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Research Article

Investigating Tef [*Eragrostistef(Zucc*.) Trotter] Yield and Yield Components Under Sowing Method and Inorganic Fertilizer Application in Guduru District, Western Oromia Regional State, Ethiopia

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Abstract

Tef (*Eragrostistef(Zucc.) Trotter)* is the main cultivated cereal crops in Ethiopia. The grain and straw of tef has more values than other cereal crops. However, the actual yield of tef is below its potential which mainly due to poor soil fertility, high seeding rate and inappropriate sowing method. Due to these constraints the study was carried out on the farmers' field at two sites, namely, Gabate and Kobo, in 2012 in Guduru district with the objective to investigate the effect of fertilizer types and sowing methods of varying seeding rate on yield components and yield of tef. The treatments were made from 3 fertilizer types (DAP, NPKSZn and control) and 2 sowing methods (row and broadcast) which arranged in RCBD and replicated three times. The result of the study revealed that DAP and NPKSZn fertilizers gave statistically at par and increased panicle lengths of tef by 35.83 and 37.91% at Gabate and by 27.11 and 31.13% at Kobo, respectively, over unfertilized plots. Minimized seeding rate-row sowing method produced 6.12 and 6.50% more panicle length at Gabate and Kobo, respectively over high seeding rate-broadcast sowing method. Broadcast sowing method under DAP and NPKSZn applications gave the highest and at par lodging percentage over row sowing method whereas the more and similar effective tillers number per plant were recorded under row sowing method using DAP and NPKSZn at both sites. Application of DAP and NPKSZn under row sowing method produced significantly the highest and similar yields (3189.67 and 3250.33 kg ha^{-1} at Gabate, and 3164.00 and 3222.67 kg ha^{-1} at Kobo, respectively). The partial budget analysis also showed that row sowing under DAP application provides maximum net profit (197825.6 ETB) with MRR (948.46%). Therefore, tef production using DAP under row sowing-minimized seeding rate provides the highest yield and yield components and also economically profitable treatment combination. Thus, farmers of the study area will benefit using minimized seeding rate-row sowing method under DAP application. The result implies that field evaluation of the selected treatment combination should be done to verify the finding at multi-locations and years.

Keywords

Guduru, Tef, Row Sowing, Broadcasting, Seed Rate, Fertilizer Type

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1. Introduction

Cereals have significant magnitude to alleviate food insecurity in Ethiopia covering about 10 million ha cultivated almost by 16 million smallholders [1]. Tef (*Eragrostistef(Zucc.) Trotter)* is the most important staple crop in the country followed by maize and wheat [2]. Ethiopia is the center of foundation of tef [3]. It is a famous nation in the world that uses tef for multipurpose [4]. It is used for making injera, which is a base and accepted food in the countrywide diet of the nation [5]. In addition, the straw of tef used for as animals' feed during off seasons and to reinforce mud and plaster the walls of *Tukuls* for constructions of houses and grain storages [6]. Currently, tef has got great attention globally due to its gluten-free, an excellent source of essential amino acids, especially lysine and long storability [7]. Tef grows well above any other crops under adverse conditions and often well though-out as a save crop that withstand and performs fine on low moisture soil after early planted crops not succeed and can also be grown-up in wet areas superior than other cereals crops [8].

In Ethiopia, tef is grown by over 7 million subsistence farmers which stands second next to maize (11. Million households) covering 2.93 million hectare (22.56%) which stands first, production of 5.5 million tons which ranked second next to maize (9.5 million tons) and productivity of 1.8 million tons which ranked fifth next to maize (4.1 tons), wheat (2.9 tons), sorghum (2.8 tons) and barley (2.3 tons), respectively [1]. The low yield is primarily due to the low soil productiveness condition which is a consequence of low input of fertilizers, poor agronomic performances, poor plant survival and lodging; are among the factors [9].

Regardless of soil type and agro ecology, many studies have demonstrated the synergetic effects of NPS application on crops productivity and growth performances including tef, however they are deleted at alarming rate. For example, Inorganic nitrogen contributes to a 50% yield advantage of crops globally [10]. An experiment done using NP fertilizer at 46/23 kg ha boosted grain yield of tef by 137% when compared to control [11]. Many of Ethiopian soils are lacking in N, P, K, S, Zn and B and thus recommend fertilization of modified and balanced nutrients is mandatory [12]. Moreover, the report of other scholars showed that S content in the soils were extremely low in Ethiopian soils [13-15]. The necessity for S application mostly based on the quantity of N being used since both nutrients are needed for protein formation. There are reports that indicate increased crop yields by application of S with N and P, suggesting the synergy of the nutrients on their availability and uptake by roots of plants [16]. As a consequence, Ethiopia imports huge amount of fertilizers holding nitrogen, phosphorus, sulfur, zinc, and boron [17].

Plant population is the main growth and yield liming factors of tef. Wider inter-row spacing resulted in better nutrients and solar radiation utilization for superior photosynthetic process which creates new tiller formation and elongated panicles per plant than crowded ones, finally increased yield [18]. Broadcasting (40-50 kg ha^{-1}) is a usual sowing method usually applied for tef production in Ethiopia mainly due to its tiny grain size [19]. It resulted in unevenly scattering of seeds and irregular population stands which make weeding and harvesting difficult when compared to row planting [20]. Row planting reduces the amount of seeds and total cost of production, and competition among plant population for nutrients and water, finally superior yields [20, 21]. On contrast, the lodging proportion of tef is high under broadcast sowing and high seeding rates. A field experiment carried out at DebreZiet Agricultural Research Center indicated that a yield would-be as high as 6 t ha^{-1} was attained by using of 46/20/12 kg ha^{-1} of N:P:S fertilizers, respectively using 5 kg ha^{-1} of seed rate [22]. Therefore, an experiment was conducted with the objective to investigate effect of DAP+urea and NPKSZn fertilizers and the farmers' superior seed rate broadcast sowing technique and the minimized seed rate line sowing technique on yield and yield components of tef.

2. Materials and Methods

2.1. Description of the Study Area

The study was conducted at two sites, namely, Gabate and Kobo, on farmers' field in Guduru District of Western Oromia Regional State, Western Ethiopia, in 2012 cropping season. Guduru district lies between 9°5' to 9°32'N and between 37°30' to 37°58' E. The altitudinal range of the district varies from 1500 to 2400 meter above sea level. It has an area coverage of 1266 km^2 with population of nearly 141, 523 (49.6 male and 50.4% female) with population per unit area of 111.7 [23]. Guduru district has three agro-ecological zones, namely, highlands (baddaa) (37.9%), midlands (badda-daree) 54.75%) and lowlands (gammoojjii) (7.86%). The dominant soil types found in the district are reddish brown Nitisol andcambic arenosols. Mixed farming, production of crops and rearing of animals, is the commonly practice. The main crops cultivated in the district includes maize (*Zea mays* L.), tef (*Eragrostistef(Zucc.) Trotter)*, barley (*Hordium vulgaris* L.), wheat (*Triticumeastivum* L.), field pea (*Pisum sativum* L), faba bean (*viciafaba* L.), potato (Solanumtuberosum) and noug (*Guizotaabyssnica*L.) [24]. The district receives an average annual rain fall of 1200 mm and average minimum and maximum temperature of 11.5. and 22.2°C, respectively. The capital city of Guduru district is Kombolcha town which is found at the distance of 312 km to northwest of Addis Ababa on the main road to Fincha'a Sugar Factory. Kobo experimental site is located at 09^0 30' N and 37° 25' E atan altitude of 1982 meters above sea level while Gabate site is located at 09°28' N and 37°28' E at an altitude of 1978 meters above sea level.

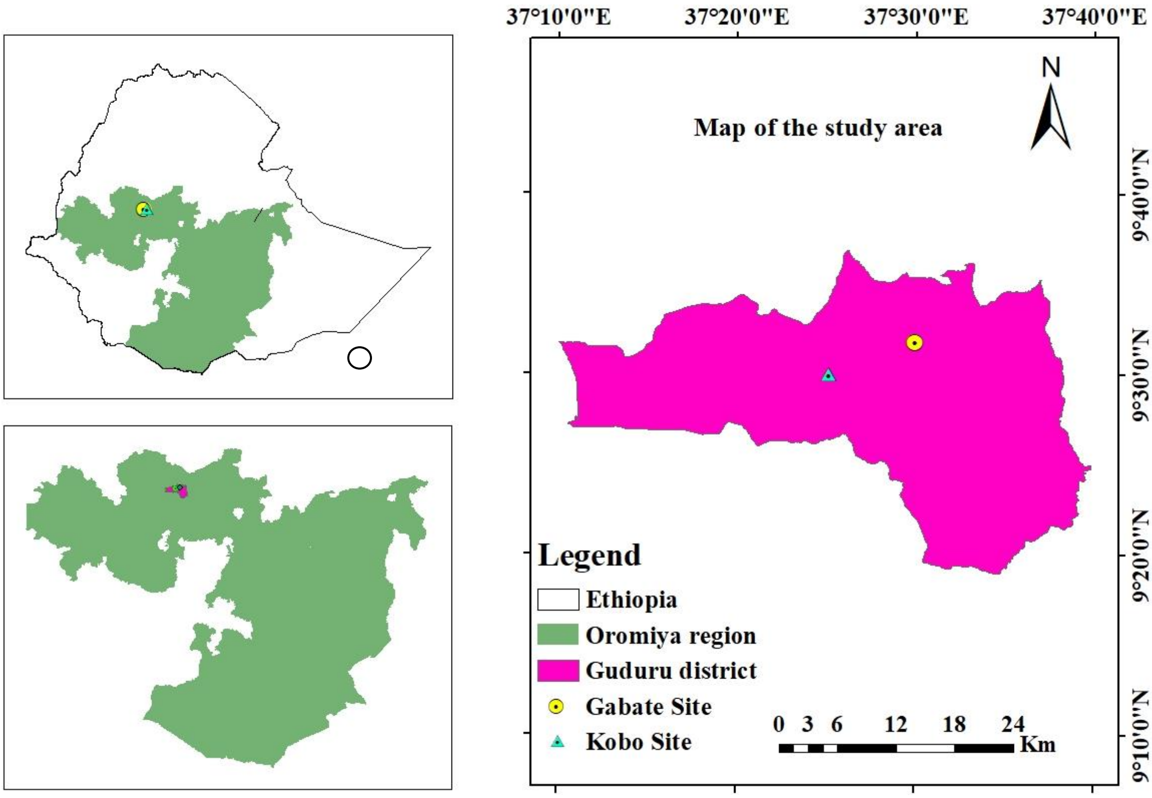

Figure 1. *Map of Guduru District and Experimental Sites.*

2.2. Experimental Materials, Treatments and Design

The experimental materials used for an experiment include an improved tef variety (kuncho), DAP (diammonium phosphate), urea, NPKSZn (Nitrogen, Phosphorus, Potassium, Sulfur, Zinc) and TSP (triple super phosphate). Three types of fertilizers (DAP, NPKSZn and zero) and two sowing methods (broadcast and row) were combined factorial to make experimental treatments. The treatments were set in a randomized complete block design (RCBD) having gross plot size 3 m x 4 m (12 m^2). Each treatment was replicated three times. The blocks were alienated by 1 m while the plots were alienated by 0.5 m. Each treatment was allocated at random to the trial units within the blocks. The net plot dimension used was 2 m x 3 m. Good field managements and supervisions were done throughout the crop growing period.

2.3. Experimental Procedures

In mid July of 2012 cropping season Kuncho variety (DZ-cr-387) was sown. The experimental areas were ploughed five times according to the farmers' cultural practice using oxen power in order to loosen the soil as suitable as for tef sowing. Just a head of sowing on that day, the experimental area was made uniform by a means of driving cattle over the experimental area. The reason of driving cattle over the experimental area was to have the same sowing deepness for upright stand as it increases roots-soil contact. 100 kg of DAP containing 20 kg P and 18 kg N while 100 kg NPKSZn containing 23 kg N, 10 kg P_2O_5, 5 kg K_2O, 3 kg S, and 0.3 kg Zn. Additional 61 kg urea ha^{-1} along with DAP was applied to fulfill 46 kg N ha^{-1}, respectively, for tef production. Similarly, 50 kg urea, 50 kg k_2SO_4 and 80 kg TSP ha^{-1} along with the blended fertilizer were used in order to achieve the suggested rates for tef which is 46 kg N ha^{-1}, 20 kg Pha $^{-1}$, 32 kg K_2O ha^{-1}, 12 kg S ha^{-1} and 0.3 kg Zn ha^{-1} fertilizers 25 and 5 kg ha^{-1} for broadcast and row sowing, respectively, were used [22]. Broadcasting was done manually by farmers. As the amount for the line sowing was exceptionally low, the seeds were mixed with sand systematically for homogeneous drilling. The distance between rows was 20 cm. For broadcast method of sowing both fertilizers and seeds had been broadcasted. DAP, TSP, NPKSZn and K_2SO_4 were applied once during sowing while 50 and 61 kg urea ha^{-1} each was applied in two splits (half at initiation of tillering and half at booting stage). Weeds were pulled periodically by hand whenever necessary.

2.4. Data Collection

Pre planting soil data were analyzed using standard laboratory procedures for each parameter. Plant height was measured as average of ten normal arbitrarily chosen normal plants at the time of harvesting using metric ruler starting from the soil level to end of the main panicle. Panicle length was measured as average of ten arbitrarily chosen normal plants at the time of harvesting starting from the tip of panicle to the point where the panicle emerged from the stem using metric ruler. Number of effective tillers per plant was counted from normal mother plants bearing productive tillers at the time of harvesting and recorded as average of ten randomly selected mother plants from each plot. Grain yield was measured in gram per plot using sensitive balance after threshing followed by cleaning by sieving. Biomass yield was measured in kilogram just before threshing using sensitive balance. Straw yield was calculated as the difference between the biomass and grain yields. Thousand seeds weight was measured using sensitive balance as average of 1000 seeds weight. Lodging percentage was determined as the inclination of the above ground parts of the plants in percent (%) by visual observation of each plot area just at the time of harvesting. The degree of lodging was assessed using scales of 1-5 where 1(0-15°) indicated no lodging, 2 (15-30°) indicated 25% lodging, 3 (30-45°) indicated 50% lodging, 4 (45-60°) indicated 75% lodging and 5 (60-90°) indicated 100% lodging [25]. The scales were determined by observing inclination of the major stalk from the upright line up to the bottom of the stalk. The data were changed according to the arcsine transformation method stated for percentage data to become stable the mistake and analysis was done using the transformed data [26].

2.5. Data Analysis

The data were subjected to analysis of variance (ANOVA) using statistical analysis system (SAS), version 9.0, general linear model procedures and mean separation for significant treatments effects was done using least significant difference (LSD) test [27].

2.6. Economic Analysis

Economic analysis was performed following the International Maize and Wheat Improvement Center (CIMMYT) partial budget methodology [28]. Both the grain and straw yields were adjusted down by subtracting 10% from field grain and straw yields. The gross yield advantage was calculated by multiplying the standardized yield by farm gate price of grain and straw. The net benefit (NB) was determined by subtracting the total variable cost from the net farm benefit in Ethiopian birr (ETB ha^{-1}). Dominance analysis was performed based on the net benefits to exclude dominated treatments from the marginal rate of return (MRR) analysis. The MRR was calculated as changes in NB divided by changes in TVC. A treatment that is non-dominated, having MRR of above or equal to 100% with maximum net profit is cost-effectively.

3. Results and Discussion

3.1. Selected Soil Chemical Properties of the Experimental Sites Before Sowing

Pre-sowing selected soil physical and chemical properties were shown in Table [1] below. The experimental soils at both Gabate and Kobo sites were classified as clay-loam in their texture. The average soil reactions were categorized as strongly acidic at both sites according to [29]. The soil available phosphorus (P) is very low as rated by [30]. The very low initial soil accessible P might be due to adsorption by oxides and hydroxides of Al and Fe as a result of low pH [31]. Both experimental sites have very low soil available sulfur (S) as determined by [32]. The low soil S content of the experimental soils might be associated with the low organic matter (%OM) contents of the experimental sites. The organic carbon (%OC) and total nitrogen (%TN) contents of both the experimental soils are grouped under low and medium value status, respectively [33]. The under optimal OC value of the experimental sites might be due to elimination of crop left over after harvest for different purposes like feeding animals, firewood, and houses and grain storages constructions (tukuls) [34]. The finding indicated that the cation exchange capacity (CEC) of the experimental soil falls in medium category [35]. Similarly, soil exchangeable bases at both sites, namely, calcium (Ca) and potassium (K) are low whereas magnesium (Mg) is medium according to the rating of [36]. The low contents of exchangeable bases might be due to the increased acidic cations, namely, H^+ and Al^{3+} under low acidic reactions [37]. The soils of the experimental sites have high di-ethylene tri-amine penta acetic acid (DTPA)-extractable zinc (Zn) [30]. The high availability of this micronutrient under low soil pH values might be due to its high solubility and mobility in the soil solutions [38].

Table 1. *Selected Soil Chemical Properties of the Experimental Sites Before Sowing.*

S/N	Soil property	Value		Rating	Source
		Gabate site	Kobo site		
1	Soil texture	Clay-loam	Clay-loam		
	Sand	32	35		
	Silt	28	26		

S/N	Soil property		Value		Rating	Source
			Gabate site	Kobo site		
	Clay		40	39		
2	Soil pH (1:2.5; soil:H_2O)		5.20	5.18	Strongly acidic	[29]
3	Available P (mg kg soil^{-1})		11.5	13	Very low	[30]
4	Available S (mg kg soil^{-1})		1.60	1.83	Very low	[32]
5	TN (%)		0.22	0.20	Low	[33]
6	OC (%)		1.97	1.76	Very low	[33]
7	CEC (cmol kg soil^{-1})		18.72	21.0	Medium	[35]
8	Exchangeable bases (cmol kg soil^{-1})	Ca	2.48	3.68	Low	[36]
9		Mg	2.05	1.70	Medium	[36]
10		K	0.22	0.27	Low	[36]
11	Soil micronutrients (mg kg soil^{-1})	Zn	1.78	2.23	High	[30]

3.2. Response of Tef Yield Components and Yield to Treatments

Plant height and Panicle length

Statistical analysis revealed that there was significant dissimilarity ($P \leq 0.01$) on the plant height and panicle length of tef due to the main effect of fertilizer type and sowing method but not by the interaction of factors at both sites Table [2]. Plants grown under DAP and NPKSZn fertilizer showed the highest plant height and panicle length which was statistically at par while the lowest were obtained from those plants raised under unfertilized plots at both sites (Table 2). The non significance in plant height and panicle length of tef between DAP and NPKSZn fertilizers is mainly due to equal amount of N and P applications contributing for cell elongation, finally plant height and panicle length. Plants treated with DAP and NPKSZn fertilizers showed plant height increments by 77.12 and 78.12% at Gabate site, and by 78.76 and 81.10% at Kobo site, respectively, over unfertilized plots. Similarly, DAP and NPKSZn fertilizers increased panicle lengths of tef by 35.83 and 37.91% at Gabate site and by 27.11 and 31.13% at Kobo site, respectively, over unfertilized plots. This is mainly due to plants grown under unfertilized plots did not supplied with any external fertilizers contributing for growth. Similar result was reported who revealed that plant tallness and panicle elongation of tef were considerably increased by N and P applications over unfertilized plots [39].

Regarding sowing method, plants grown under row sowing method significantly showed taller plant heights and panicle lengths at both sites than those grown under broadcasting (Table 2). This is due to reduced competition among plants for space, light and nutrients in row sowing due to low seed rate (5 kg ha^{-1}) than in broadcast sowing accomplished using high seed rate (25 kg ha^{-1}). Plants grown in row showed plant height increments by 5.09 and 5.20% at Gabate and Kobo, respectively; and panicle length increments by 6.12 and 6.50% at Gabate and Kobo, respectively. Similar to the present findings of revealed that higher plant [40] and [41].

Table 2. *The Main Effects of Sowing Method and Fertilizer Type on Plant Height and Panicle Length of tef Grown in Guduru District of Western Oromia Regional State in 2012.*

Fertilizer type	Plant height (cm)		Panicle length (cm)	
	Gabate site	Kobo site	Gabate site	Kobo site
DAP	134.45a	133.46a	52.13a	48.34a
NPKSZn	135.21a	135.41a	52.93a	49.87a
Control	75.91b	74.66b	38.38b	38.03b

Fertilizer type	Plant height (cm)		Panicle length (cm)	
	Gabate site	Kobo site	Gabate site	Kobo site
LSD (5%)	5.35	3.8	2.98	1.71
Sowing method				
Broadcast	111.96b	110.30b	46.55b	44.08b
Row	117.66a	116.03a	49.40a	46.94a
LSD (5%)	4.36	3.11	2.44	1.39
CV (%)	9.62	9.62	14.83	14.83

Means followed by the same letters along columns are not significantly different from each other at 5% of P level.

Height and panicle length were obtained in line sowing at a minimized seed rate when compared to broadcasting at high seed rates. Likewise, plant tallness of wheat was considerably affected by seeding amount and distance between rows implying that taller plant recorded under row sowing than broadcasting [42].

Effective tillers number per plant

Effective tillers number was appreciably ($P \leq 0.01$) affected by both sowing method and fertilizer types; and also their interaction at both sites Table [3]. Table three shows that the row sown plots treated with both DAP and NPKSZn fertilizers gave significantly the highest number of effective tillers per plant while the lowest one was recorded under broadcast sowing at all fertilizer types at both the sites. Likewise, there were no significant differences on the number of productive tillers per plant between DAP and NPKSZn fertilizers in row sowing method which might be due to equal N and P applications contributing for tiller initiations and also due to equal seed rate resulting in uniform intra-specific competitions. Similarly, all treatments in broadcast sowing method under the three types of fertilizer applications gave statistically at par effective tillers per plant at both sites. However, under broadcast sowing method, DAP and NPKSZn fertilizers figuratively gave superior effective tillers number over control. Plants grown under row minimized seeding rate produced more number of effective tillers over broadcast sowing method at both sites which might be due to the more competition among plants for growth factors between plant populations in broadcast high seeding rate resulting in reduced water and fertilizer use efficiency finally no or less tillers per plant [18]. The number of effective tillers number in row sowing method combined with DAP and NPKSZn fertilizers increased by 148 and 176%, respectively over the control at Gabate site; while at Kobo site the same treatment increased effective tillers number per plant by 70 and 110%, respectively. This could be mainly due to the number of effective tillers per unit area affected by the availability of growth inputs in that area, hence there was superior intra-specific struggle between plant populations where there was deficiency of nutrients. The present finding was alike with the findings of other scholars who stated that number of productive tillers per plant greater by 120.06% as seed rate decreased from 5 to 25 kg per hectare and by 32.00% under row over broadcast sawing method [7].

Table 3. *The Interaction Effects of Fertilizer Type and Sowing Method on Number of Effective Tillers of tef Grown in Guduru District of Western Oromia Regional State in 2012.*

Effective tillers number per plant				
Sowing method				
	Gabate site		Kobo site	
Fertilizer type	Broadcast	Row	Broadcast	Row
DAP	3.10c	12.40a	3.00c	10.20a
NPKSZn	3.40c	13.80a	2.40c	12.60a
Control	2.60c	5.00b	2.20c	6.00b
LSD ($P \leq 0.05$)	1.84		2.47	
CV (%)	12.62		15.26	

Mean followed by the same letter along columns and rows are not significantly different fromeach other at 5% P-level.

Lodging Percentage

Lodging proportion of tef was drastically ($P \leq 0.01$) affected by both sowing method and fertilizer type, and also by their interaction at both the sites Table [4]. Statistically the maximum lodging fraction was obtained in broadcast sowing method under DAP and NPKSZn fertilizers while the lowest were recorded from control plots under both sowing methods at both sites. This could be as a result of excess numbers of populations due to high seed rate resulting competition among plants leading to feeble stems and vulnerable to lodging in broadcast sowing compared to thick and stiff plant stems in row sowing method. Similar to this finding, the work of other scholars revealed that unlike broadcasting row sowing has been reported to reduce lodging and increase productivity of tef [43, 44]. Likewise, the maximum lodging percentage (68.83%) was obtained at 30 kg ha^{-1} under broadcast sowing while the minimum lodging percentage (16.17%). was obtained at of 5 kg ha¯1 under row sowing [45].

***Table 4**. The Interaction Effect of Fertilizer Type and Sowing Method on Lodging Percentage of tef Grownin Guduru District of Western Oromia Regional State in 2012.*

Lodging percentage				
Sowing method				
Gabate site			Kobo site	
Fertilizer types	Broadcast	Row	Broadcast	Row
DAP	54.34^{a}	47.15^{b}	54.04^{a}	46.63^{b}
NPKSZn	52.56^{a}	46.01^{b}	53.87^{a}	46.12^{b}
Control	44.42^{c}	44.59^{c}	44.09^{c}	44.33^{c}
LSD (P ≤0.05)	2.44		2.16	
CV (%)	11.63		13.44	

Mean followed by the same letter along columns and rows are not significantly different from each other at 5% P-level.

Grain yield

Grain yield was appreciably (P≤0.01) affected by the main effect of sowing method, fertilizer type and also by their interaction at both sites Table [5]. Statistically, the highest grain yields of tef were obtained from row sowing under both fertilizer types followed by broadcast sowing while the minimum value were obtained from the unfertilized plot at both sites (Table 5). This might be due to the low intra specific competition resulting in more effective tiller numbers per plant, longer panicle length and less lodging percentage recorded under row sowing compared to broadcast once. There were no statistically differences observed in grain yields of tef between the two fertilizer types. [DAP and NPKSZn] under both broadcast and row sowing methods. DAP and NPKSZn under row sowing boosted the yield of tef by 15.78 and 15.66%, respectively at Gabate; and by 10.85 and 10.15%, respectively at Kobo over broadcast sowing method. Similar to this finding a tripled increase in both grain and straw yields of tef under row planting by reducing seed rate to 2.5 kg ha^{-1} compared to the earlier recommendation of 25-30 kg ha^{-1} used for broadcasting [43]. Likewise, there was noteworthy boost in yield attributes of tef at minimum seed rate resulting in increased grain yields [40]. Moreover, more length of spike length, productive tillers and thousand seeds weight were obtained from row planting method contributing for yield improvements as compared to broadcasting [46].

***Table 5**. The Interaction Effect of Fertilizer Type and Sowing Method on Grain Yield Oftef Grown in Guduru District of Western Oromia Regional State in 2012.*

Grain yield (kg ha–1)				
	Sowing method			
	Gabate site		Kobo site	
Fertilizer type	Broadcast	Row	Broadcast	Row
DAP	2755.00b	3189.67a	2854.30b	3164.00a
NPKSZn	2810.33b	3250.33a	2925.67b	3222.67a
Control	455.67c	497.33c	418.30c	486.33c
LSD (P≤ 0.05)		112.54		99.77
CV (%)	11.32		9.46	

Means followed by the same letter along columns and rows are not significantly different from each other at 5% P-level.

Straw yield

Similar to grain yield, straw yield was significantly (P≤0.01) affected by both sowing method and fertilizer type, and by their interaction at both sites Table [6]. Statistically, the highest straw yields were obtained from row sowed plants treated with both DAP and NPKSZn fertilizers followed by broadcast sowed plants treated with DAP and NPKSZn fertilizers while the least straw yields were obtained from plants under unfertilized at both sowing methods at both sites (Table 6). This could be due to additional plant height, tiller numbers, thick stalk, low lodging percentage and longer panicle under row sowing method as a result of low competition between plants over broadcast once. Row sowing resulted in 15.68 and 16.22% increments in straw yield, respectively at Gabate site and 18.61 and 23.51% straw yield increments at Kobo site, respectively over broadcast sowing. This finding was alike with the report of other scholar who stated that straw and above ground yield improved with spacing in cereals crops due to increased above ground growth and superior number of tillers as a result of low competition for growth factors [18].

Table 6. The Interaction Effect of Fertilizer Type and Sowing Method on the Straw Yield of Tef Grown in Guduru District of Western Oromia Regional State in 2012.

Straw yield (kg ha^{-1})				
	Sowing method			
	Gabate site		**Kobo site**	
Fertilizer type	**Broadcast**	**Row**	**Broadcast**	**Row**
DAP	7897.00b	9135.00a	8040.3b	9536.3a
NPKSZn	7952.33b	9242.00a	8390.8b	10363.5a
Control	1866.33c	1990.33c	1688.3c	1817.0c
LSD (P≤ 0.05)	1222.02		1106.73	
CV (%)	12.35		17.12	

Mean followed by the same letter along columns and rows are not significantly different from each other at 5% P- level.

Above ground yield

The ANOVA indicated that above ground biomass of tef was drastically (P≤0.01) affected by sowing method, fertilizer type and also by their interaction at both sites Table [7]. Statistically analysis showed that the maximum total yield of tef was recorded from plants raised in row sowing method supplied with blended followed by the same sowing method treated with DAP + urea fertilizer while the least values of above ground yield were recorded from unfertilized plots under both sowing methods (Table 7). The superior value in above ground yield of tef under row*blended fertilizer could be due to the additional supplement of elements like S, K and Zn contributing for vigor and thick tef stems in addition to low competition between plants for growth factors. Blended fertilizer under row sowing increased above ground yield of tef by 5.21% over the same sowing method treated with DAP + urea; and by 12.66% over broadcast sowing method treated with blended fertilizer at Gabate site. Similarly, at Kobo site, blended fertilizer under row sowing gave 9.83% above ground yield advantage over the same sowing method treated with DAP + urea; and also gave 13.94.% increment in above ground yield of tef over plants treated with blended fertilizer in broadcast sowing method. This could due to the fact that above ground yield was directly associated to plant tallness, length of panicle, final yield and tillers number which were superior in row than broadcast sowing method. This finding was in line with other works who stated that row sowing and fertilizer placement have revealed greatest grain and above ground yields over high seed rate broadcasting and control plots [18] and [47].

Table 7. The Interaction Effect of Fertilizer Type and Sowing Method on the Biological Yield of Tef Grown in Guduru District of Western Oromia Regional State in 2012.

Above ground yield (kg ha^{-1})				
	Sowing method			
Fertilizer type	**Gabate site**		**Kobo site**	
	Broadcast	**Row**	**Broadcast**	**Row**
DAP	11752.00c	12824.00b	11650.70c	12527.0b
NPKSZn	11975.67c	13492.30a	12075.70c	13759.0a
Control	5622.00d	5837.67d	5906.67d	6233.3d
LSD (5%)	526.67		402.23	

Above ground yield (kg ha^{-1})				
	Sowing method			
Fertilizer type	Gabate site		Kobo site	
	Broadcast	Row	Broadcast	Row
CV (%)	13.41		16.86	

Mean followed by the same letter along columns and rows are not significantly different from each other at 5% P- level.

Harvest index (HI)

Harvest index was significantly (P≤0.05) affected by fertilizer type and sowing method but not by their interaction effect at both sites Table [8]. The highest mean values of HI were recorded from the control plots than the fertilized plots. Unfertilized plot gave 28.21 and 30.37% more HI when compared to DAP and NPKSZn fertilizers, respectively at Gabate site; and by 25.44 and 29.96% more HI when compared to DAP and NPKSZn fertilizers, respectively at Kobo site. This could be as a result of lowest above ground yield compared to its grain yield was obtained from control plots over fertilized plots. Alike to this finding, the lowest HI under fertilized plots when compared against to the unfertilized plot in tef was reported [48]. Regarding sowing method, the row sowing method showed lower harvest index value than broadcast sowing which might be due to the extra above ground yield compared to final yield in row due to added number of tillers, longer height and panicle length and thick stalk compared to broadcast sowing Table [7]. Broadcast sowing method showed 13.65 and 9.18% increments in HI relative to line sowing at Gabate and Kobo sites, respectively.

Table 8. *Main Effect of Sowing Method and Fertilizer Types on the HI of Tef Grown in Guduru District of Western Oromia Regional State in 2012.*

Harvest index (HI)		
Fertilizer type	**Gabate site**	**Kobo site**
DAP	0.273b	0.287b
NPKSZn	0.270b	0.277b
Control	0.352a	0.360a
LSD (5%)	0.066	0.059
Sowing method		
Broadcast	0.333a	0.321a
Row	0.293b	0.294b
LSD (5%)	0.036	0.022
CV (%)	6.79	9.88

NB means followed by same letter along columns are not significantly different from each other at 5% P-level.

3.3. Economic Analysis

From the economic analysis carried out, maximum farm net benefit (197825.6 ETB ha^{-1}) with MRR 948.46% was obtained from DAP+urea under row sowing methodfollowed by broadcast sowing method under the same fertilizer application with net farm benefit of 179865.6 ETB ha^{-1} and MRR 720.90% Table [9]. Treatment combinations having MRR above 100% with maximum net benefit would be considered as cost-effective and it will be selected to be suggested in the study area [28]. Thus, the highest net profit of 197825.6 ETB

ha^{-1} ETB ha^{-1} with MRR 948.46% which obtained from row sowing under DAP+urea application was selected as the economically profitable treatment combination in the study area. This value implies that with 1 ETB ha^{-1} cost invested 9.48 ETB ha^{-1} net profit was obtained.

Table 9. Dominance and MRR Analysis for Tef Crop Yields in Guduru District of Western Oromia Regional State in 2012.

Treatment	Input						Gross farm benefit (grain and straw) (GFB) = A	Total variable cost (TVC) = B	Net farm benefit (NFB) (C), C=(A-B)	MRR (%)= (▲C/▲B)
	DAP+urea (kg ha^{-1})		Blended fertilizer (kg ha^{-1})							
	DAP (kg ha^{-1})	Urea	NPKSZn	K_2SO_4	TSP	Urea				
Broadcast	0	0	0	0	0	0	59108.2	7254.55	51853.65	0
Row	0	0	0	0	0	0	60071	7855.24	52215.78	60.29
Broadcast	100	61	0	0	0	0	205428	25562.2	179865.6	720.90
Row	100	61	0	0	0	0	225281	27455.8	197825.6	948.46
Row	0	0	100	50	80	50	231703	32622.5	199080.3	24.28

4. Summery and Conclusion

Tef is a staple cereal foodstuff crop in the country. The grain and straw provides superior income than other cereal crops. The main constraint of tef farming in Ethiopia is due to its small yield per unit area which is mostly emerged from low soil productiveness, high seeding rate and lack of appropriate sowing methods. A field experiment was conducted on the farmers' field at Gabate and Kobo sites in Guduru District, Western Oromia Regional State to investigate the effect of inorganic fertilizer type and broadcast-high seed rate and row-low seed rate sowing method on growth, yield and yield attributes of tef. A factorial experiment with 2 levels of sowing methods (broadcasting and row sowing) and 3 fertilizer types (DAP, NPKSZn, and control) were arranged in RCBD with three replications. The findings of the study showed that DAP, NPKSZn produced statistically the highest and similar plant height and panicle length over control plots. The row sowing method showed taller plant height and longer panicles length over broadcast sowing method. Application of DAP and NPKSZn under minimized seeding rate-row sowing produced statistically the highest and at par effective number of tillers per plant, straw and grain yields, and low lodging percentage when compared to broadcast sowing method. The economic analysis showed that row sowing method under DAP application gave the highest farm net benefit with MRR above 100%. From this it can be concluded that row sowing with reduced seeding rate under DAP application resulted in more yield and yield contributing components; and economically feasible. Therefore, row sowing method under DAP fertilizer application is an appropriate treatment combination from which farmers in the study area can be benefited.

Abbreviations

ANOVA	Analysis of Variance
Ca	Calcium
CEC	Cation Exchange Capacity
CIMMYT	International Maize and Wheat Improvement Center
DAP	Di-Ammonium Phosphate
DTPA	di-ethylene Tri-amine Penta acetic Acid
ETB	Ethiopian Irr
HI	Harvest Index
K	Potassium
LSD	List Significance Difference
Mg	Magnesium
MRR	Marginal Rate of Return
NB	Net Benefit
NPKSZn	Nitrogen, Phosphorous, Potassium, Sulfur, Zinc
OC	Organic Carbon
OM	Organic Matter
P	Phospharus
RCBD	Randomized Complete Block Design
SAS	Statistical Analysis System
TN	Total Nitrogen
TVC	Total Variable Cost
TSP	Triple Super Phosphate

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Author Contributions

Refissa Leta Feyissa: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Supervision, Visualization, Validation, Writing - original draft

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Conflicts of Interest

The authors declare no conflicts of interest.

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