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RESEARCH ARTICLE

RESPONSE OF TEF [*Eragrostis tef* (zucc.)Trotter] TO TIME OF NITROGEN APPLICATION AND VARIABLE SEED RATES AT DILLA DISTRICT, SOUTHERN ETHIOPIA

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ABSTRACT

A field experiment was conducted at Dilla district, Gedio Zone Southern Ethiopia during the 2014 main cropping season under rain-fed condition, to study the effects of variable seed rates and time of nitrogen fertilizer application on yield and yield components of tef. A factorial experiment with three variable seed (15, 25 and 35 kg ha^{-1}) and four timing of applications (full dose at sowing, full dose at tillering, ½ dose at sowing + ½ dose at tillering, ¼ at sowing+ ½ after 30 days of sowing+ ¼ after 60 days of sowing) were used in Randomized Complete Block Design (RCBD) with three replication. Nitrogen fertilizer at recommendation rate of 46 kg N ha^{-1} was applied by broadcasting urea. Phosphorus was applied to all plots equally at the blanket recommendation rate of 46 kg P_20_5 ha^{-1} as TSP (Triple- supper phosphate).The tef variety used for the study was, Kuncho (DZ-CR 387 RIL 355). Both seed rates and time of nitrogen application significantly affected days to heading, physiological maturity, plant height, panicle length, straw yield, above-ground biomass, grain yield and harvest index. The treatment interaction significantly ($P<0.001$) affected plant height and lodging index of tef. Low seed rates delayed days to panicle initiation and days to physiological maturity of tef plants. Seed rate at 15 kg/ha increased above ground biomass yield by 4.65% over seed rate at 35 kg/ha. Application of the recommended rate of nitrogen 1/2 dose at sowing and 1/2 dose at tillering also increased total aboveground biomass yield and straw yield of tef as compared to other treatments. Application of the recommended rate of nitrogen half dose at sowing and half dose at tillering gave significantly higher (2308.96kg/ha) grain yield than the rest of the treatments. Significantly higher (2000.24 kg/ha) grain yield was also recorded under low seed rates. Hence, reducing seed rates and using application of the recommended rate of nitrogen half dose at sowing and half dose at tillering considerably increased the growth, yield and yield attributes of tef and can be suggested for higher tef production in the study area.

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INTRODUCTION

Tef [*Eragrostis tef* (Zucc.) Trotter] is among the major cereals of Ethiopia. It is an indigenous cereal crop to Ethiopia. Vavilov (1951) identified Ethiopia as the centre and origin of tef. Hence, Ethiopia is the appropriate and most important centre for the collection of tef germplasm and is the only country in the world that uses tef as a cereal crop (Gugsa *et al*., 2001). Tef production has been increasing from year to year and so did the demand for it as staple grain in both urban and rural areas of Ethiopia. Although the crop has been cultivated in different parts of the country, the major tef producing regions are Shoa, Gojam, Gonder, Wollo, Wellega, Keffa and Ilubabor. Tef has many prospects outside Ethiopia due to its gluten-freeness, tolerance to biotic and abiotic stress, animal feed and erosion control quality (Seyfu, 1997). Nutritionally, tef has as much, or even more food value than the major grains: wheat, barley and maize. Tef grains contain 14-15 % proteins, 11-33 mg iron, 100-150 mg calcium and rich in potassium and phosphorous (National Academy, 1996). Furthermore, Asrat and Frew (2001) reported that the carbohydrate content of tef ranges from 72.1-75.2%, protein from 8.1-11.1% and ash from 2.5-3.2%; the major components of ash being iron. Ecologically, tef is adapted to diverse agro- ecological regions of Ethiopia and grows well under stress environments better than other cereals known worldwide (Hailu and Peat, 1996). Because of this, it is said to be a "low-risk" crop for farmers. According to Seyfu (1997), tef requires an altitude of 1800-2100 m. a. s. l., annual rainfall of 750-850 mm, and a temperature range of 10-27 °C. It is predominantly cultivated on sandy loam to black clay soils.

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In Ethiopia, tef is cultivated on an area of about 2.73 million hectares. Tef and maize taking up about 22.6% and 17% of the total grain crop area, respectively. This makes tef the first among cereals in the country in area coverage (CSA, 2012). Despite the aforementioned importance and coverage of large area, its productivity is very low. The average national yield of tef is about 1.28 tone ha^{-1}(CSA, 2012). Some of the factors contributing to low yield of tef are low soil fertility and suboptimal use of mineral fertilizers in addition to weeds, erratic rainfall distribution in lower altitudes, lack of high yielding cultivars, seed rates, lodging, water-logging, low moisture, and low soil fertility conditions (Fufa, 1998 and Tareke, 2008).Therefore, this study was initiated with the following objectives:

- To study the effects of time of nitrogen fertilizer application on yield and yield components of tef in the Dilla district of Southern Ethiopia.
- To investigate the effect of variable seed rates on yield and yield components of tef in the study area.

MATERIALS AND METHODS

Description of the Study Area

The field experiment was conducted in Gedeo zone, Dilla Zuria woreda, Oddo Mike. The area is located at an altitude of 1476 meters above sea level. The latitude and longitude of the site is 6^0 18' 11" to 6^0 25' 32" and 38^0 17' 4^{0}" to 38^0 23' 43" E, respectively. The mean annual rainfall of the district ranges from 1201-1800mm with a bimodal distribution pattern. The mean minimum and maximum temperatures recorded for the same period are 12.8^0C and 28.4^0C, respectively (Zonal statistical abstract, 2008/9). The major field crops grown in the study area are wheat, barley, maize, tef, sorghum, and haricot bean. Horticultural crops include cabbage, pepper, tomato, lettuce, potato and sweet potato. The perennial crops are coffee and Enset.

Treatments and Experimental Design

The treatments were consists of three seed rates (15, 25 and 35 kg ha^{-1}) and four timing of applications (full dose at sowing, full dose at tillering, ½ dose at sowing + ½ dose at tillering, ¼ at sowing+ ½ after 30 days of sowing+ ¼ after 60 days of sowing). The experiment was laid out as a randomized complete block design in a factorial arrangement with three replications. A plot size of 3 m by 2 m was used and adjacent plots and blocks will be spaced 0.5 and 2 m apart, respectively. The net harvestable area was3.75 m^2 (2.5m x 1.5 m).

Experimental procedures

Kuncho (DZ-CR 387 RIL 355) variety was used as a test crop; which is currently grown in many tef growing agro-ecologies of the country, particularly in moisture deficit areas. L and was prepared according to the local practice. After the seedbeds were leveled and compacted, seeds were broadcasted at specified variable seed rates. Weeding was done manually by hand similar to the farmers practice. Nitrogen fertilizer at recommendation rate of 46 kg N $ha^{-1}$was applied by broadcasting urea. Phosphorus was applied to all plots equally at the blanket recommendation rate of 46 kg P_20_5 ha^{-1} as TSP (Triple- supper phosphate).

Data Collection

Soil sampling and Physico-chemical analysis

Surface soil samples (0-30 cm) was collected randomly in a zigzag pattern and composite sample of approximately 1 kg soil was made before sowing from the entire experimental field of 20 spots. The soil samples was air-dried and passed through a 2 mm mesh sieve for physico-chemical analysis. Soil color was determined using the Munsell soil color chart whereas soil pH was determined in a 1:2.5 soil water suspension using glass electrode pH meter (Von Reeuwijk, 1992). Determination of particle size distribution (texture) was carried out using the hydrometer method (Day, 1965).The soil was analyzed for total nitrogen, available phosphorus, and organic carbon contents. Organic carbon and total nitrogen will be determined by the method of Walkely and Black and Kjeldhal methods, respectively (Jackson, 1973). Available phosphorus was determined by the methods of Olsen *et al*. (1954).

Crop parameters

Phenological data

Days to panicle emergence was determined as the number of days elapsed from emergence up to the date when the tips of at least five panicles emerged from the main shoot in 1 m^2plot area.

Days to physiological maturity was recorded as the number of days elapsed from the date of emergence to the date when 90% of the plants in a plot showed light yellow color.

Growth and yield attributes

Panicle length was determined as the length of the panicle in cm from the node where the first panicle branch starts to the tip of the panicle from ten randomly selected mother plants (main shoots) from 1 m^2 demarked area in the net plot area.

Plant height was recorded as the length of the plant in cm from the base of the main stem to the tip of the panicle from ten randomly selected mother plants from 1 m^2 demarked area in the net plot.

Number of fertile tillers was recorded as the average number of tillers with panicle excluding the main shoot from five randomly selected plants in 1 m^2 demarked area.

Thousand kernel weight was determined as the weight of 1000 seeds sampled from the harvested net plot area using a sensitive balance.

Lodging index

The degree of lodging was assessed just before the time of harvest by visual observation based on the scales of 1-5 where 1 (0-15°) indicates no lodging, 2 (15-30°) indicate 25% lodging, 3 (30-45°) 50% indicate lodging, 4 (45-60°) indicate 75% lodging and 5 (60-90°) indicate 100% lodging (Donald, 2004).

Yield data

Grain yield: was determined by taking the grain yield of plants harvested from the net plot area of 2.5 x 1.5 m and adjusting the grain to 12.5% moisture content.

Biomass yield was recorded as the weight of the aboveground biomass of plants harvested from the net plot area after sun drying it for a week.

Straw yield straw yield was obtained by subtracting grain yield from total aboveground biomass yield.

Harvest index (HI)was calculated as the ratio of grain yield to the total aboveground biomass harvested.

Statistical Data Analysis

The data collected was subjected to analysis of variance (ANOVA) using general linear model (GLM) procedures SAS version 9.1.3, (SAS Institute, 2008). Means of significant treatment effects were separated using the Least Significant Difference (LSD) test at 5% level of significance.

Economic Analysis

Economic analysis was made following CIMMYT methodology (CIMMYT, 1988).The cost and tef grain price (current price) per 100 kg was used for the benefit analysis. Marginal rate of return was calculated as change of benefit divided by change of cost.

RESULTS AND DISCUSSION

Physical and Chemical Properties of the Experimental Area

Physical and chemical properties of soils critically affect the growth and the development of crops. The analytical results indicated the textural class of the soil was predominantly clay with slightly acidic (Table 1).

Table 1. Physical and chemical characteristics of top soils (0-30 cm) before planting the crop

Parameters	
Chemical properties	
pH water(1:2.5 H_2O)	6.27
Electrical conductivity (ds/m)	0.10
Available phosphorus (mg/kg)	1.86
Organic carbon(%)	1.06
Total nitrogen(%)	0.10
Available potassium(cmol(+)/kg	2.52
Physical properties	
Texture (%)	
Clay	59
Silt	22
Sand	19
Soil textural class	Clay
Soil color	Gray

According to the classification of the Netherlands Ministry of Agriculture and Fisheries (1995), the soil N content is classified as very high (>0.30), high (0.23-0.30), medium (0.13-0.23%), low (0.05-0.13) and very low (<0.05%). Sahlemedhin (1999) also rated 0.20-0.50% total N as medium, 1.74-2.90% OC as high and >2.90% OC as very high. In line with this, analysis of composite soil sample revealed that the OC and total N contents of the experimental soil were in the medium ranges (Table1).

Crop Phenology

Days to panicle emergence

Days to panicle emergence was significantly affected by time of nitrogen application (P<0.001) and main effect of seed rate (p<0.05) but not by the interaction of treatments. Application of full dose of nitrogen at sowing flowered earlier than treatments in split application (Table 2). Similarly, Abraham (2013) reported that the less number of days to panicle emergence was recorded under tef plants treated by 46 kg N ha^{-1} with full dose of nitrogen at sowing. It was also observed that plants treated with high seed rate flowered earlier than plants grown under low seed rate. This result is in line with the finding of Mitiku (2008) who reported early flowering with an increase in the seed rate of tef. Similarly, Hoshikawa (1984) reported that higher planting density hastened early heading in rice by affecting the heading and flowering order within plant, hill and population.

Table 2. Main effects of seed rates and time of nitrogen application on the phenology of tef grown

Treatments	Days to Panicle emergence	Days to Maturity
Variable Seed rate (kg/ha)		
15	49.25^{a}	80.75^{a}
25	47.75^{ab}	79.50^{ab}
35	46.42^{b}	78.58^{b}
LSD (P<0.05)	2.02	1.70
Time of Nitrogen application (T)		
N1	45.67^{c}	80.11
N2	46.89^{bc}	78.77
N3	48.44^{ab}	79.22
N4	50.22^{a}	80.33
LSD (P<0.05)	2.33	NS
CV (%)	4.99	2.53

N1 = full dose at sowing; N2 = full dose at tillering; N3 = ½ dose at sowing + ½ dose at tillering; N4 =¼ at sowing +1/2 after 30 days +1/4 after 60 days of sowing.

Days to physiological maturity

Days to maturity of tef plant was significantly (P < 0.05) affected only by the main effect of seed rates but not by the main effect of timing of application and their interaction effects (Appendix 1) & (Table 2). Plants grown under increased rate of seed rates matured earlier than plants with low rate of seed rate. Low seed rate, particularly seed rate at 15 kg ha^{1-}remained green while the panicle, leaves and stems of plants with increased seed rates, became yellow and matured early. Sewenet (2005) also reported that increasing levels of seed rate promoted early physiological maturity of rice.

Growth and Yield Attributes

Plant height

Plant height at physiological maturity was significantly affected by seed rates (P<0.001) and time of nitrogen application (p<0.05). It was also affected (P<0.001) by the interaction of treatment combinations (Appendix 1). Plant height was significantly increased under both seeds rate and time of nitrogen application (Table 3). Plants treated with low seed rates (15 and 25 kg/ha) and time of nitrogen application ½ dose at sowing + ½ dose at tillering and ¼ dose at sowing + ½ dose after 30 days + ¼ dose after 60 days of sowing were taller than plantsupplied with high seed rates across time of nitrogen application. Similar to the present study, Tareke (2008) reported that plant height was affected by both seed rates and fertilizer treatments in tef.

Table 3. Interaction effects seed rates and time of Nitrogen applicationon plant height of tef grown

Seed rate (kg/ha)	Time of Nitrogen application (T)				
	N1	N2	N3	N4	Mean
15	105.00^{ab}	96.80^{bc}	113.867^{a}	116.33^{a}	108.00
25	88.80^{c}	100.07^{bc}	115.33^{a}	109.40^{ab}	103.40
35	91.40^{c}	98.07^{bc}	99.33^{bc}	98.73^{bc}	211.40
Mean	64.60	65.62	76.40	75.24	
LSD (P<0.05)	R 6.42				
	N 7.41				
	R x N 12.83				
CV (%)	7.38				

Where, R = rate; N1 = full dose at sowing; N2 = full dose at tillering; N3 = ½ dose at sowing + ½ dose at tillering; N4 =¼ at sowing +1/2 after 30 days +1/4 after 60 days of sowing. Means sharing the same superscript letterdo not differ significantly at P = 0.05 according to the LSD test

Panicle length

Panicle length at physiological maturity was significantly affected only by main effect of seed rate (P<0.001). The higher panicle length was recorded under low seed at 15 kg/ha as compared to 25 and 35 kg/ha seed rates. This might be due to less competition in low seed rates for nutrients and space. Plants grown under low seed rate showed panicle length increment 10.97 % and 18.73 % over 25 and 35 kg/ha, respectively. Tareke (2008) also reported significantly higher panicle length was observed under low seed rate than in high seed rates.

Table 4. Mean panicle length and tiller number as influenced by seed rates and time of Nitrogen application

Treatments	Panicle Length (cm)	Effective tillers
Seed rate (kg/ha)		
15	42.78^{a}	4.00^{a}
25	38.55^{b}	3.00^{b}
35	36.03^{b}	2.25^{c}
LSD (P<0.05)	4.04	0.67
Time of Nitrogen application (T)		
N1	39.73	2.56^{b}
N2	37.96	2.67^{b}
N3	39.00	3.67^{a}
N4	39.80	3.44^{a}
LSD (P<0.05)	NS	0.78
CV (%)	12.19	25.72

N1 = full dose at sowing; N2 = full dose at tillering; N3 = ½ dose at sowing + ½ dose at tillering; N4 =¼ at sowing +1/2 after 30 days +1/4 after 60 days of sowing.

Number of effective tillers

Tiller number is one of the yield components of tef that contributes to high straw and biomass yield. Number of tiller at physiological maturity was highly significantly affected (P<0.0001) by seed rates and time of nitrogen application (P<0.001) but it was not affected by their interaction effect (Table 4). The higher number of tillers was recorded under low seed rates at 15 kg/ha whereas the lowest was recorded under highest seed rates at 25 and 35 kg/ha at experimental site (Table 4). This implies that as the number of productive tillers per plant increases the yield per hectare also increases. As the seed rate increases the numbers of productive tillers decreases and vice versa. Similar to the present study, high tiller number was reported for tef sown in low seed rate with blended fertilizers (Tareke, 2008).The present study was similar to the findings of Hoshikawa (1984) who reported that sparsely planted rice achieve a high yield than dense ones. Application of nitrogen 1/2 dose at sowing +1/2 dose at tillering increased number of tillers as compared to other time of nitrogen application (Table 4). This might be due to split application of N promotes vigorous vegetative growth, effective tillers and no other element has such an effect on promoting vigorous plant growth.

Lodging

Lodging percentage was significantly affected (P<0.001) by seed rates and time of nitrogen application (Table 5). It was also affected (P<0.001) by the interaction effect of treatments (Appendix Table 1). The higher lodging indices was found with increased seed rate andtime of nitrogen application in full dose at tillering and ½ dose at sowing +1/2 dose tillering and the lowest was recorded under low seed rates at 15 kg/ha and across time of nitrogen application (Table 5). According to (Bekabil *et al*., 2011) almost all tef varieties are susceptible to lodging. However, there is also trade-off between fertilizer use and lodging as fertilizer leads to increase in the number of panicles and grains per panicle, which in turn increases the weight of the stem and the likelihood of lodging. Similarly, Seyfu (1983) reported that lodging in cereals considered to be caused by high rate of nitrogen fertilizer application, wind, heavy rain, fungal damage, failure of root system, weakness of the straw, high rate of seeding, deficiency of potassium.

Table 5. Interaction effects of seed rates and time of nitrogen application on lodging percentage of tef grown

Seed rate (kg/ha)	Time of Nitrogen application (T)				
	N1	N2	N3	N4	Mean
15 (R1)	27.0^{d}	26.0^{d}	24.7^{d}	26.1^{d}	26.0
25 (R2)	36.3^{c}	29.0^{d}	26.5^{d}	70.5^{ab}	40.6
35 (R3)	69.0^{b}	75.5^{a}	75.7^{a}	70.6^{ab}	72.7
Mean	44.1	43.5	42.3	55.7	
LSD (P<0.05)	R 3.1				
	N 3.6				
	R x N 6.2				
CV (%)	7.93				

Where, R = rate; N1 = full dose at sowing; N2 = full dose at tillering; N3 = ½ dose at sowing + ½ dose at tillering; N4 =¼ at sowing +1/2 after 30 days +1/4 after 60 days of sowing.

Yield Data

Straw yield

Straw yield was significantly affected (P<0.01) only by the main effect of time of nitrogen application. The results indicated that the highest straw yield was recorded under application of recommended rate of nitrogen into two splits whereas the lowest was recorded under full dose of nitrogen at sowing. This result is in agreement with that of Alcoz *et al*. (1993) and Tilahun *et al*. (1996) who reported enhancement of straw yield in response to applying nitrogen in split doses compared to applying the whole dose of the nutrient at seeding or mid-tillering stages of wheat.

Total aboveground biomass

Aboveground biomass was significantly (P<0.001) affected by time of nitrogen application and seed rates (P<0.05) but not by the interaction effects. Total aboveground biomass yield was enhanced by both low seed rates at 15 kg ha^{1-} and time of nitrogen applications in two splits. The results showed that total above-ground biomass yield of tef at 15 kg/ha seed rates increased above ground biomass yield by 4.65% over seed rate at 35 kg/ha (Table 6).This result is, however, in contrast to that of Mitiku (2008) who found the highest 50% biomass yield increase in tef at seed rate of 35 kg /ha. Application of the recommended rate of nitrogen 1/2 dose at sowing and 1/2 dose at tillering increased total aboveground biomass yield of tef as compared to other treatments (Table 6).Thus, the maximum biomass yield exceeded the minimum biomass yield by about 15 %.

Table 6. Mean straw yield, above ground biomass yield, harvest index and 1000 seed weight of tef as influenced by seed rates and time of nitrogen application

Treatments	TSW (g)	SY (kg/ha)	AGBM (kg/ha)	GY (kg/ha)	HI (%)
Seed rates(kg/ha)					
15	0.29	2999.76	5000.00[a]	2000.24[a]	40.00
25	0.29	2926.39	4805.57[b]	1879.18[b]	39.10
35	0.30	2908.57	4777.78[b]	1869.21[b]	39.12
LSD (P<0.05)	NS	NS	185.47	112.65	NS
Time of Nitrogen application					
N1	0.30	2850.7[b]	4639.6[b]	1788.9[b]	38.56[ab]
N2	0.30	2946.34[b]	4740.8[b]	1794.46[b]	37.85[b]
N3	0.28	3135.44[a]	5444.4[a]	2308.96[a]	42.41[a]
N4	0.29	2857.07[b]	4629.6[b]	1772.53[b]	38.29[ab]
LSD (P<0.05)	NS	140.26	214.16	130.08	1.79
CV (%)	8.01	6.54	4.51	4.99	3.33

N1 = full dose at sowing; N2 = full dose at tillering; N3 = ½ dose at sowing + ½ dose at tillering; N4 =¼ at sowing +1/2 after 30 days +1/4 after 60 days of sowing

Harvest index

Harvest index was computed as the ratio of grain yield to the total above ground dry biomass yield. The main effect of seed rate and the interaction effect of seed rate and timing of nitrogen application did not affect harvest index. However, the main effect of timing of nitrogen application significantly affected harvest index. The highest harvest indices were recorded under time of nitrogen application 1/2 dose at sowing +1/2 dose at tillering as compared to other time of nitrogen application (Table 6). This could be due to higher vegetative dry matter production under application of nitrogen into two splits than under full dose of nitrogen application. On top of that, full dose of nitrogen application may have led to relatively less shoot biomass growth due to leaching at the seedling stage of the crop, when the plant had no sufficient capacity to take up larger amounts of the nutrient. The current result is also in agreement with the result of Mulugeta (2000) that excess nitrogen application resulted in a reduction of harvest index in cereal crops. Generally, an increase in N application favors huge vegetative growth and thereby results in ultimately low harvest index (Tanaka *et al.*, 1994).

Thousand kernel weight

Weight of 1000-kernels was measured at a seed moisture content of 12.5%. Seed weight was not affected by both seed rates and time of nitrogen application (Table 6)

Grain yield

Grain yield was significantly affected by seed rates (P<0.05) and fertilizer types (P<0.001). But it was not affected by their interaction effects (Table 6).Application of the recommended rate of nitrogen half dose at sowing and half dose at tillering gave significantly higher (2308.96 kg/ha) grain yield than the rest of the treatments (Table 6).This result is also in agreement with the findings of Mohammad *et al*. (2011) who reported significantly higher yield of wheat from two equal split applications of N with 1/2 dose at sowing and 1/2 dose at tillering. Significantly higher (2000.24 kg/ha) grain yield was also recorded under low seed rates. This might be due to the fact that longer panicle length (more grain number per panicle), much more number of effective tillers and low lodging were observed in low seed rate which are directly related to grain yield (Table 6).Similarly to the present study, Mitiku (2008) reported that there was significant increase in yield components of tef with decreased seed rates.

Economic Analysis

The higher marginal rate of return with least cost was obtained from seed rate of 15 kg ha^{-1}. The marginal return obtained from 25 kg ha^{-1} seed rate was also showed further earnings as compared to seed rate at 35 kg ha^{-1}.

Table 7. Economic analysis for Seed rate

Treatments	variable cost (birr ha^{-1})	Grain yield (kg ha^{-1})	Net benefit (birr ha^{-1})	Marginal rate of return (%)
15(R1)	450	2000.24	39554.8	8790
25(R2)	750	1879.18	36833.6	746
35(R3)	1050	1869.21	36334.2	153

Where, R3=seed rate at 35 kg ha^{-1} ;R2= seed rate at 25 kg ha^{-1} ; R1= seed rate at 15 kg ha^{-1}

Conclusion

Reducing seed rates and using application of the recommended rate of nitrogen half dose at sowing and half dose at tillering considerably increased the growth, yield and yield attributes of tef and can be suggested for higher tef production in the study area.

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