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Performance of Tef [*Eragrostis tef* (Zucc) Trotter] Varieties Influenced by Soil Compaction and Sowing Dates in Toke Kutaye District in Ethiopia

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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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 effects 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 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, total number of 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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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 smallholder farmers and its total cultivated area is 6860 ha, producing 16,464.4 tons with an average productivity of 2.4 t ha^{-1} [1]. Thus, tef is one of the most widely grown crops in the study area.

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 [1].

Soil compaction increases root penetration resistance due to reduced soil porosity [2]. “Moreover, compaction decreases air and water transport capability of soil due to its negative effects on soil hypoxia” [3]. “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” [4]. “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” [4]. 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 seeds and prevents seeds from desiccation and consequently enhances good germination and seedling establishment.

Date of sowing is one of the most important agronomic practices in tef production [5]. “It is an important factor which governs 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 has longer crop duration, thus gets an opportunity to accumulate more biomass as compared to late-sown and results in higher grain yield and biological yield” [6].

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 [1].

The district 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 [1].

The tef varieties namely *Quncho* (DZ-CR-387, off white in colour), *Dagim* (white in colour) and *Dedefe* [DZ-01-99, red in color, (standard check)] which were developed and released by Debre Zeit Agricultural Research Centre 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% P_2O_5, 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, [7]. 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 [1]. However, majority of the farmers do tef sowing during mid-July. The treatments were laid-out in 2x3x3 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 m x 3 m = 6 m².

The field was ploughed four times using oxen and prepared according to local practices before planting. The first ploughing 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. 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 of 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 [7].

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 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 growth. Harvesting was done manually using hand sickles at the physiological maturity of the crop.

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 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 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 at least 90% of the plants reached physiological maturity based on visual observation.

Plant height: 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.

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

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 and the average number of tillers was taken per plant.

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 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}.

Straw yield: After threshing, the straw yield was computed 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 above-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^o) indicates no lodging, 2 (15-30^o) indicate 25% lodging, 3 (30-45^o) indicate 50% lodging, 4 (45-60^o) indicate 75% lodging, and 5 (60-90^o) indicate 100% lodging.

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}.

The data collected was subjected to analysis of variance (ANOVA) following the standard procedure given by Gomez and Gomez [8] using SAS software program version 9.0 (SAS, 2002). Means of significance between were separated using the Least Significant Difference (LSD) test at 5% level of probability [8].

3. RESULTS AND DISCUSSION

3.1 Total number of Tillers per Plant

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

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

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 2). 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 utilizing the available resources such as residual moisture from rain, light and nutrients as compared to late-sown tef. Zucca [6] reported that tillering capacity of the variety determines 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.

3.2 Number of Productive Tillers per Plant

The total number of productive tillers was significantly ($p< 0.001$) affected by the interactions of soil compaction, sowing dates, and varieties (Table 3). The highest number 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 tillers per plant 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 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.

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 5). 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.

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

Treatments	Number of total tillers
Compacted soils	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

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

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

Treatments	Compacted soils	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	

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

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

Treatments	Compacted soils	Un-compacted soil	Mean
Variety			
Dagim	4.72[b]	6.38[a]	5.55
Quncho	3.70[c]	4.33[b]	4.02
Dedefe	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

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				
Dagim	7.41[a]	5.75[b]	3.50[c]	5.55
Quncho	5.83[b]	3.83[c]	2.38[d]	4.01
Dedefe	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

Similarly, the highest number of productive tillers 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 4). 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 [6] reported that the number of tillers per plant of tef was affected by sowing date based on the response of varieties to available resources.

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).

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. [9] who reported significant difference in tef aboveground dry biomass yield when *Kora* variety was sown in early July. Moreover, Juraimi et al. [10] reported that delaying of sowing time caused a decrease in biological yield in an experiment undertaken at Alem Tena (Central Ethiopia) that when sowing dates were delayed by 1 or 2 weeks, the biological yield was reduced by 35%.

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

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 1.95 t ha^{-1} was recorded from late-sown in *Dedefe* variety on un-compacted soil (Table 7).

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. [10] and Zucc [6] 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”. Juraimi et al. [10] and Mengistu [11] reported that early sown tef produced higher yield as compared with the late-sown one.

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.

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

Treatments	**Compacted soils**			**Un-compacted soil**			
Sowing date	**SD1**	**SD2**	**SD3**	**SD1**	**SD2**	**SD3**	**Mean**
Variety							
Dagim	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				

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

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

Treatments	**Compacted soils**			**Un-compacted soil**			
Sowing date	**SD1**	**SD2**	**SD3**	**SD1**	**SD2**	**SD3**	**Mean**
Variety							
Dagim	2.66^{b}	2.54^{c}	2.23^{ef}	2.8^{a}	2.38^{d}	2.36^{d}	2.50
Quncho	2.41^{d}	2.28^{e}	2.12^{hi}	2.24^{ef}	2.18^{fgh}	2.16^{gh}	2.23
Dedefe	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)			1.44				
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

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

Sowing date	SD1	SD2	SD3	Mean
Variety				
Dagim	4.42[a]	3.64[b]	3.46[bcd]	3.84
Quncho	3.64[b]	3.63[bc]	3.33[de]	3.54
Dedefe	3.37[cde]	3.18[d]	3.17[e]	3.24
Mean	3.81	3.48	3.32	
LSD (0.05)		2.77		
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

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

Treatments	Compacted soils			Un-compacted soil			
Sowing date	**SD1**	**SD2**	**SD3**	**SD1**	**SD2**	**SD3**	**Mean**
Variety							
Dagim	38.4[abcde]	40.4[ab]	39.6[abcde]	37.0[de]	39.9[abcd]	40.1[abc]	39.2
Quncho	39.8[abcd]	37.7[de]	38.7[abcde]	36.9[e]	38.5[bcde]	39.4[abcde]	38.5
Dedefe	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

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 agreement with Assefa et al. [12] who reported that "the shortened vegetative growth period of crop due to changes in the photoperiod enhanced the rate of development towards the reproductive phase".

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 *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 [11] reported that harvest index increased significantly as sowing date was delayed which was influenced by the genetic variation of tef. Likewise, Assefa et al. [12] reported that the harvest index in different tef varieties ranged from 5% to 39%.

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 are less prone to lodging. Kebebew [13] 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".

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

Treatments	Compacted soils			Un-compacted soil			
Sowing date	**SD1**	**SD2**	**SD3**	**SD1**	**SD2**	**SD3**	**Mean**
Variety							
Dagim	26.6^{i}	28.3^{hi}	31.6^{fgh}	31.0^{gh}	26.6^{i}	31.0^{gh}	29.2
Quncho	38.6^{de}	35.0^{ef}	39.3^{d}	43.3^{bc}	41.0^{bcd}	43.3^{bc}	40.1
Dedefe	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

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

	DPM	PH	PL	NNT	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, NTT; Total number of tillers per plant, NTPT; Total number of productive tillers, AGBY; Above ground biomass yield, GY; Grain yield, SY; Straw yield

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 more grain yield production.

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 [14] who reported that strong and significant positive correlation of grain yield with plant height, panicle length, productive tillers, and straw yield in tef. Similarly, Chanyalew [15] reported that grain yield of tef was significantly and positively correlated with growth parameters and yield components.

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. The 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.

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 increased growth and grain yield of tef. 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 with early sowing date to increase tef productivity in Toke Kutaye district.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. TKANRO (Toke Kutaye Agriculture and Natural Office). Report on area and production of major crops. Guder, Ethiopia; 2021.
2. Laura C. Soil compaction. In: Jakobsson, Christine: Ecosystem health and sustainable agriculture. 2012;1:28.
3. Kuncoro K, Kuncoro P, Koga K, Sattaa N, Muto Y. A study on the effect of compaction on transport properties of soil gas and water. Relative gas diffusivity, air permeability, and saturated hydraulic conductivity. Soil Tillage Res. 2014;143:172-179.
4. Colombi C. Feedbacks between soil penetration resistance, root architecture and water uptake limit water accessibility and crop growth-a vicious circle. Sci. Total Environ. 2018;626:1026-1035.
5. Atis I, Akar M. Grain yield and quality of the tef is affected by sowing date. Turkish Journal of Field Crops. 2018;23(1):38-48.
6. Zucca C. Response of tef row planting to sowing dates on the highland heavy clay soils. Technical Report of Experimental Activities, Project Agreement No. 100202; 2016.
7. MoA (Ministry of Agriculture). Improving tef production and productivity: Special programme. Debre Zeit, Ethiopia; 2017.
8. Gomez K, Gomez A. Statistical procedure for agricultural research, 2nd ed. John Willey and Sons, New York. 1984;680.
9. Desta BT, Gezahegn AM, Tesema SE. Impacts of tillage practice on the productivity of durum wheat in Ethiopia. Cogent Food Agri. 2020;7(1):1-15.
10. Juraimi AS, Begun M, Sherif AM, Rahim AA. Competition effects of date of sowing and nutsedge removed time on yield and yield contributing characters of tef [*Eragrostis tef*) (Zucc.)Trotter]. American Journal of Applied Sciences. 2009;6(10):1820-1825.
11. Mengistu D. Effects of genotypes and sowing time on phenology and yield performance traits of tef (*Eragrostis tef*) in low moisture stress environments. 2020;16(12):1710-1720.
12. Assefa K, Cannarozzi G, Girma D, Kamies R, Chanyalew S, Plaza-Wuthrich S, Blosch R, Rindisbacher A, Rafuden S, Tadale Z. Genetic diversity in tef [*Eragrostis tef)* (Zucc.) Trotter]. Frontiers in Plant Science. 2015;6:177-209.
13. Kebebew A, Solomon C, Zerihun T. Achievements and prospects of Tef improvement; proceedings of the second international workshop, November 7-9, 2011, Debre Zeit, Ethiopia. Research Ethiopian Institute of Agricultural, Addis Ababa, Ethiopia; Institute of Plant Sciences, University of Bern, Switzerland. Printed at Stämpfli AG, 3001 Bern, Switzerland; 2013.
14. Teklay T, Girmay G. 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. 2016;6(1):409-422 40.
15. Chanyalew C. Phenotypic evaluation and molecular study of parents and recombinant inbred lines of Tef [*Eragrostis Tef* (Zucc.) Trotter]. PhD. Dissertation. Haramaya University, Haramaya, Ethiopia; 2007.

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