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RESPONSE OF Tef [*Eragrostis tef (*Zucc.) Trotter] VARIETIES TO APPLIED RATES OF NITROGEN FERTILIZER ON VERTISOLS IN ANEDED DISTRICT, NORTH WEST ETHIOPIA

Berihanu Sime (MSc)[1]*, Ahadu Menzir (PhD)[2], Mulatu Kassaye (PhD)[2]

[1]Jinka University, College of Agriculture and Natural Resource, P.O.Box 165, Jinka, Ethiopia

[2] Debre Markos University, College of Agriculture and Natural Resource, Debre Markos, Ethiopia

*Corresponding author

ABSTRACT

Tef is one of the most important food grain sources of livelihood for smallholder farmers in North Western Ethiopia. However, the productivity of the crop is stumpy due to limited use of improved varieties and inappropriate use of rate of nitrogen fertilizer. Therefore, the field experiment was conducted in Aneded district in 2016/17 main cropping season to evaluate response of tef varieties to different rates of nitrogen fertilizer. To accomplish these objective, the experiment 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 was used. The collected data on yield and yield components were subjected to statistical analysis by using SAS 9.1 and mean difference were compared by DMRT at 5 % level of significance. The measured values of growth and yield parameters increased with the rate of nitrogen fertilizer. From this finding, 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: Fertilizer, Grain yield, Harvest 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.

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Volume:05, Issue:01 "January-February 2019"

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 which is another importance of tef over other cereals (3). Tef is traditionally harvested for grain in Ethiopia, where it was first domesticated between 4000- 1000 B.C. The common name of the crop in Ethiopia is 'tef' which seems to be derived from the Amharic word '*tefa*' to mean 'lost' to reflect the small size of the grain which disappears if scattered on the ground (4). Tef crop is also gaining popularity in the western world as a source of food because of its health advantage for the people having celiac disease which is a chronic systemic autoimmune disorder caused by a permanent intolerance to gluten proteins in genetically susceptible individuals (5).

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 (6). 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 (7). Relying on national household consumption data, urban and rural consumption per capita is as high as 61 and 20 Kg per year, respectively (8). 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 (9). Maintaining soil fertility and use of plant nutrients in sufficient and balanced amounts is one of the key factors in increasing crop yields (10).

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 (7). Of all Amhara Regional State Zones, East Gojjam is the leading Zone contributing for more than 10 percent of the national annual tef production (11). 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 (13). Aneded District is one of the areas in East Gojjam Zone in which 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 application and
- To determine the economic optimum rate of nitrogen fertilizer and select the best 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 2016/2017 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 were collected from Adet Agricultural Research Center; one local variety (Basomure) which was purchased from the farmer were used. Urea [$CO(NH_2)_2$] (46% N) and triple super phosphate (TSP) [$Ca(H_2PO_4)_2$] (20% P) was 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 x1.4 m (2.8 m^2) 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 m^2), 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

ISSN: 2455-6939

Volume:05, Issue:01 "January-February 2019"

Field was prepared according to the local tillage practices required for tef plantation 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 of the recommended rate of phosphate fertilizer (50 kg/ha) was applied (band application) at time of sowing while urea was applied in two splits by top dressing; the first and the second half dose 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.

2.5. Soil sampling and chemical analysis

Prior to planting, one composite surface (0- 30 cm) soil samples of 1 Kg was collected from 10 points across the experimental field by zigzag (to make the sampling process more inclusive and to minimize the fate of taking sample from almost similar point that may not represents the soil of experimental field) 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 by using a glass electrode attach 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*. (14). Total nitrogen was determined by the micro Kjeldhal distillation and titration method as described by Jackson (15). Organic carbon was determined following the wet digestion method as described by Walkley and Black (16). 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. Growth parameters

Plant height (PH): It was measured at physiological maturity from the ground level to the tip of panicle from ten randomly selected plants of the interior rows in each plot and recorded as the average height of 10 randomly selected plants.

Panicle length (PL): It is the length of the panicle from the node where the first panicle branches emerge to the tip of the panicle which was determined from an average of ten randomly selected plants per plot at physiological maturity.

2.7. Yield and yield component parameters

Grain yield (GY): Is the total economic yield of the crop that was measured in tone per hectare after harvesting, threshing of the plant and winnowing.

ISSN: 2455-6939

Volume:05, Issue:01 "January-February 2019"

Straw yield (SY): After threshing and measuring the grain yield, the straw yield was measured in tone 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 grain that was air- dried.

Harvest index (%): It was recorded by dividing grain yield by the total above ground air dried biomass yield.

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 (17). 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 (18).

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 by using the prevailing farm gate prices for inputs at planting/sowing season and for outputs at the time the 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. Results of Physico- chemical properties of experimental soil

The result of the soil physical and chemical analysis indicated that the texture of the experimental soil was clay that possess about 75 % of the soil of study 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 sited by Sate (19). The soil pH of study area was slightly acidic (pH= 6.30) since it was in the range of 6.0- 6.6.

ISSN: 2455-6939

Volume:05, Issue:01 "January-February 2019"

According to FAO (20), 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 rated by Havlin *et al.* (21) 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 experimental area possessed 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 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.* (22), the soil had medium organic carbon content which indicates that it has medium nitrogen supplying potential to the crop as organic matter content is often used as an index of nitrogen availability. Another examined soil parameter was cation exchange capacity (CEC) which describes the property of the fertility of soil. According to Hazelton and Murphy (23), the soil had high cation exchange capacity (36.20) which was in the range of 25- 40 cmol /kg of soil.

3.2. Growth parameters

3.2.1. Plant height

Plant height was highly significantly ($P < 0.01$) affected by the main and interaction effects of variety and nitrogen application rate. The highest plant height was obtained at Quncho variety applied with 97.5 kg N/ha. Gimbichu applied with 97.5 kg N/ha and Quncho with 65 kg N/ha were the treatments at which the second and third highest plant high was recorded, respectively (Table 1).

Table 1: Means of plant height (cm) as influenced by rates of N 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	84.34^{k}	92.93^{ij}	98.00^{g}	105.59^{e}	95.22^{d}
Gimbichu	91.66^{j}	96.45^{gh}	103.00^{1f}	114.81^{b}	101.48^{b}
Quncho	98.36^{g}	106.27^{de}	111.84^{c}	134.87^{a}	112.84^{a}
Basomure (L)	90.91^{j}	94.96^{hi}	101.04^{f}	108.17^{d}	98.77^{c}
Mean for N	91.32^{d}	97.65^{c}	103.47^{b}	115.86^{a}	
CV (%)		1.43			

LCR (0.05) for main and interaction = 1.218 and 2.436, respectively. Means within columns and rows followed by the same letter (s) are not significantly different at 5 % level of significance. CV= Coefficient of variation; LCR= Least common rage

The current result is consistent with the finding of Temesgen (24) who indicated that nitrogen has synergic effects on enhancing plant height on tef crop. This is attributed to the fact that nitrogen usually favors vegetative growth of tef, as it has significant effect on plant height to the major role the nutrient plays in cell division, elongation and vegetative growth resulting in higher stature of the plants with greater panicle length (25, 26). In contrast, Adam (27) reported as increased rate of nitrogen has no effect on tef crop.

3.2.2. Panicle length

Panicle length was highly significantly ($p < 0.01$) affected by the main and interaction effects of nitrogen rates and varieties. Out of the treatment combinations, the longest panicle recorded at treatment combination of Quncho variety with 97.5 Kg N /ha followed by Gimbichu with the same level of nitrogen even if there was statistical parity with Quncho applied with 65 Kg N/ha. Quncho showed better response to all the rates followed by Gimbichu which was also variety of good potential in responding to applied fertilizer in producing longer panicle (Table 2).

ISSN: 2455-6939

Volume:05, Issue:01 "January-February 2019"

Table 2: Means of panicle length (cm) as influenced by rates of N 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	31.96^{i}	34.21^{gh}	36.13^{e}	38.26^{cd}	35.14^{c}
Gimbichu	32.6^{i}	34.78^{fg}	37.34^{d}	40.69^{b}	36.35^{b}
Quncho	35.43^{ef}	38.70^{c}	40.35^{b}	44.74^{a}	39.81^{a}
Basomure (L)	32.12^{i}	33.77^{h}	35.99^{e}	38.02^{cd}	34.97^{c}
Mean for N	33.03^{d}	35.36^{c}	37.45^{b}	40.43^{a}	
CV (%)		1.55			

LCR (0.05) for main and interaction = 0.472 and 0.944, respectively. Means within columns and rows followed by the same letter (s) are not significantly different at 5 % level of significance. CV= Coefficient of variation; LCR= Least common rage

This finding is agreeable with that of Temesgen who also revealed different effects of variety and nitrogen rates on panicle length of tef and recorded the highest panicle length on Quncho variety (24). Similarly, some other findings showed that as application of nitrogen rates increased to optimum quantity, panicle length can also be increased (28, 29).

3.3. Yield and yield components

3.3.1. 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 resulted in the first and second highest grain yield, correspondingly. 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).

ISSN: 2455-6939

Volume:05, Issue:01 "January-February 2019"

Table 3: Means of grain yield (t/ha) as influenced by rates of N 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. CV= Coefficient of variation; LCR= Least common rage

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. Similar to current finding, Abraha reported that tef grain yield was significantly influenced by the rates of nitrogen and identified as the grain yield generally increased with the increasing in the rate of nitrogen application (30). Moreover, other scholars also reported significant increase in grain yield with increase in rate of nitrogen (31).

3.3.2. Straw yield

The analyzed result of present finding exposed that straw yield was highly significantly ($p < 0.01$) and significantly ($p < 0.05$) affected by the main and interaction effects of nitrogen rates and tef varieties, respectively. The first and second highest straw yield was recorded under Quncho applied with 97.5 and 65 Kg N/ha, respectively, while Gimbichu applied with 97.5 Kg N/ha was resulted in the third highest yield. Except Dega Tef which had the highest straw yield at 65 Kg N/ha, all the varieties resulted in the highest straw yield when applied with the highest rate of nitrogen (Table 4).

Table 4: Means of tef straw yield (t/ha) as influenced by rates of N 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	2.67^{h}	3.38^{fgh}	5.02^{bcd}	4.87^{cd}	3.98^{c}
Gimbichu	3.65^{fg}	3.45^{fg}	4.85^{cd}	5.40^{abc}	4.34^{b}
Quncho	3.36^{fgh}	4.03^{ef}	5.63^{ab}	5.83^{a}	4.71^{a}
Basomure (L)	2.93^{gh}	4.53^{de}	4.73^{cde}	5.32^{abc}	4.38^{ab}
Mean for N	3.15^{c}	3.85^{b}	5.06^{a}	5.35^{a}	
CV (%)		9.48			

LCR (0.05) for main and interaction = 0.344 and 0.688, respectively. The means within the columns and rows followed by the same letter (s) are not significantly different at 5 % level of significance. CV= Coefficient of variation; LCR= Least common rage

Similar to present result, some finding reported increased in straw yield with nitrogen rate over the control on tef (30, 31, 32).

3.3.3. Biomass yield

The result of present 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 was resulted in the highest biomass yield and except at the control, Quncho showed superiority over the other varieties at all the rates. There was also sorts of statistical parity between Quncho with 65 and Gimbichu and Basomure with 97.5 Kg N/ha; Dega Tef and Gimbichu with 65 as well as Dega Tef and Basomure with 97.5 Kg N/ha; Dega Tef and Basomure with 65 Kg N/ha; Quncho with 32.5 and Basomure with 65 Kg N/ha; Gimbichu and Quncho without nitrogen, Gimbichu, Dega Tef and Basomure with 32.5 Kg N/ha; Dega Tef and Basomure without nitrogen application, respectively (Table 5).

ISSN: 2455-6939

Volume:05, Issue:01 "January-February 2019"

Table 5: 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. CV= Coefficient of variation; LCR= Least common rage

This result is in consistent with that of others scholars who found the significant biomass yield increasing on tef in response to increasing in application rate of nitrogen (24, 28, 29, 33). This finding is however, in contrast to that of Adam who reported no significant difference between different rates of nitrogen on tef biomass yield (27).

3.3.4. Harvest index

The result of the present finding showed that harvest index was highly significantly ($p < 0.01$) affected by main and interaction effects of nitrogen rates and varieties. Except Quncho and Basomure, the other varieties showed decreasing trend in harvest index with increasing in the nitrogen level. Quncho variety showed superiority to other varieties (Table 6).

ISSN: 2455-6939

Volume:05, Issue:01 "January-February 2019"

Table 6: Means of harvest 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	32.17^{bc}	31.00^{bc}	30.73^{bc}	27.77^{bcd}	30.42^{a}
Gimbichu	22.20^{e}	24.93^{de}	37.27^{a}	32.60^{b}	29.25^{b}
Quncho	30.53^{bc}	24.67^{de}	40.13^{a}	40.20^{a}	33.88^{b}
Basomure (L)	9.93^{f}	9.90^{f}	27.37^{cd}	30.33^{bc}	19.38^{c}
Mean for N	23.71^{b}	22.63^{b}	33.87^{a}	32.73^{a}	
CV (%)		9.62			

LCR (0.05) for main and interaction = 2.265 and 4.529, respectively. The means within the columns and rows followed by the same letter (s) are not significantly different at 5 % level of significance. CV= Coefficient of variation; LCR= Least common rage

Similar to present finding, Kumela and Thomas disclosed increasing in harvest index with the rate of nitrogen and said that plant supplied with the adequate amount of fertilizer had better ability to absorb moisture and mineral nutrients efficiently on tef (29). In contrast to this finding, reports revealed that increased in the rates of nitrogen has no significant effect on harvest index (31, 34).

3.4. Correlation among yield and yield components

Strong and positive correlation of grain and straw yield with all the agronomic parameters was observed and indicated that these yields could invariably increased by increasing growth parameters. The higher amount of growth parameter production, the more numbers of yielding parameter production that later resulted in more grain, straw and biomass yield production. The correlation of grain yield with plant height indicated that the higher the plant height, the longest the panicle, the highest number of spikelets per panicle that resulted in formation of enhanced number of florets per spikelet that resulted in more grain production per hectare. Straw yield also showed positive and strong correlation with growth and yield parameters. The longer the plant height, the longer the panicle, the more number of spikelets and florets produced that produces more straw yield per hectare (Table 7).

ISSN: 2455-6939

Volume:05, Issue:01 "January-February 2019"

Table 7: Correlation coefficients of tef yields and growth parameters

	PH	PL	GY	SY	BMY	HI
PH	1					
PL	0.96**	1				
GY	0.90**	0.93**	1			
SY	0.76**	0.78**	0.79**	1		
BMY	0.87**	0.91**	0.91**	0.95**	1	
HI	0.54**	0.62**	0.78**	0.42**	0.62**	1

** Indicates highly significant difference at 5 % probability level. GY: grain yield; SY: straw yield; HI: harvest index; PH: plant height; PL: panicle length; BMY= biomass yield

Concurrent to the result of this study, the finding of Chanyalew on 18 tef genotypes showed that grain yield was positively correlated with plant height, panicle length, shoot biomass, grain weight and harvest index (35). Likewise, Abdel also disclosed that grain yield was positively associated with plant height (36). Similarly, Teklay and Girmay found strong and significant positive correlation of grain yield with others agronomic parameters and reported as grain yield could consistently increase by increasing these attributes (37).

3.5. 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 treatment as there was minimum increment in cost of production when compared with the obtained net returns with an acceptable marginal rate of returns (MRR). Local variety (Basomure) was resulted in the lowest net returns under the same level of nitrogen fertilizer when compared with improved varieties. 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% (18). Only one treatment was eliminated by dominance analysis since it gave the lower gross margin than the treatment received lower fertilizer rate (Table 8).

Table 8: Economic analyses for nitrogen fertilizer rates at Aneded 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

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 make it the variety of preference at the experimental area with 97.5 Kg/ha level of nitrogen (Table 8).

4. CONCLUSION AND RECOMMENDATION

Increasing in the rate of nitrogen application markedly increased the growth, yield and yield attributes of the tef varieties. Among varieties, Quncho identified as the most promising variety in producing the highest yield and positively responding to the applied rates of nitrogen fertilizer (even showed hints to be resulted in further yielding under higher rate of nitrogen) that makes the potential and wide adapting variety that fetches the maximum returns. However, definite recommendation may not be drawn from this research result, the use of Quncho variety with 97.5 Kg N/ha was identified to be the best variety and economic nitrogen level in producing the highest yield for the study area. Therefore, the result will need to be further evaluated over

ISSN: 2455-6939

Volume:05, Issue:01 "January-February 2019"

different seasons to recommend for tef producing farmers for significant improvements in crop field efficiency and enhanced the production and productivity of the crop.

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