compacted soil in early sown Dagim variety. Therefore, farmers in the study area are advised to grow Dagim variety with July 15 sowing date without trampling the soil to improve tef production and yield. However, the experiment has to be repeated across locations and seasons to provide a reliable recommendation for improved tef production for similar agroecology.

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Comment [B10]: Separate figures from unit of measurement

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Keywords: Soil compaction; sowing dates; tef; yield

1. INTRODUCTION

Tef is a highly demanded crop in Ethiopian diet as tef flour is used to prepare Injera which is the most popular food of the country. In Toke Kutaye district, tef is a major crop produced by

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small holder farmers and its total cultivated area is 6860 ha, producing 16,464.4 tons with an average productivity of 2.4 t ha⁻¹ (TKANRO, 2021). Thus, tef is one of the most widely grown crops in the study area.

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Even though tef has high economic value among Toke Kutaye farmers, its productivity is low as compared to the yield potential of the crop. This could be due to unknown effect of soil compaction, early or late time of sowing, and inadequate adaptable high yielding varieties in the study area (TKANRO, 2021).

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Soil compaction increases root penetration resistance due to reduced soil porosity (Laura, 2012; Batey, 2009). Moreover, compaction decreases air and water transport capability of soil due to its negative effects on soil hypoxia (Kuncoro *et al.*, 2014). Both high penetration resistance and poor soil aeration can reduce root elongation rate, delay in initiation of lateral roots, and thus results in shallow root systems (Colombi *et al.*, 2018; Mckenzie, 2010). Thus, root growth into deeper soil layers is reduced under compaction and soil exploration by plant roots is often limited to the topsoil. These effects of soil compaction on root system development can limit the access of plants to soil water and nutrients and ultimately reduce shoot growth and crop productivity (Colombi *et al.*, 2018). However, tef farmers in the study area compact the soil before sowing to make seedbed firm and flat, to prevent the soil surface from quick drying, to provide a thin coverage of broadcasted seeds and prevents seeds from desiccation and consequently enhances good germination and seedling establishment (TARI, 2007; Fufa *et al.*, 2001).

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Moreover, Date of sowing is one of the most important agronomic practices in tef production (Atis and Akar, 2018). It is an important factor which govern the phenological development of the crop and efficient conversion of biomass into economic yield. It has been observed that tef crop sown at normal date usually have longer crop duration, with an opportunity to accumulate more biomass as compared to late-sown and results in higher grain yield and biological yield (Zucca, 2016).

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2. MATERIALS AND METHODS

The study was carried out during the main rainy season from June to November, 2021 at *Wajira kebele*, Farmer's Training Centre of Toke Kutaye district, West Showa Zone of Oromia National Regional State, Ethiopia. Toke Kutaye district is located at 100 km from Addis Ababa towards western direction. Geographically, the district is situated at latitude of 9.81°47' to 10.08°11'N, longitude of 38°27' to 38.67°43'E, with an altitude of 1500 to 3167 m above sea level (TKANRO, 2021).

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It receives an average rainfall of 950 mm per annum with a minimum of 800 mm per annum and a maximum of 1100 mm per annum. The average temperatures were 17°C annually with a minimum of 15°C and a maximum of 29°C. The major agro-ecologies of the study area are 25% high land, 57% mid land, and 18% low land. The experiment was undertaken on Nitsols (light soils). The major crops cultivated in the district are maize, tef, barley, wheat, sorghum, fababean etc (TKANRO, 2021).

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The tef varieties namely *Quncho* (DZ-CR-387, off white in color), *Dagim* (white in color) and *Dedefe* [DZ-01-99, red in color, (standard check)] which were developed and released by Debre Zeit Agricultural Research Center were used for the study. The varieties were chosen based on high yield, resistance to diseases and pests, tolerance to lodging, and suitability to agro-ecological conditions of the study area. NPS (19% N, 38% P₂O₅, and 7% S) and Urea (46% N) fertilizers were used as the source of nutrient elements. Quantity of fertilizer used for the study was 100 kg ha⁻¹ NPS and 100 kg ha⁻¹ urea as recommended by MoA, (2017). Soil compaction was done manually. The treatment consisted of two levels of soil compaction (compacted and un-compacted soil), three dates of sowing, which include early sowing date (July 15) = SD1, mid-sowing date (July 22) = SD2, and late sowing date (July 29) = SD3 as well as three varieties such as *Dagim*, *Quncho* and *Dedefe* (standard check). Recommended sowing time of tef for the district is from 1st week of July to mid July (TKANRO, 2021). However, majority of the farmers sow tef during mid-July. The treatments were laid-out in 2 x 3 x 3 factorial arrangement in RCBD design with three replications. The experiment consisted

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of 18 treatments which were assigned randomly to each plot. The spacing between blocks and plots was 1 m and 0.5 m respectively with net plot size of 2 m x 3 m (6 m²).

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The field was plowed four times using oxen and prepared according to local practices before planting. The first ploughing was done at the onset of the rainfall on May 10, 2021 while the second and third ploughings were done on June 1, 2021 June 22, 2021. The last ploughing was done at sowing. In accordance with the specifications of the design, a field layout was prepared. The plots were leveled manually, and each treatment was assigned randomly to the experimental plots within a block.

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The soil was compacted and rows were made manually before sowing. Tef was sown by drilling in rows. Both NPS and urea fertilizers were used for compacted soil and un-compacted soil in equal amount. NPS fertilizer was applied at the rate of 100 kg ha⁻¹ as a basal application to each plot, and nitrogen at the specified rate 100 kg ha⁻¹ was applied in two splits in the form of urea (½ of the urea at sowing date and the remaining half was applied during tillering) for optimum nutrient use efficiency of tef (MoA, 2017).

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The seed rate used for all tef varieties was 10 kg ha⁻¹. The seeds were sown in rows and the spacing used between rows was 20 cm. Each plot had ten rows out of which the first and tenth rows were considered as boarder rows, while the remaining eight rows were used for data collection. Weeds were removed manually at the early stages of growth. Harvesting was done manually using hand sickles at the physiological maturity of the crop.

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2.1. Data Collected and Measurements

Crop growth, yield and yield components were measured from each net plot across treatments using following sampling and analytical procedures.

Days to 50 % emergence: This parameter of the plant was recorded as the number of days from sowing to the date when 50 % of the plants in a plot started to emerge, through visual observation.

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Days to 50 % panicle emergence: This parameter of the plant was recorded as the number of days from sowing to the date when 50% of the plants in a plot started to emerge panicles, through visual observation.

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Days to 90% physiological maturity: Days to physiological maturity was determined as the number of days from sowing up to the date when at least 90% of the plants reached physiological maturity based on visual observation.

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Plant height (cm): This was measured at physiological maturity from the ground level to the tip of the main shoot panicle from ten randomly selected pre-tagged plants in each plot.

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Panicle length (cm): This was the length of the panicle from the node where the first panicle branch emerged to the tip of the panicle measured as the main shoot panicle from ten randomly selected pre-tagged plants in each plot.

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Total number of tillers per plant: Ten plants were counted from inner rows excluding the main shoot from randomly selected pre-tagged plants from each plot from which the average number of tillers was taken per plant.

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Number of productive tillers per plant: This was recorded as the average number of fertile tillers of ten randomly selected pre-tagged plants from the inner rows of the plots at the maturity stage by excluding the main shoot.

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Above-ground biomass yield: This was recorded at maturity as the weight (kg) of the whole above-ground plant biomass harvested from the net plot area after sun-drying for seven days in open field, and then converted to kg ha^{-1} .

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Grain yield: This was taken as the weight (kg) of the grains harvested from the net plot area after threshing and then converted to kg ha^{-1} .

Straw yield: After threshing, the straw yield was obtained by subtracting the grain yield from the total above-ground biomass yield.

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Harvest index: Harvest index was calculated by dividing grain yield by the total ground biomass yield and multiplying by 100.

Comment [B64]: Above-ground?

Lodging index (%): The degree of lodging was assessed just before the time of harvest by visual observation based on the scales of 1 to 5, where: 1 ($0-15^\circ$) indicates no lodging, 2 ($15-30^\circ$) indicate 25% lodging, 3 ($30-45^\circ$) indicate 50% lodging, 4 ($45-60^\circ$) indicate 75% lodging, and 5 ($60-90^\circ$) indicate 100% lodging. I suggest that lodging index, straw yield and harvest index should be reported before grain yield.

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The data collected were subjected to analysis of variance (ANOVA) following the standard procedure given by Gomez and Gomez (1984) and analysis was done using SAS software program version 9.0 (SAS, 2002). Means of significance between and among treatment effects were separated using the Least Significant Difference (LSD) test at 5% level of significance (Gomez and Gomez, 1984).

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3. RESULTS AND DISCUSSION

3.1. Total number of tillers per plant

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The analysis of variance showed that the total number of tillers was significantly influenced ($p < 0.01$) by the interaction effects of sowing dates with varieties, however the main factor of sowing dates and varieties, and all possible interactions of treatments did not significantly ($P < 0.05$) affect number of total tillers (Table 1).

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The highest total number of tillers per plant of 5.59 was recorded from un-compacted soil, while the lowest number of 4.58 was recorded on compacted soil (Table 1). Compacted soil is less aerated and can limit root growth which in turn affects absorption of nutrients in the soil and total number of tillers produced per plant.

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The highest total number of tillers of 9.08 was obtained from early sown *Dagim* variety, while the lowest number of total tillers of 1.91 was recorded from late sown *Dedefe* variety (Table 1). Early sown *Dagim* variety had total number of tillers that was 78.96% higher than lately sown *Dedefe* variety. This might be due to the fact that early sown tef had an advantage in more efficiently utilising the available resources such as residual moisture from rain, light and nutrients as compared to late-sown tef. Zucca (2016) reported that tillering capacity of the variety determines the number of tillers produced per plant depending on the availability of growth resources. The number of tillers per plant of tef was affected by sowing date based on the response of varieties to the available resources and conditions.

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Table 1. Main effect of soil compaction on total number of tillers per plant of tef

Treatment	Total No of tillers
Compacted soil	4.58 ^b
Un-compacted soil	5.59 ^a
LSD (0.05)	0.47
CV (%)	16.8

Means with the same letter(s) in columns are not significantly different at $p < 0.05$ probability level

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Table 2. Interaction effects of sowing dates and varieties on total number of tillers of tef

Sowing date	SD1	SD2	SD3	Mean
Variety				
Dagim	9.08 ^a	7.91 ^b	5.33 ^c	7.44
Quncho	7.41 ^b	5.00 ^c	3.33 ^d	5.25
Dedefe	3.08 ^d	2.75 ^{de}	1.91 ^e	2.58
Mean	6.52	5.22	3.52	
LSD (0.05)			1.00	
CV (%)			16.80	

Where SD1; Early sowing date, SD2; Mid-sowing date, SD3; Late sowing date

Means with the same letter(s) in columns and rows are not significantly different at $p < 0.05$ probability level

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Comment [B88]: variety not varieties

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3.2. Number of productive tillers per plant

The total number of productive tillers was significantly ($p > 0.05$) affected by the interaction effects of soil compaction, sowing dates, and varieties (Table 3). However, there was no significant ($P < 0.05$) interaction effect on number of productive tillers.

The highest numbers of productive tillers of 5.77 tillers per plant was recorded from un-compacted soil with early sowing date. The lowest numbers of productive tillers per plant of 2.41 and 2.56 were recorded on lately sown tef from both compacted and un-compacted soils, respectively (Table 3). This difference might be due to the availability of growth resources on

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un-compacted soil and early sowing date for tef growth and root development which later contributed to maximum productive tillers as compared to late sown.

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The highest number of productive tillers of 6.38 tillers per plant was obtained from un-compacted soil with *Dagim* variety, while the lowest number of productive tillers per plant of 1.74 per plant was recorded from *Dedefe* variety sown on compacted soil (Table 3). This difference might be due to suitability of un-compacted soil for better root growth, which enhances tillering ability of the crop, and *Dagim* variety's inherent genetic potential in tillering ability.

Similarly, the highest number of productive tillers per plant of 7.41 tillers per plant was obtained from early sown *Dagim* variety, while the lowest number of productive tillers per plant of 1.58 was recorded from late sown *Dedefe* variety (Table 3). This difference could be due to high inherent potential of early sown *Dagim* variety for maximum productive tillers, and genotypic variation in response to time of sowing. Zucca (2016) reported that the number of tillers per plant of tef was affected by sowing date based on the response of varieties to available resources.

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Table 3. Interaction effects of soil compaction and sowing dates on number of productive tillers per plant of tef

Treatment	Compacted soil	Un-compacted soil	Mean
Sowing date			
SD1	4.46 ^b	5.77 ^a	5.12
SD2	3.28 ^c	4.44 ^b	3.86
SD3	2.41 ^d	2.56 ^d	2.48
Mean	3.38	4.26	
LSD (0.05)		0.63	
CV (%)		17.26	

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Where SD1; Early sowing date, SD2; Mid-sowing date, SD3; Late sowing date

Means with the same letter(s) in columns and rows are not significantly different at $p < 0.05$ probability level

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Table 4. Interaction effects of soil compaction and varieties on number of productive tillers per plant of tef

Treatment	Compacted soil	Un-compacted soil	Mean
Variety			
<i>Dagim</i>	4.72 ^b	6.38 ^a	5.55
<i>Quncho</i>	3.70 ^c	4.33 ^b	4.02
<i>Dedefe</i>	1.74 ^e	2.06 ^d	1.9
Mean	3.9	4.26	
LSD (0.05)		0.63	
CV (%)		17.26	

Means with the same letter(s) in columns and rows are not significantly different at $p < 0.05$ probability level

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Table 5. Interaction effects of sowing dates and varieties on number of productive tillers per plant of tef

Sowing date	SD1	SD2	SD3	Mean
Variety				
<i>Dagim</i>	7.41 ^a	5.75 ^b	3.50 ^c	5.55
<i>Quncho</i>	5.83 ^b	3.83 ^c	2.38 ^d	4.01
<i>Dedefe</i>	2.11 ^{de}	2.01 ^{de}	1.58 ^e	1.9
Mean	5.12	3.86	2.49	
LSD (0.05)		0.77		
CV (%)		17.26		

Where SD1; Early sowing date, SD2; Mid-sowing date, SD3; Late sowing date

Means with the same letter(s) in columns and rows are not significantly different at $p < 0.05$ probability level

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3.3. Above-ground biomass yield

The analysis of variance showed that above-ground biomass yield was significantly ($p < 0.01$) affected by the interactions of soil compaction, sowing dates, and varieties (Table 6).

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The highest dry biomass yield of 7.47 t ha⁻¹ was recorded from un-compacted soil with early sown *Dagim* variety, while the lowest dry biomass yield of 4.98 t ha⁻¹ was obtained from un-compacted soil with lately sown tef *Dedefe* variety, which was statistically at par with lately sown *Dedefe* variety on compacted soil (Table 6). This difference might be due to the suitability of early sowing on un-compacted soil for *Dagim* variety, which contributed to maximum dry biomass yield. These results are in agreement with Desta *et al.* (2020) who reported that significant difference in tef above-ground dry biomass yield when *Kora* variety was sown in early July. Moreover, Juraimi *et al.* (2009) reported that delaying of sowing time caused a decrease in biological yield in an experiment undertaken at Alem Tena (Central Ethiopia) and that when sowing dates were delayed by 1 or 2 weeks, the biological yield was reduced by 35 %.

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Table 6. Interaction effects of soil compaction, sowing dates and varieties on above-ground biomass yield of tef

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Treatment	Compacted soil			Un-compacted soil			Mean
	SD1	SD2	SD3	SD1	SD2	SD3	
Sowing date							
Variety							
<i>Dagim</i>	6.83 ^b	6.21 ^c	5.64 ^{fg}	7.47 ^a	5.96 ^{cd}	5.89 ^{def}	6.34
Quncho	5.95 ^{cde}	6.08 ^{cd}	5.46 ^{gh}	5.97 ^{cd}	5.65 ^{fg}	5.5 ^{gh}	5.77
Dedefe	5.67 ^{efg}	5.33 ^{hi}	5.05 ^{ij}	5.44 ^{gh}	5.33 ^{hi}	4.98 ⁱ	5.30
Mean	6.15	5.87	5.38	6.29	5.65	5.46	
LSD (0.05)	293.89						
CV (%)	3.05						

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Where SD1; Early sowing date, SD2; Mid-sowing date, SD3; Late sowing date

Means with the same letter(s) in columns and rows are not significantly different at $p < 0.05$ probability level

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3.4. Grain yield

Grain yield is the overall result of response of tef to different inputs, agronomic practices, ecological conditions and genetic differences. The analysis of variance revealed that the grain

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yield of tef was significantly ($p < 0.05$) influenced by interaction of soil compaction, sowing dates and varieties (Table 7).

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The highest grain yield of tef of 2.8 t ha⁻¹ was recorded from early sown *Dagim* variety on un-compacted soil while the lowest grain yield of tef of 1.95 t ha⁻¹ was recorded from late-sown in *Dedefe* variety on un-compacted soil (Table 7).

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The results of the study showed that *Dagim* variety sown early on un-compacted soil had increased grain yield by 30.35% above lately sown *Dedefe* variety. This is because of genotypic differences, appropriate sowing time and un-compacted soil which contributed to high-yielding ability as compared to local cultivars. Yield increase on early sown *Dagim* variety might be due to better translocation of photosynthates to reproductive cells and accumulation of carbohydrates in grain as compared to delayed sowing. Juraimi *et al.* (2009) and Zucc (2016) reported that there was a significant relationship among plant height, biomass and grain yield where grain yield responded positively to taller plants and higher biomass when the crop was sown early in the season. Fazal *et al.* (2015) reported that delay in sowing date and genetic variation reduced the grain yield due to smaller number of productive tillers and grains per spike in wheat. Juraimi *et al.* (2009) and Mengistu (2020) reported that early sown tef produced higher yield as compared with the late-sown one.

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Table 7. Interaction effects of soil compaction, sowing date and variety on grain yield of tef

Treatment	Compacted soil			Un-compacted soil			Mean
	SD1	SD2	SD3	SD1	SD2	SD3	
Sowing date							
Variety							
<i>Dagim</i>	2.66 ^b	2.54 ^c	2.23 ^{ef}	2.8 ^a	2.38 ^d	2.36 ^d	2.50
<i>Quncho</i>	2.41 ^d	2.28 ^e	2.12 ^{hi}	2.24 ^{ef}	2.18 ^{fgh}	2.16 ^{gh}	2.23
<i>Dedefe</i>	2.16 ^{gh}	2.15 ^{gh}	2.06 ⁱ	2.19 ^{fg}	2.13 ^{hi}	1.95 ^j	2.11
Mean	2.41	2.32	2.14	2.41	2.23	2.16	
LSD (0.05)	144.12						
CV (%)	3.81						

Where SD1; Early sowing date, SD2; Mid-sowing date, SD3; Late sowing date

Means with the same letter(s) in columns and rows are not significantly different at $p < 0.05$ probability level

3.5. Straw yield

The analysis of variance showed that the interactions of sowing date and variety significantly ($p < 0.001$) affected straw yield (Table 8). The main factor of soil compaction and other interactions did not significantly ($P < 0.05$) affect straw yield.

The highest straw yield of 4.42 t ha⁻¹ was obtained from early-sown *Dagim* variety, while the lowest straw yield of 3.17 t ha⁻¹ was recorded from lately-sown *Dedefe* variety (Table 8). The difference in straw yield might be due to suitability of early sowing date and genotypic variation of *Dagim* variety which contributed to increasing straw yield. These results are in line agreement with Assefa *et al.* (2015), who reported that shortened vegetative growth period of crop due to changes in the photoperiod that enhanced the rate of development towards the reproductive phase.

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Table 8. Interaction effects of sowing date and variety on straw yield of tef

Sowing date	SD1	SD2	SD3	Mean
Variety				
<i>Dagim</i>	4.42 ^a	3.64 ^b	3.46 ^{bcd}	3.84
<i>Quncho</i>	3.64 ^b	3.63 ^{bc}	3.33 ^{de}	3.54
<i>Dedefe</i>	3.37 ^{cde}	3.18 ^d	3.17 ^e	3.24
Mean	3.81	3.48	3.32	
LSD (0.05)	277.21			
CV (%)	6.67			

Where SD1; Early sowing date, SD2; Mid-sowing date, SD3; Late sowing date

Means with the same letter(s) in columns and rows are not significantly different at $p < 0.05$ probability level.

3.6. Harvest index

The results of harvest index were significantly ($p < 0.05$) affected by interactions of soil compaction, sowing date and variety (Table 9).

The highest harvest index of 40.9 % was obtained on compacted soil in lately-sown tef from *Dedefe* variety, while the lowest harvest index of 36.9 % was obtained from un-compacted soil in early sown *Quncho* variety. The difference in harvest index might be due to sowing date gaps and genetic variability of tef varieties. Similarly, Mengistu (2020) reported that harvest index increased significantly as sowing date was delayed in different tef varieties. Likewise, Assefa *et al.* (2015) also reported that the harvest index in tef varieties ranged from 5% to 39%.

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Table 9. Interaction effects of soil compaction, sowing date and variety on harvest index

Treatment	Compacted soil			Un-compacted soil			Mean
	SD1	SD2	SD3	SD1	SD2	SD3	
Sowing date							
Variety							
<i>Dagim</i>	38.4 ^{abcde}	40.4 ^{ab}	39.6 ^{abcde}	37.0 ^{de}	39.9 ^{abcd}	40.1 ^{abc}	39.2
<i>Quncho</i>	39.8 ^{abcd}	37.7 ^{de}	38.7 ^{abcde}	36.9 ^e	38.5 ^{bcde}	39.4 ^{abcde}	38.5
<i>Dedefe</i>	38.2 ^{cde}	40.3 ^{abc}	40.9 ^a	40.2 ^{abc}	40.6 ^{ab}	39.0 ^{bcde}	39.9
Mean	38.8	39.5	39.7	38	39.6	39.6	
LSD (0.05)			2.43				
CV (%)			3.75				

Where SD1; Early sowing date, SD2; Mid-sowing date, SD3; Late sowing date

Means with the same letter(s) in columns and rows are not significantly different at $p < 0.05$ probability level.

3.7. Lodging index

Lodging index of tef was significantly ($p < 0.001$) affected by interaction of soil compaction, sowing date and variety (Table 10).

The highest lodging index of 50.0 % was recorded on un-compacted soil with early-sown *Dedefe* variety, while the lowest lodging index of 26.6 % was recorded on compacted and un-compacted soils with early and mid-sown *Dagim* variety, respectively, which was statistically at par with mid-sown *Dagim* variety on compacted soil (Table 10). This difference in harvest index may be due to the difference in the genetic make-up of *Dedefe* variety which is tall in stature and prone to lodging in comparison with the improved genotypes, which are medium in stature and have stiff straw and consequently are less prone to lodging. Kebebew (2013) reported that although lodging does little harm to total biomass yield, it is known to cause serious economic losses by reducing yield and quality of both grains and straw in small grains like tef.

Comment [B170]: singular

Comment [B171]: singular

Comment [B172]: singular

Comment [B173]: p not P

Comment [B174]: delete and remove italics

Comment [B175]: singular

Comment [B176]: add hyphen (-)

Comment [B177]: add

Comment [B178]: delete

Comment [B179]: like

Table 10. Interaction effects of soil compaction, sowing date and variety lodging index of tef

Treatment	Compacted soil			Un-compacted soil			Mean
	SD1	SD2	SD3	SD1	SD2	SD3	
Sowing date							
Variety							
<i>Dagim</i>	26.6 ⁱ	28.3 ^{hi}	31.6 ^{fgh}	31.0 ^{gh}	26.6 ⁱ	31.0 ^{gh}	29.2
<i>Quncho</i>	38.6 ^{de}	35.0 ^{ef}	39.3 ^d	43.3 ^{bc}	41.0 ^{bcd}	43.3 ^{bc}	40.1
<i>Dedefe</i>	33.3 ^{fg}	40.0 ^{cd}	39.3 ^d	50.0 ^a	44.3 ^b	41.6 ^{bcd}	41.4
Mean	32.8	34.4	36.7	41.4	37.3	38.6	
LSD (0.05)	3.90						
CV (%)	6.37						

Where SD1; Early sowing date, SD2; Mid-sowing date, SD3; Late sowing date

Means with the same letter(s) in columns and rows are not significantly different at $p < 0.05$ probability level

3.8. Correlation of Grain Yield with Growth and Yield Components of Tef

Correlation analysis of tef showed a significant relationship between growth parameters, yield components and grain yield. Grain yield had a significant ($p < 0.01$) and positive correlation with the growth parameters and yield components (Table 11). The higher the amount of growth parameters, the higher the yield component production, which later resulted in higher grain yield production.

The results also indicated that grain yield was positively correlated with days to 90% physiological maturity (0.62), plant height (0.68), panicle length (0.68), total number of tillers (0.80), number of productive tillers (0.80), biomass yield (0.92) and straw yield (0.93) (Table 11). This result agrees with the findings of Teklay and Girmay (2016), who reported that strong and significant positive correlation of grain yield with plant height, panicle length, productive tillers and straw yield were recorded in tef. Similarly, Chanyalew (2007) reported that grain yield of tef was significantly and positively correlated with growth parameters and yield components. This means that with increasing value of this trait, the grain yield increases and vice versa.

Comment [B180]: singular

Comment [B181]: singular

Comment [B182]: singular

Comment [B183]: singular

Comment [B184]: p not P

Comment [B185]: remove italics

Comment [B186]: p not P

Comment [B187]: note change

Comment [B188]: delete

Comment [B189]: higher not more

Comment [B190]: slight change

Comment [B191]: correlated

Comment [B192]: total number of tillers

Comment [B193]: note change

Comment [B194]: delete

Comment [B195]: delete

Comment [B196]: Similarly,

Comment [B197]: plural

Comment [B198]: No need for this as preceding statement is explicit.

Table 11. Correlation matrix of grain yield with growth parameters and yield components of tef

	DPM	PH	PL	TNT	TNPT	AGBY	GY	SY
DPM		0.80**	0.74***	0.75**	0.71***	0.58**	0.62***	0.45**
PH			0.89***	0.76**	0.76***	0.74**	0.68***	0.65**
PL				0.68***	0.67**	0.74**	0.68***	0.66**
TNT					0.97***	0.80***	0.80***	0.69***
TNPT						0.81**	0.80***	0.71***
AGBY							0.92***	0.93***
GY								0.78**
SY								

DPM; Days to 90% physiological maturity, PH ;Plant height, PL; Panicle length, TNT; Total number of tillers per plant, TNPT; Total number of productive tillers, AGBY; Above ground biomass yield, GY; Grain yield, SY; Straw yield

4. CONCLUSION

Tef production is highly dependent on soil available nutrient, sowing time, environmental factors and plant genotypes for plant growth and yield. Lack of information on soil compaction, inappropriate sowing dates and inadequate improved tef varieties are among the major challenges responsible for low productivity of tef in the study area. The current information on effects of soil compaction, sowing date and improved varieties of tef are crucial to draw conclusions on profitable and sustainable tef production. Soil compaction, sowing dates and tef varieties affect phenology, growth, yield and yield-related parameters of tef. Therefore, The study results showed that the longest days to 50% emergence of 4.11 days and longest days to panicle emergence of 56.16 days were recorded on lately-sowing date. The longest days to physiological maturity of 135 days was recorded in recently released *Dagim* variety. Compaction of soil also reduced duration for physiological maturity.

Comment [B199]: Note modification

Comment [B200]: TNT

Comment [B201]: TNPT

Comment [B202]: TNT

Comment [B203]: TNPT

Comment [B204]: Total number of tillers per plant

Comment [B205]: Total number of productive tillers

Comment [B206]: plural

Comment [B207]: on

Comment [B208]: affect

Comment [B209]: add hyphen (-)

Comment [B210]: delete

Comment [B211]: delete

Comment [B212]: to

Comment [B213]: add hyphen (-)

Comment [B214]: to

Comment [B215]: in

Comment [B216]: compaction

The tallest plant height of 124.26 cm, longest panicle length of 36.26 cm, highest above-ground biomass yield of 7.47 t ha⁻¹ and the highest grain yield of 2.8 t ha⁻¹ were obtained from un-compacted soil with early sown *Dagim* variety. Among the varieties used in this study, *Dagim* variety was the best in overall performance in the study area. The study revealed that early sowing of *Dagim* variety in un-compacted soil resulted in increased growth and grain yield. The highest grain yield of 2.8 t ha⁻¹ was recorded from un-compacted soil sown early with *Dagim* variety. It is, therefore, recommended that farmers should use *Dagim* variety on un-compacted soil and sow early in order to increase tef production and productivity in Toke Kutaye district.

Comment [B217]: add hyphen (-)

Comment [B218]: sown

Comment [B219]: note slight change

Comment [B220]: add grain

Comment [B221]: note change

Comment [B222]: note modification

Comment [B223]: delete

REFERENCES

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Comment [B224]: add ,

Comment [B225]: add ,

Comment [B226]: add and

Comment [B227]: Food

Comment [B228]: Wiley

Comment [B229]: Add hyphen (-)

Comment [B230]: Title of journal before volume No

Kebebew, A., Solomon C. and Zerihun T. (2013). Achievements and prospects of Tef improvement; Proceedings of the Second International Workshop, November 7-9, 2011, Debre Zeit, Ethiopia. *Research Ethiopian Institute of Agriculture*, Addis Ababa, Ethiopia; Institute of Plant Sciences, University of Bern, Switzerland. Printed at Stämpfli AG, 3001 Bern, Switzerland.

Comment [B231]: Add , and ,.

Comment [B232]: Capitalize first letters

Teklay, T. and Girmay, G. (2016). Agronomic and Economic Evaluations of Compound Fertilizer Applications under Different Planting Methods and Seed Rates of Tef [*Eragrostis tef* (Zucc.) Trotter] in Northern Ethiopia. *Journal of the Dry Lands*, 6(1): 409-422 40.

Comment [B233]: Lands not lands

TKANRO (Toke Kutaye Agriculture and Natural Office). (2021). Report on area and production of major crops. Guder, Ethiopia.

Zucca, C. (2016). Response of tef row planting to sowing dates on the highland heavy clay soils. Technical Report of Experimental Activities, Project Agreement No. 100202.

Note: Out of 20 references cited in the text, only 11 were listed. Ensure that all references are listed

Comment [B234]: Take note