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RESPONSE OF Tef [*Eragrostis tef (*Zucc.) Trotter] VARIETIES TO DIFFERENT RATES OF NITROGEN FERTILIZER IN EAST GOJJAM, NORTH WEST ETHIOPIA

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ABSTRACT

Tef is one of the mostly important food grain sources of livelihood for farmers of the Aneded district in North Western Ethiopia. Nevertheless, the productivity of the crop is noticeably low due to limited use of improved variety and inappropriate use of rate of nitrogen fertilizer. Therefore, the field experiment conducted in Aneded district during 2016/17 main cropping season to evaluate the response of tef varieties to different rates of nitrogen fertilizer. It contained factorial combinations of four tef varieties [three improved varieties (Dega Tef, Gimbichu and Quncho) and one local check (Basomure)] and four levels of nitrogen (0, 32.5, 65 and 97.5 Kg/ha) that laid out in Randomized Complete Block Design (RCBD) with three replications. The collected data subjected to statistical analysis by using SAS 9.1 and mean difference compared by DMRT at 5% level of significance. From this finding, Quncho variety and the highest rate of nitrogen (97.5 kg/ha) was identified to be the high yielding (3.68 t/ha) and economic nitrogen level with acceptable marginal rate of returns and as a result, Quncho variety with 97.5 kg N/ha is recommendable for the study area even if it needs to be tested again for complete recommendation.

Keywords: Days to maturity, Grain yield, Logding index, Variety

1. INTRODUCTION

Tef [*Eragrostis tef (*Zucc.) Trotter] is a cereal crop that belongs to the family Poaceae, sub family Eragrostidae, tribe Eragorsteae and genus Eragrostis, self pollinated and sexually propagated C_4 annual tropical love grass, an allotetraploid species with a base chromosome number of 10 (2n=4x=40) Mulu *et al*. (1996) as cited by Tsion (1). It is reported to be drought and water logging tolerant, relatively resistant to many biotic and abiotic stresses and grow on a wide variety of soils (2). It grows at altitudes ranging from 1000- 2500 and even to 2800 meter above sea level with varying annual rainfall of 750- 850 mm and temperatures between 10 and 27^{o}C.

In case of its morphology, tef has a large crown, many tillers and a shallow diverse root system. It can also be stored for many years without being seriously damaged by common storage insect pests (3). Tef crop is gaining popularity in the western world as a source of food because of its health advantage for the people having celiac disease (4). Tef flour is preferred in the production of '*keta'* and '*injera'*, a major food stable in Ethiopia and also eaten as porridge or used as an ingredient of home brewed alcoholic drinks. It is considered to have an excellent amino acid composition, lysine levels higher than wheat or barley and slightly less than rice or oats and contains 11% protein, 80% complex carbohydrate and 3% fat Piccinin (2002) as sited by Tsion (1). It has high dietary fiber, iron, phosphorus, copper, aluminum, barium and thiamin plus has a sour taste and is similar to millet (5). Tef is the main Ethiopian cereal annually grown on more than 3 million hector and accounts for 30 percent of total acreage and 19 percent of gross cereal production (6).

The economic importance of the crop is mainly as a human food which is believed to provide over two- third of the nutrition in the country. The high market prices of both its grains and the straw make it a highly valued cash crop for tef growing smallholder farmers (7). Maintaining soil fertility and use of plant nutrients in sufficient and balanced amounts is one of the key factors in increasing crop yields (8).

Looking at the regional distribution of tef production, there are five tef producing regions in Ethiopia namely Oromia, Amhara, Tigray, SNNP and Benishangul Gumuz that have 1.43, 1.14, 0.18, 0.23 and 0.02 million hectare area coverage, respectively (6). Of all Amhara Regional State Zones, East Gojjam is the leading Zone contributing for more than 10 percent of the national annual tef production (9). However, tef is considered to be an orphan crop since it is only of regional importance and has until recently not been the focus of crop improvement plus it's yield is far below the average annual yield of other major cereal crops growing in the country (10).

Lack of information on response of different and high yielding varieties, non optimum site specific and improper use of recommended fertilizer rate like nitrogen and insufficient research findings for most highland parts of the country unlike some other cereals are among the major constraints for sustainable tef production (11). Aneded District is one of the areas in East Gojjam Zone where tef is widely cultivated as a dominant crop, but the obtained yield is relatively low due to inadequate use of improved varieties and rate of nitrogen fertilizer.

Introducing high yielding variety and site specific rate of nitrogen is very crucial to optimizing the production and productivity of the crop and increasing the income of the study area community. So, it is paramount importance to evaluate the response of tef varieties to different rates of nitrogen fertilizer at Aneded District, East Gojjam, North Western Ethiopia. This experiment was intended with the following objectives:

- To evaluate the responses of tef varieties to different rates of nitrogen fertilizer and
- To determine the economic optimum rate of nitrogen fertilizer and select the most superior variety for better producing of the crop.

2. MATERIALS AND METHODS

2.1. Description of experimental location

The study was conducted at Amber in Aneded district, north- western Ethiopia in the Amhara National Regional State during 2016/17 main cropping season. Amber is located on 280 kilometers north- west of the capital Addis Ababa and 285 kilometers south- east of Bahir Dar, the capital of the Amhara National Regional State. The site is located at 10° 14' N latitude and 37° 52' E longitude and has an altitude of 2175 meter above sea level.

2.2. Experimental materials

2.2.1. Planting and fertilizer materials

Three tef varieties namely, Gimbichu (DZ- 01- 899), Dega Tef (DZ- 01- 2675) and Quncho (DZ-CR- 387- RIL- 355) which released by DZARC in 2006 while the rest improved varieties were released during 2005 by the same center and collected from Adet Agricultural Research Center plus one local variety Basomure were used. Urea [CO $(NH_2)_2$] (46% N) and triple super phosphate (TSP) [Ca $(H_2PO_4)_2$] (20% P) also used as sources of nitrogen and phosphorous, respectively.

2.3. Experimental treatments and design

The treatments consisted of four rates of nitrogen (0, 32.5, 65 and 97.5 Kg N/ha) and four tef varieties which were one local variety (Basomure) and three improved varieties namely Dega Tef, Gimbichu and Quncho. The experiment was laid out in Randomized Complete Block Design (RCBD) in factorial arrangement with three replications. The size of each plot was 2 m x 1.4 m (2.8 m2) with 20 cm row spacing and total of 7 rows per plot. The net harvestable area was 1.6 m x 1 m (1.6 m2), while the distance between adjacent plots and blocks was 0.5 m and 1 m, respectively. Treatments were assigned to each plot randomly.

2.4. Experimental procedures

Field was prepared according to the local tillage practices required for tef plantation with the use of the traditional '*maresha*' and pulverized well to make it the best seed bed for the crop. After preparation of the field lay out, the seed (4 kg/ha) was sown along the rows on July 30, 2016. All the recommended rate of phosphate fertilizer (50 kg/ha) was applied (band application) at sowing time, while urea applied in two splits by top dressing; the first and the second half dose

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application was undertaken at 16 and 40 days after sowing, respectively. Weeding was done manually similar to local farmers practice based on the frequency of weed emergence and finally the crop harvested at harvest maturity of each treatment.

2.5. Soil sampling and chemical analysis

Prior to planting, one composite surface (0- 30 cm) soil samples of 1 Kg collected from 10 points across the experimental field by zigzag method and analyzed for physicochemical properties. The samples was mixed, homogenized, air dried in shade, ground to pass through a 2 mm sieve and analyzed for soil texture, pH, total N, available P and K, organic carbon and CEC at Debre Markos Soil Laboratory. Soil pH was determined from the filtered suspension of 1:2.5 soils to water ratio using a glass electrode attached to a digital pH meter (potentiometer). Texture of the soil was also determined by the hydrometer method. Available phosphorus was determined by the methods of Olsen *et al*. (12). Total nitrogen was determined by the micro Kjeldhal distillation and titration method as described by Jackson (13). Organic carbon was determined following the wet digestion method as described by Walkley and Black (14). Cation exchange capacity of the soil was determined from ammonium acetate (NH_4OAC) saturated samples and measured through distillation using the micro kjeldhal procedure.

2.6. Data collection and measurements

2.6.1. Phenological parameter

Days to 90% maturity (DM): It was determined as the number of days from sowing to the time when 90% of the crop stems, leaves and floral bracts in a plot changed to light yellow color based on visual observation.

2.6.2. Growth parameters

Number of tillers per plant (TN): Ten plants were counted from inner five rows excluding the main shoot from randomly selected plants from each plot and the average was taken per plant.

Number of fertile tillers per plant (FT): It was recorded as the average number of fertile tillers (panicle bearing tillers) of ten plants from inner five rows of the plots at the reproductive stage by excluding the main shoot.

2.6.3. Yield and yield component parameters

Grain yield (t/ha): The total economic yield of the crop that measured in ton per hectare after harvesting, threshing and winnowing of the plant. Before direct weighing of the grain, the sample of two replications was taken from the grain harvested from net area of one of the plot, weighed by sensitive balance, kept in the oven adjusted at 130 ^{0}C for 2 hours and 15 minutes to adjust the correction factor for the grain weight after which it was determined by quick moisture detector.

Straw yield (t/ha): After threshing and measuring the grain yield, the straw yield was measured in ton per hectare by subtracting the grain yield from the total above ground air dried biomass yield. Biomass yield (t/ha): It was the sum of weight of the whole above ground harvested plant part from the net plot area including leaves, stems and grains that was air- dried. Thousand grain weight (gm): The 1000 grain weight of each net plot determined by carefully counting the small grains and weighing them using a sensitive balance.

2.7. Lodging index (^{o})

Lodging, the permanent displacement of crop plants from their vertical because of root or shoot failure, is a major yield constraint of the gluten free, panicle bearing cereal tef (15). 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^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 (16). The scales determined by the angle of inclination of the main stem from the vertical line to the base of the stem by visual observation. Each plot divided based on the displacement of the aerial stem in to all scales and the average of the value recorded. Finally, the data recorded on lodging percentage was subjected to arcsine transformation described for percentage data by Gomez and Gomez (17).

2.8. Statistical data analysis

Data were subjected to analysis of variances (ANOVA) procedures which are recommended for Randomized Complete Block Design (RCBD) by using SAS version 9.1 with a General Linear Model procedure (18). The mean differences comparison was undertaken by Duncan's Multiple Range Test (DMRT) at 5 percent probability level, while correlation analyses was carried out by calculating simple correlation coefficients between yields and yield components. Economic analysis was performed to identify the economically profitable nitrogen rate in the study area. The average grain price (Birr) per kg was considered for the computation. The average price (Birr) per kg for urea and labor cost for application of fertilizer and any other required work was considered for economic analysis. The economic evaluation comprising a partial budget with dominance and marginal analysis were carried out as described by CIMMYT (19).

The minimum acceptable rate of return was set at 100% that indicates a return of one Birr on every Birr of expenditure in the given variable inputs. Economic analysis was done using the prevailing farm gate prices for inputs at planting/sowing season and for outputs at the time the

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crop harvested. All costs and benefits were calculated on hectare basis in Ethiopian Birr (Birr/ha). The Dominance analysis procedure was used to select potentially profitable treatments.

3. RESULTS AND DISCUSSION

3.1 Physico- chemical properties of the soil of the study area

The result of the soil physical and chemical analysis indicated that the textural class of the soil of study area was clay that possess about 75% of the total area, while the rest small composition was sand (12%) and silt (16%). Soil pH is classified as very strongly acidic (< 4.5), strongly acidic (4.5- 5.2), moderately acidic (5.3- 5.9), slightly acidic (6.0- 6.6), neutral (6.7- 7.3), moderately alkaline (7.4- 8.0) and strongly alkaline (> 8.0) according to Tekalign (1991) as cited by Sate (20). The soil pH of study area was slightly acidic (pH= 6.30) since it was in the range of 6.0- 6.6.

According to FAO (21), the soil pH is within the suitable range for the growth of most crops including tef. Other soil chemical properties was total nitrogen (TN %) which is rated by Havlin *et al.* (22) as very low (< 0.1), low (0.1 to 0.15), medium (0.15 to 0.25) and high (> 0.25). Depending on these scales, the soil of study area had medium total nitrogen (0.21%) that indicates the soil need to be supplemented with some external application of nitrogen to satisfy the crop nutrient requirement for producing of potential yield.

The available phosphorus of soil was very low which was found in the range below 10 PPM (4.33 PPM). The same author classified soil organic matter in to very low (< 0.86), low (0.86- 2.59), moderate (2.59- 5.17) and high (> 5.17). According to this classification, the organic matter content of the soil of the study area was moderate (4.2). According to Roy *et al.* (23), the soil had medium organic carbon content. Another examined soil parameter was cation exchange capacity (CEC) which describes the property of the fertility of soil. According to Hazelton and Murphy (24), the soil had high cation exchange capacity (36.20) which was in the range of 25- 40 cmol /kg of soil.

3.2. Phenological parameter

3.2.1. Days to 90% maturity

Days to 90% maturity was highly significantly ($p < 0.01$) influenced by the main and interaction effects of nitrogen rates and varieties. Basomure combined with 97.5 Kg N/ha was the treatment at which the shortest number of days to 90% maturity was recorded. Following this, Quncho variety with rate of 97.5 kg N/ha was the second early matured even if there was no significance difference with Gimbichu applied with the similar nitrogen rate. In all the treatment combinations, the days to maturity was decreased with increasing in the rate of nitrogen fertilizer (Table 1).

Table 1: Means of days to 90% maturity as affected by rates of nitrogen fertilizer and tef varieties at Aneded in 2016/17 cropping season

Varieties	Nitrogen (Kg/ha)				
	0	32.5	65	97.5	Mean for variety
Dega Tef	145.33^{a}	142.00^{b}	139.67^{c}	137.67^{e}	141.167^{a}
Gimbichu	142.33^{b}	138.67^{d}	137.00^{e}	133.33^{gh}	138.000^{b}
Quncho	140.00^{c}	138.00^{d}	136.00^{f}	132.67^{hi}	136.667^{c}
Basomure (L)	136.00^{f}	134.00^{g}	132.33^{i}	128.33^{j}	132.667^{d}
Mean for N	140.917^{a}	138.167^{b}	136.417^{c}	133.000^{d}	
CV (%)	0.34				

LCR (0.05) for main and interaction = 0.389 and 0.779, respectively. Means within columns and rows followed by the same letter (s) are not significantly different at 5% level of significance. LCR= least common range; CV= coefficient of variation

The early maturing of the treatment received more nitrogen could be due to the role of nitrogen in facilitating plant growth and development through it influence on plant physiological and biochemical activities that accelerates crop maturity and also it is a part of the chlorophyll molecule which controls photosynthesis as well as the solar energy capturing reaction of green plants (25). This finding is coincide with the finding of Sate (20) who reported that the longer days to physiological maturity were recorded in unfertilized treatment over fertilized treatments on the same crop. Similarly, Mitiku (26) also found as days to physiological maturity significantly decreased with increased in the rates of nitrogen on tef. On the other hand, some other scholars disagreed to the present finding and reported as number of days to physiological maturity increased with increased in rates of nitrogen fertilizer (27, 28).

3.3. Growth parameters

3.3.1. Fertile tillers number per plant

The result of present finding showed that the number of fertile tillers per plant was highly significantly ($p < 0.01$) affected by the main and interaction effects of nitrogen rates and tef varieties. Quncho applied with 97.5 Kg N/ha resulted in production of the maximum number of fertile tillers per plant. Basomure (local check) resulted in lowest number of fertile tillers compared to improved varieties with the same fertilizer levels (Table 2).

Table 2: Means of fertile tillers number per plant as affected by rates of nitrogen fertilizer and tef varieties at Aneded in 2016/17 cropping season

Varieties	Nitrogen (Kg/ha)				
	0	32.5	65	97.5	Mean for variety
Dega Tef	9.62[j]	12.53[gh]	16.08[f]	21.07[c]	14.82[c]
Gimbichu	11.70[hi]	12.9[gh]	18.67[d]	22.77[b]	16.51[b]
Quncho	12.93[gh]	17.60[de]	21.70[bc]	25.59[a]	19.46[a]
Basomure (L)	7.08[k]	11.31[i]	13.07[g]	16.95[ef]	12.10[d]
Mean for N	10.33[d]	13.59[c]	17.38[b]	21.59[a]	
CV (%)		4.39			

LCR (0.05) for main and interaction = 0.576 and 1.151, respectively. Means within the columns and rows followed by the same letter (s) are not significantly different at 5% level of significance. LCR= least common range; CV= coefficient of variation

The present finding revealed that all the treatments showed increasing in fertile tillers number per plant with increasing in the level of nitrogen. Similar to current finding, reports showed significantly increased in number of fertile tillers due to increasing in rates of nitrogen on the same crop (29, 30). The reason why fertile tiller increased with the rate of nitrogen is due to its essentiality for cell division, growth and improves tiller survival (31).

3.4. Yield and yield components

3.4.1. Grain yield

The current finding revealed that tef grain yield was highly significantly ($p < 0.01$) affected by the main and interaction effects of nitrogen rates and varieties. Quncho and Gimbichu applied with 97.5 Kg N/ha were resulted in the first and second highest grain yield, respectively. The sorts of statistical parity was observed at Dega Tef and Basomure applied with 97.5 and Gimbichu with 65 Kg N/ha; Quncho without nitrogen, Gimbichu and Dega Tef with 32.5 as well as Basomure with 65 Kg N/ha; Basomure without nitrogen and 32.5 Kg N/ha, respectively (Table 3).

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Table 3: Means of grain yield (t/ha) as affected by rates of nitrogen fertilizer and tef varieties at Aneded in 2016/17 cropping season

Varieties	Nitrogen (Kg/ha)				
	0	32.5	65	97.5	Mean for variety
Dega Tef	1.26[i]	1.79[g]	2.21[e]	2.58[d]	1.96[c]
Gimbichu	1.40[h]	1.91[g]	2.47[d]	3.09[b]	2.22[b]
Quncho	1.89[g]	2.07[f]	2.87[c]	3.68[a]	2.63[a]
Basomure (L)	0.83[j]	0.89[j]	1.89[g]	2.58[d]	1.55[d]
Mean for N	1.35[d]	1.67[c]	2.36[b]	2.98[a]	
CV (%)		3.85			

LCR (0.05) for main and interaction = 0.067 and 0.134, respectively. The means in the columns and rows followed by the same letter (s) are not significantly different at 5% levels of significance, LCR= least common range; CV= coefficient of variation

The increasing in the grain yield with the nitrogen levels in all the treatments could be due to the role of nitrogen in facilitating the uptake of other nutrient responsible for grain yield like phosphorus and increasing the leaves chlorophyll content mainly for flag leave which holds more probability of light trapping at grain filling period. Similar to current finding, other results also revealed as tef grain yield significantly increased with the increasing in the rate of nitrogen application (32, 33, 34).

3.4.2 Biomass yield

The result of this finding revealed that biomass yield was highly significantly ($p < 0.01$) affected by the main and significantly ($p < 0.05$) by the interaction effects of nitrogen rates and varieties. Quncho applied with 97.5 Kg N/ha resulted in the highest biomass yield and except at the control, Quncho showed superiority over the other varieties at all the rates (Table 4).

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Table 4: Means of biomass yield (t/ha) as affected by rates of nitrogen fertilizer and tef varieties at Aneded in 2016/17 cropping season

Varieties	Nitrogen (Kg/ha)				
	0	32.5	65	97.5	Means for variety
Dega Tef	3.93^{g}	5.17^{f}	7.23^{cd}	7.45^{c}	5.94^{c}
Gimbichu	5.06^{f}	5.35^{f}	7.32^{c}	8.49^{b}	6.55^{b}
Quncho	5.25^{f}	6.11^{e}	8.50^{b}	9.51^{a}	7.34^{a}
Basomure (L)	3.77^{g}	5.42^{f}	6.62^{de}	7.90^{bc}	5.93^{c}
Mean for N	4.50^{d}	5.51^{c}	7.42^{b}	8.33^{a}	
CV (%)		6.11			

LCR (0.05) for main and interaction = 0.328 and 0.657, respectively. The means within the columns and rows followed by the same letter (s) are not significantly different at 5% level of significance. LCR= least common range; CV= coefficient of variation

The current finding showed that, the treatment that received the highest nitrogen was resulted in the highest biomass yield regardless of variety. Agreeable to the present finding, Temesgen (35) also reported that Quncho variety was the most performed variety over the other varieties contained in his study at the highest rate of nitrogen studied. This result is again in consistent with others who found the significant biomass yield increasing on tef in response to increasing in nitrogen application (33, 36). Harvesting of the highest biomass yield with the rates of applied nitrogen indicated that the applied fertilizer was utilized by the plant for growth and development.

3.4.3 Thousand grain weight

Thousand grain weight was highly significantly ($p < 0.01$) affected by the main and interaction effects of nitrogen rates and varieties. All the varieties were resulted in the significant highest thousand grain weight at the application of 97.5 Kg N/ha and the first, second and third largest thousand grain weight recorded under the same level of nitrogen application on Quncho, Gimbichu and Dega Tef, respectively (Table 5).

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Table 5: Means of thousand grain weight (gm) as affected by rates of nitrogen fertilizer and tef varieties at Aneded in 2016/17 cropping season

Varieties	Nitrogen (Kg/ha)				
	0	32.5	65	97.5	Means for variety
Dega Tef	0.234^{h}	0.274^{f}	0.293^{e}	0.321^{c}	0.280^{c}
Gimbichu	0.239^{h}	0.277^{f}	0.294^{e}	0.334^{b}	0.286^{b}
Quncho	0.231^{h}	0.287^{e}	0.312^{d}	0.365^{a}	0.299^{a}
Basomure (L)	0.231^{h}	0.261^{g}	0.292^{e}	0.316^{d}	0.275^{d}
Mean for N	0.233^{d}	0.275^{c}	0.298^{b}	0.333^{a}	
CV (%)		1.62			

LCR (0.05) for main and interaction = 0.004 and 0.008, respectively. The means within the columns and rows followed by the same letter (s) are not significantly different at 5% level of significance. LCR= least common range; CV= coefficient of variation

Similar to this finding, some other scholars also reported that increased in the rate of nitrogen fertilizer resulted in significant increased in thousand grain weight on different crops (30, 37, 38).

3.5 Lodging index

Basomure (local check) showed susceptibility to lodging in all the rates and even at the control. The highest rate of nitrogen resulted in total lodging (90^{o}) of local variety. Having the weakest stem makes Basomure the most susceptible one to lodging when compared to the others. Quncho variety showed bit susceptibility when applied with the highest rate of nitrogen, while Gimbichu and Dega Tef exhibited the same response except at application of 65 Kg N/ha. The improved varieties showed the same response to lodging at the control and 32.5 Kg N/ha. At the second highest rate, Gimbichu showed more susceptibility than Quncho, while Dega Tef showed similar response at that level. Basomure with 32.5 and 65 Kg N/ha; Gimbichu with 65, Dega Tef and Gimbichu with 97.5 Kg N/ha showed the same response to lodging (Table 6).

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Table 6: Means of lodging index (°) as affected by rates of nitrogen fertilizer and tef varieties at Aneded in 2016/17 cropping season

Varieties	Nitrogen (Kg/ha)				
	0	32.5	65	97.5	Mean for variety
Dega Tef	7.50^{h}	15.07^{g}	25.10^{f}	33.89^{e}	20.38^{c}
Gimbichu	7.50^{h}	15.07^{g}	33.89^{e}	33.89^{e}	22.57^{b}
Quncho	7.50^{h}	15.07^{g}	25.10^{f}	37.66^{d}	21.33^{bc}
Basomure (L)	45.19^{c}	65.15^{b}	65.15^{b}	90.00^{a}	66.37^{a}
Mean for N	16.92^{d}	27.58^{c}	37.31^{b}	48.86^{a}	
CV (%)			4.99		

LCR (0.05) for main and interaction = 1.360 and 2.719, respectively. The means within the columns and rows followed by the same letter (s) are not significantly different at 5% level of significance. LCR= least common range; CV= coefficient of variation

Even if the incremental rate is different with the variety, all the varieties showed bit susceptibility to lodging with increasing in the rates of nitrogen. The reason for the increasing in susceptibility with the rates of nitrogen is due to the role of nitrogen in facilitating plant height that posse the longer panicle that aggravates load on the shoot and makes it to be lodged. Similar to present finding, some other scholars also reported as lodging increased with the application rate of nitrogen on different crops (29, 39, 40).

3.6 Correlation among yields and yield components

Strong and positive correlation of biomass yield with the growth parameters was observed and indicated that biomass yield could invariably increased by increasing these attributes. As the biomass yield is cumulative effects of all other yield and growth parameters, the higher amount of growth parameter production, the more numbers of yielding parameter production that later resulted in more biomass yield production. The higher the total tillers number, the higher number of fertile tillers, the more number of spikelets that resulted in more biomass yield production. Similarly, grain yield was also indicated strong correlation with other growth parameters. All the growth parameters contributed to grain yield as well as well managed and well grown crop resulted in more tillers number, more fertile tillers number that would have more number of panicles per area which holds more spikelets that possessed higher number of florets that later resulted in more grain yield per hectare. Grain yield was also strongly and positively correlated with thousand grain weight. As the total grain yield is cumulative effectives of each grain, the

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grain with higher weight resulted in more grain yield than grain of smaller weight of the same area (Table 7).

Table 7: Correlation among tef yields and growth parameters

	TN	FT	SPP	GY	BMY	TGW
TN	1					
FT	0.97**	1				
SPP	0.95**	0.94**	1			
GY	0.94**	0.94**	0.91**	1		
BMY	0.92**	0.92**	0.86**	0.91**	1	
TGW	0.96**	0.96**	0.93**	0.95**	0.93**	1

**, * Indicates highly significant and significant difference at 1% and 5% probability level, respectively.

GY: grain yield; BMY: biomass yield; SPP: spikelet per panicle; PH: plant height; TGW: thousand grain weight; TN: total tiller number; FT: fertile tiller number

Concurrent to the result of this study, the finding of Chanyalew (41) on 18 tef genotypes showed that grain yield was positively correlated with plant height, panicle length, grain weight and harvest index. Similarly, other finding also found strong and significant positive correlation of grain yield with others agronomic parameters signifying that grain yield could consistently increase by increasing these attributes (42).

3.7 Economic analysis for rates of nitrogen fertilizer

The results of economic analysis showed that the maximum net benefit of all the varieties under study was higher at the highest nitrogen fertilized treatments as there was minimum increment in cost of production when compared with the obtained net returns with an acceptable marginal rate of returns (MRR). An increased in output will always raise profit as long as the marginal rate of return is higher than the minimum rate of return 100% (19). Only one treatment was eliminated by dominance analysis since it gave the lower gross margin than the treatment received lower fertilizer rate. Considering the comparison with control, the net returns obtained in Birr were 60481.8, 49721.8, 40581.8 and 28976.8 from Quncho, Gimbichu, Dega Tef and Basomure varieties, respectively at the highest nitrogen level. Among this, Quncho can be selected from the rest varieties as the outstanding variety in fetching maximum net return that makes it the variety of preference at the experimental area with 97.5 Kg/ha level of nitrogen (Table 8).

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Table 8: Economic analyses for rates of nitrogen fertilizer at Aneded, North Western Ethiopia in 2016/17 cropping season

Variety	N (Kg/ha)	AY (T/ha)	Adjusted yield (T/ha)	GFB (Br/ha)	TVC (Br/ha)	NB (Br/ha)	MRR (%)
Dega Tef	0	1.264	1.138	22760	3340	19420	-
	32.5	1.793	1.614	32280	4219.4	28060.6	982.56
	65	2.207	1.987	39740	5028.8	34711.6	905.45
	97.5	2.578	2.321	46420	5838.2	40581.8	847.08
Gimbichu	0	1.409	1.269	25380	3340	22040	-
	32.5	1.907	1.717	34340	4219.4	30120.6	918.88
	65	2.469	2.223	44460	5028.8	39431.2	1029.8
	97.5	3.086	2.778	55560	5838.2	49721.8	1108.07
Quncho	0	0.833	1.701	34020	3340	30680	-
	32.5	2.073	1.866	37320	4219.4	33100.6	275.26
	65	2.867	2.581	51620	5028.8	46591.2	947.16
	97.5	3.684	3.316	66320	5838.2	60481.8	1192.93
Basomure	0	0.833	0.75	11250	3340	7910	-
	32.5	0.892	0.803	12045	4219.4	7825.6^{D}	-436.03
	65	1.899	1.71	25650	5028.8	20621.2	530.63
	97.5	2.578	2.321	34815	5838.2	28976.8	693.17

AY= adjusted yield; TVC= total variable cost (contains all the variable production costs); GFB= gross field benefit; MRR= marginal rate of return; NB= net benefit; D= dominated

4. CONCLUSION AND RECOMMENDATION

With the increasing price of nitrogen fertilizer, the potential of using nutrient efficient varieties for increasing and sustaining tef production becomes increasingly pretty. The results of this study which intended to evaluate response of the tef varieties to rates of nitrogen fertilizer demonstrated that all the tested varieties positively responded to the increasing rate of nitrogen. Improved varieties showed dominance over local check in producing the higher yield. Increased in the rate of nitrogen resulted in speeding up the crop Phonological stage when compared with the lower rates and control. This also markedly increased the growth, yield and yield attributes of the tef varieties. However, increased in the rate of nitrogen resulted in profound increasing in yield for all varieties, it was also resulted in the increasing in the lodging.

Among the varieties, Quncho was identified as the most promising variety in producing the highest yield and positively responding to the applied rates of nitrogen fertilizer that makes the potential and wide adapting variety that fetches the maximum returns. Among the rates of nitrogen, 97.5 Kg/ha was identified to be the most economic and optimum level of nitrogen fertilizer in the study area with acceptable marginal rate of returns. The rate that able to activate variety in expressing its yielding potential is also the rate of preference for the farming community in getting adequate return of their field expenses. However, definite recommendation may not be drawn from this research result, use of Quncho variety with 97.5 Kg N/ha was identified to be the best variety and the economic nitrogen level in producing the highest yield for the study area.

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