

Effect of Soil Compaction and Sowing Dates on Growth and Yield of Tef [*Eragrostis tef* (Zucc) Trotter] Varieties in Toke Kutaye District

ABSTRACT

Tef is a highly valued crop in Ethiopia as tef flour used to prepare Injera which is the most popular food of the country. However, its production and productivity are constrained by a number of problems, out of which soil compaction, inappropriate sowing time, and limited use of improved varieties are the most important. Hence, a field experiment was conducted during the 2021 main cropping season to evaluate 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 (124.26cm), panicle length (36.26cm), above ground biomass yield (7.47 t ha⁻¹), and grain yield (2.8 t ha⁻¹) were recorded from un-compacted soil, from early sown Dagim variety. Therefore, it can be recommended that farmers of the study area can grow Dagim variety with July 15 sowing date without trampling the soil to enhance the tef production and productivity.

Keywords: *Soil compaction, sowing dates, tef, yield*

1. INTRODUCTION

Tef [*Eragrostis tef*] (*Zucc.*) *Trotter*] is a self-pollinated and warm season cereal crop 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. It has the largest value in terms of both production and consumption in Ethiopia.

It is grown annually on 2.93 million hectares of land in Ethiopia with a total production of 5.51 million tons at an average productivity of 1.88 t ha⁻¹. Tef is grown by more than 6.86 million households and constitutes the major staple food grain for over 50 million Ethiopians (CSA, 2021). Tef is a highly-valued crop, as it is nutritionally rich and free of protein gluten.

Oromia Regional National State is among the most important tef growing areas of the country which accounts for 1,393,455.62 ha of area coverage annually with expected production of 26,904,67.012 tons with average productivity of 1.93 t ha⁻¹ yield. Besides, West Shewa Zone accounted for 233,023.11 hectares of land and 4,765,75.6 tons of tef grain with average productivity of 2.05 t ha⁻¹ (CSA, 2021).

3. MATERIALS AND METHODS

The study was carried out during the main rainy season from June to November, 2021 at *Wajira kebele*, Farmer's Training Center 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).

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).

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 100kg ha⁻¹ NPS and 100kg 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 such as early sowing date (July 15) = SD1, mid-sowing date (July 22) = SD2, and late sowing date (July 29) = SD3) and 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 do tef sowing during mid-July. The treatments were laid-out in 2*3*3 factorial arrangement in RCBD design with three replications. The experiment consisted of 18 treatments which were assigned randomly to each plot. The spacing between blocks and plots was 1m and 0.5m respectively with net plot size of 2*3=6m².

The field was plowed four times using oxen and prepared according to local practices before planting. The first plowing was done at the onset of the rainfall on 10th May 2021 and the second ploughing was done after 21 days on 1st June 2021 and the third ploughing was done after 21 days on 22nd June 2021 and the last ploughing was 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.

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. 100kg/ha NPS fertilizer was applied as a basal application to each plot, and nitrogen at the specified rates 100kg/ha 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).

The seed rate used for all tef varieties were 10 kg ha⁻¹. The seeds were sown in rows and the spacing used between rows was 20 cm. Each plot had ten rows and 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 tef. Harvesting was done manually using hand sickles at the physiological maturity of the crop.

3.5. 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.

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.

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

Plant height (cm): It 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.

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

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

Number of productive tillers per plant: It 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.

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} .

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.

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

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.

The data was 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).

3. RESULTS AND DISCUSSION

3.1. Days to 50 % emergence

The analysis of variance showed that days to 50% emergence of tef was significantly ($P<0.01$) affected by the main effect of soil compaction, sowing dates, and varieties (Table 1). However, their interactions were not significantly ($P<0.05$) influence days to 50% emergence.

The longest days to 50% emergence of 4.33 days was recorded on soil compaction treatment, while the shortest days of 3.85 days was recorded on un-compacted soil. This could be due to the effect of soil compaction on soil aeration and availability of oxygen which is essential for seed germination and its related metabolic activities such as respiration, which in turn affects the emergence of seedlings.

On the other hand, the longest days to 50% emergence of 4.27 days was recorded on lately sown treatment of July 29, 2021 and the shortest days to 50% emergence of 4.00 days was recorded from early sown treatment of July 15, 2021 which was statistically at par with mid-sown treatment of July 22, 2021. This is due to the fact that timely sown of tef can utilize the soil moisture available during early sowing dates, compared to late sown seeds. Similar results were obtained by Zucca (2016) who reported that there was significant effect of different sowing dates on days to emergence of tef.

Days to emergence showed variability among varieties. The longest days to emergence of 4.19 days was recorded on variety *Dedefe*, while the shortest days to emergence of 3.97 days was obtained from *Quncho* variety (Table 1). This could be due to difference in seed size and their genetic variation.

3.2. Days to 50 % panicle emergence

The analysis showed that days to 50% panicle emergence was significant ($P < 0.001$) affected by the main effect of sowing dates and varieties, however soil compaction and the interaction of the main factors did not significantly ($P < 0.05$) affect days to 50% emergence (Table 1).

The longest days to panicle emergence of 56.16 days was recorded from late sown treatment of July 29, 2021, which was statistically at par with mid-sown date, while the shortest days to panicle emergence of 52.94 days was recorded from early sown date of July 15, 2012. In late sown tef, panicle emergence was late, which might be due to unavailability of optimum moisture and nutrients required for panicle emergence.

However, the longest days to attain 50% panicle emergence of 57.27 days was recorded from *Dagim* variety, while the shortest 50% panicle emergence of 52.11 days was recorded from

Dedefe variety (Table 1). This might be due to ecological suitability of *Dedefe* variety as a result of timely sowing and genotypic advantage. Mebratu *et al.* (2016) reported that improved varieties and local check significantly differ in days to panicle emergence in tef because of genotypic variation.

3.3 Days to 90% physiological maturity

The analysis of variance showed that days to 90 % physiological maturity was significantly ($P < 0.05$) affected by main effect of soil compaction, sowing dates and varieties (Table 1). However, their interactions did not significantly ($P < 0.05$) affect days to 90% physiological maturity.

The highest and lowest number of days of 130.96 and 129.33 days for 90% physiological maturity were recorded from un-compacted and compacted soils, respectively while the shortest days to achieve 90% physiological maturity of 128.61 days was recorded from lately sown tef sown on July 29, 2021 which was statistically at par with early sown tef on July 15. Where as, the longest days to physiological maturity of 131.72 days was recorded from mid-sown tef sown on July 22, 2021 (Table 1). This difference in days to reach physiological maturity might be due to the variation in availability of nutrients in the soil and the suitability of agro-climatic conditions for vegetative growth of plants.

However, the shortest days for 90% physiological maturity of 123.72 days was recorded from *Dedefe* variety, while the longest days to physiological maturity of 135.00 days was recorded from *Dagim* variety. The difference in days to reach physiological maturity among tef varieties could be due to their inherent genetic variability. Mebratu *et al.* (2016) reported that improved varieties and local tef significantly differ in days to reach physiological maturity because of their genotypic variation.

Table 1. Main effect of soil compaction, sowing dates and varieties on phenological parameters of tef in Toke Kutaye district

Treatments	Days to emergence	Days to panicle emergence	Days to maturity
Compacted soil	4.33 ^a	54.51 ^a	129.33 ^b
Un-compacted soil	3.85 ^b	55.37 ^a	130.96 ^a

LSD (0.05)	0.13	NS	1.60
Sowing dates			
July 15,2021	4.00 ^b	52.94 ^b	130.11 ^{ab}
July 22,2021	4.00 ^b	55.72 ^a	131.72 ^a
July 29,2021	4.72 ^a	56.16 ^a	128.61 ^b
LSD (0.05)	0.16	1.70	1.97
Varieties			
<i>Dagim</i>	4.11 ^{ab}	57.27 ^a	135.00 ^a
<i>Quncho</i>	3.97 ^b	55.44 ^b	131.72 ^b
<i>Dedefe</i>	4.19 ^a	52.11 ^c	123.72 ^c
LSD (0.05)	0.16	1.70	1.97
CV (%)	6.03	4.59	2.24

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

3.4. Plant height

The analysis of variance showed that plant height was significantly ($P < 0.001$) affected by the main factors of soil compaction, sowing dates and varieties, as well as their interaction (Table 2).

The tallest plant height of 124.27 cm was recorded from un-compacted soil with early sown *Dagim* variety, while the shortest plant height of 69.17 cm was recorded from late sown *Dedefe* variety on compacted soil (Table 2). The tallest plant height obtained from early sown *Dagim* variety on un-compacted soil exceed by 44.33% over the treatment that produced the shortest plant height. Soil compaction and delaying of sowing date might be the reason for decrease in plant height. The increase plant height might be due to adequate amount of nutrients which promoted the vegetative growth in treatments of early sowing date with *Dagim* variety on un-compacted soil and due to the inherent genetic differences among varieties. In addition, the difference in plant height of the varieties could be attributed to the difference in their genetic makeup (Jemal *et al.*, 2015). Similarly, Zucca (2016) reported tallest plant height

of 95.3 cm in response to early sowing with on un-compacted soil while the shortest of 63.3 cm observed on delayed sowing dates and on compacted soil.

Table 2. Interaction effects of soil compaction, sowing dates and varieties on plant height of tef in Toke Kutaye district.

Treatments	Compacted soils			Un-compacted soils			
Sowing dates	SD1	SD2	SD3	SD1	SD2	SD3	Mean
Varieties							
<i>Dagim</i>	110.40 ^b	97.70 ^f	98.70 ^f	124.27 ^a	108.97 ^{bc}	99.80 ^f	106.64
<i>Quncho</i>	101.6 ^{ef}	106.3 ^{bcde}	102.6 ^{ef}	105.07 ^{cde}	102.8 ^{def}	107.8 ^{bcd}	104.16
<i>Dedefe</i>	75.00 ^{gh}	79.03 ^g	69.17 ⁱ	74.87 ^{gh}	78.60 ^g	72.70 ^{hi}	74.89
Mean	95.67	94.34	90.15	101.4	96.79	93.4	
LSD (0.05)	5.14						
CV (%)	3.26						

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.

3.5. Panicle length

Panicle length was significantly ($P < 0.001$) affected by the main effect of soil compaction, sowing dates, varieties and their interaction (Table 3).

The longest panicle length of 36.26 cm was recorded from un-compacted soil with early sown on July 15, 2021 in *Dagim* variety, which was statistically at par with early sown on compacted soil, while the shortest panicle length of 22.80 cm was obtained on compacted soil with early sown date from *Dedefe* variety. The significant difference among the varieties for these growth traits might be attributed to their genetic difference which reflects on their different responses to sowing dates and soil compaction. Sherif (2004) and Zucca (2016) also reported that early sowing influenced increased panicle length in tef.

Table 3. Interaction effects of soil compaction, sowing dates and varieties on panicle length of tef in Toke Kutaye district

Treatments	Compacted soils			Un-compacted soils			Mean
	SD1	SD2	SD3	SD1	SD2	SD3	
Varieties							
<i>Dagim</i>	36.26 ^a	30.73 ^{cd}	28.76 ^{ef}	36.33 ^a	30.93 ^{bcd}	32.00 ^{bc}	32.5
<i>Quncho</i>	27.03 ^f	31.56 ^{bcd}	32.60 ^b	30.36 ^{cde}	30.10 ^{de}	31.36 ^{bcd}	30.5
<i>Dedefe</i>	22.80 ⁱ	24.56 ^{gh}	23.10 ^{hi}	24.40 ^{ghi}	25.16 ^g	24.93 ^g	24.12
Mean	28.69	28.95	28.15	30.36	28.73	29.43	
LSD (0.05)	1.73						
CV (%)	3.60						

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. Grain yield

Grain yield is the result of overall response of tef to different inputs, agronomic practices, ecological conditions and genetic differences. The analysis of variance revealed that the grain yield of tef was significantly ($P < 0.05$) influenced by interaction of soil compaction, sowing dates and varieties (Table 4).

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 4).

The results of the study showed *Dagim* variety sown early on un-compacted soil increased grain yield by 30.35% over 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 photosynthesis to reproductive cells and accumulation

of carbohydrates in grain as compared to delayed sowing. Juraimi *et al.* (2009) and Zucc (2016) reported that there is 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 caused by smaller number of productive tillers and grains per spike in wheat. Juraimi *et al.* (2009) and Mengistu (2020) reported that timely sown tef produced higher yield as compared with late sown.

Table 4. Interaction effects of soil compaction, sowing dates, and varieties on grain yield of tef

Treatments	Compacted soils			Un-compacted soils			Mean
	SD1	SD2	SD3	SD1	SD2	SD3	
Sowing dates							
Varities							
<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

3.7. Straw yield

The analysis of variance showed that the interactions of sowing date and varieties significantly ($P < 0.001$) affected straw yield (Table 5). The main factor of soil compaction and other interactions 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 13). This difference in straw yield might be due to suitability of early sowing date and genotypic variation of *Dagim* variety which contributed for increasing straw yield. These results were in

line agreement with Assefa *et al.* (2015) reported that the shortened vegetative growth period of crop due to changes in the photoperiod that enhanced the rate of development towards the reproductive phase.

Table 5. Interaction effects of sowing dates and varieties on straw yield of tef

Sowing dates	SD1	SD2	SD3	Mean
Varieties				
<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.

4. CONCLUSION

Tef production is highly dependent on soil available nutrient, sowing time, environmental factors and plant genotypes for plant growth and production. Lack of information on soil compaction, sowing dates and recently released tef varieties are among the major challenges responsible for low productivity of tef in the study area. The current information on effect of soil compaction, sowing date, and improved varieties of tef is very important to draw conclusions for profitable and sustainable tef production. To conclude that, soil compaction, sowing dates and tef varieties affect all 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 for panicle emergence of 56.16 days were recorded on lately sowing date. The longest days for panicle emergence of 57.27 days and the longest days for physiological

maturity of 135 days were recorded from recently released *Dagim* variety. Compacting of soil in tef production also reduced duration for physiological maturity.

The tallest plant height of 124.26 cm, longest panicle length of 36.26 cm, and the 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.

Based on the findings of this study, the following recommendations are forwarded: The study revealed that early sown *Dagim* variety on un-compacted soil increased growth and yield of tef. The highest grain yield (2.8 t ha⁻¹) was recorded from un-compacted soil with early sown on *Dagim* variety.

It is advisable for farmers to use *Dagim* variety on un-compacted soil with early sown date to increase tef production and productivity in Toke kutaye district.

In order to draw reliable recommendations, further study should be conducted on similar topic and agro-ecology as the study was conducted for only one season and site. This document could be used as a bench mark for future related study, policy makers, and researchers.

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