RESEARCH ARTICLE

Productivity, Nutrient removal, Soil nutrient dynamics and Economics of Tef (*Eragrostis tef (zucc.)Trotter*) Production in Relation to Genotypes and Integrated Nutrient Management on Vertisols of Mid high lands of Oromia region of Ethiopia, East Africa

Yonas Mebratu; Cherukuri V Raghavaiah *and Habtamu Ashagre.

Department of plant science, College of Agriculture and Veterinary Sciences, Ambo University, Ambo, Post Box No.19, West Shoa Zone ,Ethiopia.
***Corresponding author**: Cherukuri V Raghavaiah

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ABSTRACT

Tef, a highly valued nutritious cereal crop, plays an important role in the diet of Ethiopians. Field experiment was carried out during 2014/15 cropping season on a field belonging to Hommicho Ammunition Engineering Industry with the objective to evaluate the response of Tef genotypes to integrated nutrient management in terms of productivity in Guder, Toke kuttai district. The treatments consisted of six levels of integrated nutrient management practices:1) 0 -0 -0 (check) 2) 40 -60 -0 NPK (RDF) 3) 50%RDF + 50% N (FYM) 4) 75%RDF + 25% N (FYM) 5) 100% RDF + 5t FYM/ha and 6)RDF through new complex fertilizer (19 -38 – 7 NPS) tested on five genotypes (Magna, Simoda , Quncho , Dz –Cr -409, Local variety). The experiment was laid out in a randomized complete block design with factorial arrangement with three replications. The results revealed that there was distinct variation between varieties and integrated nutrient management practices in grain and straw yield, where DZ-01-196 recorded maximum grain and straw yield with application of 100% RDF + 5t/ha FYM which was comparable with 75%RDF + 25% FYM. Therefore application of 50% RDF + 50%FYM, 75%RDF + 25%FYM and 100%RDF + 5tha^{-1} to DZ-01-196, DZ-CR-409 and Local varieties of Tef , respectively exhibited best production performance on Vertisols of mid high lands of Ethiopia. The nutrient content of grain was found to be greater than that of straw. Application of 100%RDF +5t/ha^{-1} FYM and 75%RDF +25%FYM analysed higher content of NPK both in grain and straw than other treatments, ultimately resulting in greater nutrient removal than with inorganic fertilizer alone and no fertilizer check . The- post harvest available NPK content of soil in comparison with initial status was found to be higher with INM than no fertilizer and inorganic fertilizer treatments. Economic analysis showed that higher MRR, Benefit: cost ratio and return /Birr investment were accrued with 100%RDF+5t/ha FYM and 75%RDF+25%FYM when compared with inorganic fertilizer and no fertilizer check.

Key words: Tef, genotypes, nutrient management, Vertisols, mid high lands, productivity, Nutrient removal, soil nutrient balance , economics.

INTRODUCTION

Ethiopian economy is principally agro- based and the sector accounts for 46% of Ethiopia GDP and 90% of its export earnings and employ 85% of the countries labour force (Mulatu, 1999; UNDP, 2002). Tef is a superior cereal grain crop solely produced and is considered as the noble grain of Ethiopia. Most of the areas used for production of grains especially tef, wheat and barley fall under the low fertility (Yihenew, 2002). Soils in the highlands of Ethiopia usually have low levels of essential plant nutrients and organic matter content, especially low availability of nitrogen and phosphorus has been considered to be major constraint to cereal production (Tekalign et al., 1988). There are now Ethiopian restaurants in USA that are flourishing due to demand for ethnic foods, enjera and watt (stew) (Flarlan,1991).

Tef is the major cereal crop of Ethiopia and occupies about 2.7 million hectares (27% of the grain crop area) of land which is more than any other major cereals such as maize (22.7%), sorghum (19%) and wheat (16%) (CSA, 2011). It is an indigenous cereal crop to Ethiopia and it has been recognized that Ethiopia is the centre of origin and diversity of tef. It is a C4 self pollinated chasmogamous annual cereal which belongs to the family P*oacea*, sub family *Eragrostidae* and genus *Eragrostis*. Of the 82% gross grain production (about 17 million tonnes) contributed by cereals, tef accounts for 19.9% during the main season of 2010/11 (CSA, 2011).

Ethiopian farmers grow tef due to a number of merits, which are mainly attributed to the socio-economic, cultural and agronomic benefits (Seyfu, 1993). Tef has more food value than the major grains such as wheat, barley and maize. Tef grain contains 14-15% proteins, 11-33 mg iron, 100-150 mg calcium, and rich in potassium and phosphorus nutrients (National Academy Press, 1996). Tef has merits such as gluten free nature, tolerance to biotic and abiotic stresses, animal feed value and soil erosion control quality (Seyfu, 1997). Small-scale commercial production of tef has begun in areas of the wheat belts of the USA, Canada and Australia. Tef has been introduced to South Africa and cultivated as a forage crop, and in recent years cultivated as a cereal crop in Northern Kenya (Seyfu, 1997).

Tef production has been going north wards from year to year and so does the demand for it as staple grain in both rural and urban areas of Ethiopia (Mitiku, 2008). The major areas of production in Ethiopia are Shewa, Gojam, Gonder, Wellega and Wello in central highlands of the country (Doris-Piccinin, 2010). In areas of its consumption as a staple food, tef contributes about two-thirds of the dietary protein intake (Seyfu, 1997).

Tef is adapted to diverse agro-ecological zones which are marginal to most other crops (Hailu and Seyfu, 2001). Tef suffers less from diseases and gives better grain yield and possesses higher nutrient content especially protein when grown on Vertisols rather than Andosols (Mitiku, 2008). Since tef tolerates water logging, it is sown during the wet season, from late July to mid August, is mainly cultivated as a mono-crop and is the most suitable crop for multiple cropping systems such as double and relay cropping.

Tef is predominantly cultivated on sandy-loam to black clay soils (Seyfu, 1993). Tef withstands low moisture conditions and it is often considered as a rescue crop that survives and grows well in the season when early planted crops (*e.g*. maize) fail due to low moisture. It is primarily grown for its grain that is used for making *injera* (Abel, 2005).

Regardless of its high area coverage, adaptation to different environmental conditions and requirement as a staple food in Ethiopia, the yield of tef grain is low with an average grain yield of 1.2 t/ha (CSA, 2011).

Tef yields are almost stagnant probably because of the occurrence of accelerated soil erosion and lack of appropriate cultural practices on farmers' fields (Fufa *et al*., 2001). Lodging is an important factor threatening production and productivity of tef (Yu *et al.,* 2007) up to 22 % grain yield reduction and reduces straw quality (Seyfu, 1993), lodging restricts the use of high doses of nitrogen fertilizer (Tekalign *et al*., 2001).

Increasing agricultural productivity is absolutely necessary to feed the ever growing demography by enhancing land productivity. Improved tef varieties have been developed since the mid-1950s, only about 20 improved varieties have been released (Fufa et al. 2001).Tef is also valued for its fine straw, which is used for animal feed as well as mixed with mud for building purposes. Tareke (2008) found sowing tef with application of 46 kg N/ha^{-1}, 46 kg P_2O_5/ha, 32kg K_2O /ha,12kg S/ha and 0.3 kg Zn /ha provided a grain yield of up to 6 t /ha. However, this result has not been validated under farmers' fields.

The principal factors for low productivity of tef are: improper use of recommended fertilizer rates, lack of information on response of different varieties, non availability of genotypes suitable for this area and paucity of information on integrated nutrient management practices. Hence, the current study was made to evaluate the productivity response of tef varieties to integrated nutrient management practices, apart from working out nutrient removal, effect on soil fertility and economics of tef production on vertisols of mid high lands of Ethiopia.

MATERIALS AND METHODS

2.1 Description of the study area

The field experiment was conducted under rain fed condition during the main cropping season from July to December, 2014 at Guder located in the central high lands of west Shoa zone of Oromiya Regional state, Ethiopia. Guder is situated at 8°56'30"-8°59'30" N latitude and 37°47'30"-37°55'15" longitude the altitude of the area ranges from 1380-3030 *m.a.s.l,* characterized by warm temperate weather which is locally called *Bada-dare* (mid altitude). The temperature ranges from 15°C-29°C with an average of 22°C. It receives a mean annual rain fall ranging from 800-1000 mm with an average of 900 mm. The highest rainfall occurs from June to September, and the mean monthly relative humidity varies from 64.6% in August to 35.8% in December. The soil is clay loam in texture with good moisture holding capacity.

2.2. Seed material of the varieties

Four improved varieties of tef which are adapted to the agro- ecology of high lands were evaluated. The variety *Quncho* (*Dz-CR-387*), *Magna* (*DZ-01-196*) *Simada* (*DZ-CR-385)* and DZ-CR-409 were tested for their performance and compared with a local variety.

2.3 Soil and FYM analysis

The field selected for the study was analysed for initial soil nutrient status in terms of physical (Texture), Chemical parameters (PH, EC, O.C, available N, P, K,). The farm yard manure was analysed for available N, P, and K content before its application as an organic source. Auger samples were taken from 10 spots of the experimental area at a depth of 0-30cm and composite sample of approximately 1 kg soil was made separately before sowing. After crop harvesting, soil sample was taken from each plot and the same treatments from each block were composited and 1 kg soil sample was made for each treatment. The composited soil was air dried, ground and sieved through 2 mm mesh sieve before laboratory analysis. The analysis for specific soil parameters was carried out at the National Soil Laboratory. Soil colour was determined using the Munsell soil colour 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).Based on the oxidation of organic carbon with acid potassium dichromate, organic matter was determined using the Walkley and Black wet digestion method as described by Nelson and Sommers (1982), and total nitrogen was analyzed using the Kjeldhal method as described by Bremner and Mulvaney (1982). Available and total phosphorus were determined using the Olsen (NaHCO3) extraction method (Olsen and Sommer, 1982). Cation exchange capacity (CEC) of the soil was determined from ammonium-saturated sample that was subsequently replaced by sodium (Na) from a percolating sodium chloride solution. The excess salt was removed by washing with alcohol and the ammonium that was displaced by sodium was measured by Kjeldahl method (Chapman, 1965). Exchangeable K was determined with flame photometer (Chapman, 1965).

2.4. Layout of the experiment

After analysing the soil for chemical and physical parameters, land preparation with two times ploughing, harrowing and levelling were done to obtain a fine tilth. The field was then marked out into 90 plots of 3.2mX2.0m^2. After preparing the land the layout of the experiment was done as per the treatments randomly in factorial randomized block design with 3 replications. Farm yard manure was applied to the plots as per the treatments 20 days before application of inorganic fertilizer. Before seeding, inorganic fertilizer as per treatments was applied. Urea was top dressed 2 times, once before sowing as basal dose and the other 7 days after emergence.

2.5 Treatments and design

There were six nutrient management treatments and five varieties of tef. The experiment was laid out in 5x6 factorial randomized Complete Block Design with three replications.

Varieties of Tef:1. Magna (DZ-01-196) 2.Simada (DZ-Cr-385) 3. Quncho (Dz-Cr-387) 4.Dz –Cr -409) 5. Local variety.

Nutrient management practices:T_1 – 0 -0 -0 (check),T_2 – 40 -60 -0 NPK (RDF), T_3 – 50%RDF + 50% N (FYM), T_4 - 75%RDF + 25% N (FYM), T_5 – 100% RDF + 5t FYM/ ha., T_6 - RDF through new complex fertilizer (19 -38 – 7 NPS).The net plot size was 3.2m x 2.0m = 6.2m^2 . Sowing was done on 23 July 2015, adapting a row spacing of 20cm using a seed rate of 5Kg/ha^{-1}. The crop was harvested at physiological maturity in November 2014.

2.6 Data collection

2..6.1 Yield and yield components

The panicles from five randomly selected and tagged plants from the net plot at the time of harvest were used.

Panicle length (cm):-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 five selected plants per plot.

Panicle weight(g):-The average panicle weight of the main panicle at harvest was recorded from the average of five randomly selected pre-tagged plants from net plot.

1000 seed weight (g):- The weight of 1000 seeds was determined by carefully counting the grains and weighing them using a sensitive balance.

Grain yield (Kg/ha^{-1} -Grain yield was measured by harvesting the crop from the net plot area of 3.2 x 2 m to avoid border effects.

Straw yield (Kg/ha^{-1}:- After threshing and recording the grain yield, the straw yield was measured by drying the straw to a constant weight.

Statistical analysis

The crop data collected were subjected to analysis of variance (ANOVA) using SAS software program version 9.0 (SAS Institute, 2004). Significant differences among treatment means were separated using the least significant difference (LSD) at 5% level of probability (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

3.1 **Initial soil physico-chemical properties.**

The soil particle distribution has 2.5% Sand, 22.5% Silt and 75%Clay which can be classified as clay loam soil with better moisture holding capacity suitable for rising a successful crop of tef. The soil pH of the experimental field was 6.79 and neutral in reaction (Table 1). The organic matter and organic carbon content of 2.91 and 1.69%, respectively are considered to be medium (Krishnan, 2002, London, 1991).Total N of 0.12% which is low (London, 1991) ,available Phosphorous content of 12.8ppm which is medium; available Potassium content of 1.63 mg/100g of soil which is high (London, 1991) and Cation exchange capacity of 1.17mg/100g of soil which is very low (London, 1991).

Chemical Composition of farmyard manure (FYM)

The FYM used in the current study has organic matter content of (51.76g/kg^{-1}), Organic carbon content of 33.21g/kg^{-1}; Nitrogen (2.24g/kg^{-1}); Phosphorous (58.29mg/kg^{-1}) and exchangeable K content of 2.55cmol/kg^{-1}. (Table 1).

Table.1:-**The initial physico-chemical properties of the experimental soil and analysis of FYM**

Chemical property	**pH**	**OM (%)**	**O.C (%)**	**Total N (%)**	**Av.P (ppm)**	**Av.K (mg/100g)**	**CEC (mg/100g)**	**Physical Properties**	**Textural classification**
								Sand %, Silt % Clay %	Clay loam
Soil	6.97	2.91	1.69	0.12	12.8	163	1.17	2.5 22.5 75	
FYM	-	51.76	33.21	2.24	58.29	2.55	-		

3.2 Effective/productive tillers

Effective tillers are those bearing panicles that contribute to the grain yield. There was a decrease in the number of tillers at reproductive stage in comparison with those observed at vegetative stage owing mainly to mortality and variable source to sink relationships. The effective tillers followed a trend akin to the vegetative tillers in relation to the nutrient management practices ; in that integrated nutrient management had an edge (21 -23.4tillers) over exclusive application of inorganic fertilizer(16.4 tillers) or no fertilizer control (7.8tillers) in manifestation of tillering capacity. Enhancement in productive tillers due to application of nitrogen has also been reported by Al-Abdul Salam (1997) and Warraichet.al (2002). Tef varieties showed distinct variation in panicle bearing tillers where variety DZ-CR-387(20 tillers) remaining comparable with DZ-CR-385(19 tillers), DZ-01-196 and DZ-CR-409 produced greater number of tillers than local cultivar (17 tillers).Variation in productive tillers has also been reported by Belay and Baker (1996).

Significant interaction between varieties and nutrient management revealed that all the improved varieties exhibited significant improvement in effective tillers over local variety with the application of 75% RDF + 25% FYM (Table 2).Application of 100% RDF + 5t/ha FYM for all varieties produced higher number of effective tillers. The fertile tillers were significantly lower with RDF through inorganic fertilizer, which in turn was superior to unfertilized control.

Table 2.Interaction effect of genotype and fertilizer on fertile tillers

	T_1	T_2	T_3	T_4	T_5	T_6	Mean
DZ-01-196	9.1^{i}	14.1^{h}	22.0^{abcdef}	22.7^{abcde}	23.7^{abc}	22.1^{abcdef}	18.9
DZ-CR-385	7.2^{i}	18.7^{fg}	20.9^{bcdef}	22.7^{abcde}	24.7^{ab}	21.3^{abcdef}	19.2
DZ-CR-387	8.4^{i}	18.8^{fg}	22.3^{abcdef}	23.7^{abc}	24.9^{a}	20.8^{cdef}	19.8
DZ-CR-409	7.9^{i}	15.3^{gh}	20.8^{cdef}	23.4^{abc}	21.7^{abcdef}	23.1^{abcd}	18.6
Local Varity	6.5^{i}	15.5^{gh}	19.3^{cdef}	21.0^{bcdef}	22.1^{abcdef}	19.1^{efg}	17.2
Mean	7.8	16.4	21	25	25.8	21.2	18.7
LSD (5%) 3.8							
CV (%) 6.33							

Where, $\mathbf{T_1}$ = Control (0-0-0) ; $\mathbf{T_2}$ = RDF (40-60-0) ; $\mathbf{T_3}$ = 50% RDF + 50% FYM ; $\mathbf{T_4}$ = 75%RDF + 25% FYM ; $\mathbf{T_5}$ = 100%RDF + 5t/ha FYM and $\mathbf{T_6}$ = RDF NPS 23-10-5. Value within a column followed by the same letter is not significant different at LSD 5% probability level.

Table 3.Interaction effect of genotype and fertilizer on panicle length (cm)

	T_1	T_2	T_3	T_4	T_5	T_6	Mean
DZ-01-196	22.6^{h}	29.5^{bcdef}	32.9^{abcde}	33.9^{abcd}	35.8^{a}	35.7^{a}	31.7
DZ-CR-385	23.5^{gh}	28.6^{defg}	32.7^{abcde}	32.5^{abcde}	33.8^{abcd}	33.2^{abcde}	30.7
DZ-CR-387	24.1^{fgh}	32.8^{abcde}	34.7^{ab}	35.1^{a}	37.0^{a}	35.7^{a}	33.1
DZ-CR-409	23.9^{gh}	28.9^{cdefg}	34.0^{abcd}	36.1^{a}	37.2^{a}	34.4^{abc}	32.4
Local Varity	24.3^{fgh}	27.9^{efgh}	36.0^{a}	37.8^{a}	36.6^{a}	36.7^{a}	33.1
Mean	23.6	29.5	34	35	36	35.1	32.2
LSD (5%) 5.5							
CV (%)5.27							

Where, $\mathbf{T_1}$ = Control (0-0-0) ; $\mathbf{T_2}$ = RDF (40-60-0) ; $\mathbf{T_3}$ = 50% RDF + 50% FYM ; $\mathbf{T_4}$ = 75%RDF + 25% FYM ; $\mathbf{T_5}$ = 100%RDF + 5t/ha FYM AND $\mathbf{T_6}$ = RDF NPS 23-10-5. Value within a column followed by the same letter is not significant different at LSD 5% probability level.

3.3 Yield Components

3.3.1 Panicle length(cm).

Application of fertilizer either in organic or inorganic form (29.5cm) and their integrated application (35.0cm) brought about discernible variation in the length of panicle in comparison with unfertilized control (23.7cm) .Higher number of tillers in fertilized plots could also produce longer panicles due to less competition for sinks in comparison with unfertilized plots. This is in accordance with the reports that combined application of half dose of inorganic and half dose of organic source resulted in more panicle length apart from plant height and tiller production (Haftom *et.al,* 2009). Panicle length is an indicator of sink capacity which differed significantly with the varieties; where the varieties DZ-CR-387(33.2cm) remaining comparable with the local cultivar (33.2cm) and DZ-CR-409 (32.4cm) produced distinctly longer panicles than DZ-01-196 (31.7cm) and DZ-CR-385(30.7cm).Variation in panicle length among tef varieties was also reported by Belay and Baker (1996). Interaction of varieties with nutrient management practice was significant for panicle length (Table 3) where Tef varieties showed distinct improvement in length of panicle with integrated nutrient management and application of new complex fertilizer over RDF and unfertilized control. Application of RDF through inorganic source was superior to no fertilizer control in all varieties.

3.3.2 Panicle weight (g).

The panicle weight has been significantly higher with integrated use of inorganic fertilizer with organic manure (1.9g) as compared with sole application of inorganic nutrient (1.5g) or no fertilizer (1.1g) .This is in agreement with the finding of Tekalign *et.al.*, 2001. The panicle weight tended to be in accordance with the length of the panicle .Among the varieties, DZ-CR-387 possessed panicles of greater weight (1.72g), closely followed by local cultivar (1.68g) and DZ-CR-409(1.66g); while the lower panicle weight was obtained from DZ-CR-385(1.59g) and DZ-01-196(1.54g).These findings are in agreement with the report of Blum (1989) and Belay and Baker (1996). The panicle weight of all the varieties improved substantially with integrated nutrient management in comparison with application of RDF through inorganic source and no fertilizer check. The least panicle weight was recorded in all the varieties with no fertilizer (Table 4).

3.3.3 Thousand seed weight (g)

Application of fertilizer significantly improved thousand seed weight (0.318g) over no fertilization check (0.248g).Further, integration of inorganic fertilizer with farm yard manure in different proportions had a synergistic effect on thousand seed weight (0.337g-0.368g) in comparison with sole inorganic fertilizer or no fertilizer application. Improvement in thousand seed weight due to fertilizer application has also been reported by AL-Abdul Salam (1997). The tef varieties differed significantly in their thousand seed weight where DZ-CR-387 had superior thousand seed weight (0.33g) followed by DZ-CR-409(0.331g) and local cultivar (0.331g) which in turn were comparable. The variety DZ-CR-385(0.316g) was found superior to DZ-01-196 (0.309g) which gave the least thousand seed weight.

Table 4. Interaction effect of genotype and fertilizer on panicle weight (g)

	T_1	T_2	T_3	T_4	T_5	T_6	Mean
DZ-01-196	1.1^{ij}	1.3^{hij}	$1.8^{abcdefg}$	1.9^{abcde}	1.9^{abcd}	1.3^{ghij}	1.53
DZ-CR-385	1.1^{ij}	1.5^{efghi}	1.9^{abcde}	$1.8^{abcdefg}$	1.9^{abcd}	1.4^{fghij}	1.59
DZ-CR-387	1.1^{ij}	1.6^{cdefgh}	1.9^{abcde}	2.1^{a}	1.9^{abcde}	1.8^{abcdef}	1.71
DZ-CR-409	1.0^{j}	1.5^{defgh}	2.0^{abc}	1.9^{abcd}	2.0^{a}	1.5^{efghi}	1.66
Local Varity	1.3^{hij}	1.6^{cdefgh}	1.9^{abcd}	1.9^{abcde}	1.8^{abcdef}	$1.6^{bcdefgh}$	1.68
Mean	1.1	1.49	1.88	1.9	1.92	1.53	1.63
LSD (5%) 0.4							
CV (%) 8.07							

Where, $\mathbf{T_1}$ = Control (0-0-0) ; $\mathbf{T_2}$ = RDF (40-60-0) ; $\mathbf{T_3}$ = 50% RDF + 50% FYM ; $\mathbf{T_4}$ = 75%RDF + 25% FYM ; $\mathbf{T_5}$ = 100%RDF + 5t/ha FYM and $\mathbf{T_6}$ = RDF NPS 23-10-5. Value within a column followed by the same letter is not significant different at LSD 5% probability level.

Table5.Interaction effect of genotype and fertilizer on 1000 seed weight (g)

	T_1	T_2	T_3	T_4	T_5	T_6	Mean
DZ-01-196	0.22^{k}	0.28^{ghij}	0.28^{ghijk}	0.35^{abcdef}	0.35^{abcde}	0.38^{abc}	0.30
DZ-CR-385	0.28^{ghijk}	0.29^{fghi}	0.33^{bcdef}	0.32^{defgh}	0.38^{abcd}	0.29^{efghi}	0.31
DZ-CR-387	0.27^{hijk}	0.28^{ghij}	0.36^{abcd}	0.38^{abcd}	0.39^{ab}	0.35^{abcdef}	0.33
DZ-CR-409	0.25^{ijk}	0.35^{abcdef}	0.38^{abcd}	0.40^{a}	0.33^{cdefgh}	0.29^{ghi}	0.33
Local Varity	0.22^{jk}	0.40^{a}	0.33^{bcdefg}	0.37^{abcd}	0.39^{ab}	0.28^{ghijk}	0.33
Mean	0.24	0.31	0.33	0.36	0.36	0.31	0.32
LSD (5%) 0.06							
CV (%)5.7							

Where, $\mathbf{T_1}$ = Control (0-0-0); T2 = RDF (40-60-0); $\mathbf{T_3}$ = 50% RDF + 50% FYM; $\mathbf{T_4}$ = 75%RDF + 25% FYM; $\mathbf{T_5}$ = 100%RDF + 5t/ha FYM and $\mathbf{T_6}$ = RDF NPS 23-10-5. Value within a column followed by the same letter is not significant different at LSD 5%.

The interaction of varieties with nutrient management was significant on thousand seed weight of tef where DZ-CR-409 and DZ-CR-387 possessed higher thousand seed weight with 50% RDF + 50% FYM and 75% RDF + 25% FYM over RDF and unfertilized control(Table 5).The thousand seed weight of DZ- 01- 196, DZ-CR-385 and Local cultivar improved with 100% RDF + 5t FYM/ha^{-1}. All the varieties recorded least thousand seed weight with no fertilizer treatment.

3.3.4 Grain yield (kg/ha).

Application of 50% recommended dose of fertilizer through inorganic source and 50% through farmyard manure resulted in significant improvement in grain yield (1133kg/ha^{-1}) over no fertilizer check (619kg/ha). Application of RDF through complex fertilizer (866kg/ha^{-1});and remained comparable with 75% RDF through inorganic fertilizer + 25% N through farmyard manure (1300kg/ha^{-1}).Thus the superior performance of integrated nutrient management comprising 50%+ 50% through inorganic and farmyard manure of nutrients could be attributed to enhancement in various growth parameters and increased seed yield. In line with the present finding, at Holleta Research centre on Nitosols, incorporation of organic mustard meal @ 31kg/ha^{-1} 20 days ahead of sowing tef resulted in yield increase of 42, 32 and 25 % over control (Blesh et.al,2008).Improvement in yield due to fertilizer application has also been reported by Haftom et.al (2009), Al-Abdul Salam (2002) and Warriach *et.al.,* (2002), DZARC (1988) ,NFIU (1993) reported response of tef to 60kg N/ha^{-1} on high land Vertisols of Ethiopia. Kenea et.al (2001) reported that the recommended fertilizer for tef is 100kg DAP and 100kg urea/ha^{-1}.

Grain yield is a product of all the yield attributes and is the principal economic output of the crop. Tef varieties exhibited significant variations in the grain yields. Improved tef variety DZ-01-196(1172kg/ha^{-1}) remaining comparable with DZ-CR-409(1026kg/ha^{-1}) and local cultivar (1018Kg/ha^{-1}) offered substantially greater grain yield than DZ-CR-385(913Kg/ha) and DZ-CR-387(902Kg/ha) which in turn were comparable. In the present study, the lower yield of DZ-CR-385 and DZ-CR-387 could probably be attributed to genetic potential of varieties as compared to others. Differential performance tef varieties with varied grain yield was also reported by Kelsa (1999) on three tef varieties at Awassa and Areka areas of Ethiopia. Considerable genetic variability in grain yield and dry matter accumulation has been reported to exist between and within crop species (Blum, 1989).Belay and Baker (1996) also reported variation in biological yield of tef varieties.

There was significant interaction between varieties and nutrient management on grain yield of tef (Table 6)where DZ-01-196 yielded higher with 100% RDF + 5tFYM/ha^{-1}.(1644kg/ha^{-1}.) which was comparable with 75% RDF + 25%FYM (1626kg/ha^{-1}) and local variety fertilized with 75%RDF + 25%FYM (1442kg/ha^{-1}).The variety DZ-CR-409 yielded better with 50% RDF + 50%FYM (1300kg/ha^{-1}).Tef varieties DZ-CR-385 and DZ-CR-387 performed well with 75% RDF + 25% FYM application.

Table 6.Interaction effect of genotype and fertilizer on grain yield (kg/ha)

	T_1	T_2	T_3	T_4	T_5	T_6	Mean
DZ-01-196	659.0^{jkl}	893.7^{fghij}	1256.0^{bcd}	1626.0^{a}	1644.0^{a}	953.0^{efghi}	1171.8
DZ-CR-385	680.3^{ijkl}	758.3^{hijk}	985.3^{defgh}	1113.0^{cdefg}	1156.0^{cdef}	783.3^{hijk}	912.6
DZ-CR-387	447.7^{l}	945.0^{fghi}	1027.0^{cdefgh}	1167.0^{bcdef}	978.7^{defgh}	846.3^{ghij}	901.8
DZ-CR-409	749.0^{hijk}	965.7^{efgh}	1300.0^{b}	1157.0^{cdef}	1237.0^{bcde}	749.0^{hijk}	1025.8
Local Varity	560.0^{kl}	999.3^{defgh}	1100.0^{cdefg}	1442.0^{ab}	1008.0^{defgh}	999.7^{defgh}	1018.1
Mean	619	912.4	1133.6	1301	1204.2	866.2	1006.2
LSD (5%)281.5							
CV (%) 8.6							

Where, **T_1** = Control (0-0-0); T2 = RDF (40-60-0); **T_3** = 50% RDF + 50% FYM; **T_4** = 75%RDF + 25% FYM; **T_5** = 100%RDF + 5t/ha FYM AND **T_6** = RDF NPS 23-10-5. Value within a column followed by the same letter is not significant different at LSD 5% probability level.

Table 7.Interaction effect of genotype and fertilizer on straw yield (kg/ha)

	T_1	T_2	T_3	T_4	T_5	T_6	Mean
DZ-01-196	2790^{jk}	3205^{efghi}	3949^{c}	4771^{a}	4824^{a}	2810^{jk}	3724.7
DZ-CR-385	2834^{jk}	2980^{ghij}	3333^{ef}	3352^{e}	3955^{c}	2995^{fghij}	3241.4
DZ-CR-387	1139^{l}	3251^{efgh}	3440^{de}	4045^{bc}	3296^{efg}	3311^{efg}	3080.3
DZ-CR-409	2909^{hij}	3292^{efg}	4333^{b}	3841^{c}	3955^{c}	2904^{ij}	3538.9
Local Varity	2553^{k}	3332^{ef}	3771^{cd}	3930^{c}	3470^{de}	3342^{e}	3399.6
Mean	2444.9	3212.1	3764.9	3987.7	3899.8	3072.5	3397.03
LSD (5%) 342.9							
CV (%)3.18							

Where, **T_1** = Control (0-0-0); T2 = RDF (40-60-0); **T_3** = 50% RDF + 50% FYM; **T_4** = 75%RDF + 25% FYM; **T_5** = 100%RDF + 5t/ha FYM AND **T_6** = RDF NPS 23-10-5. Value within a column followed by the same letter is not significant different at LSD 5% probability level.

Table 8.Interaction effect of genotype and fertilizer on Harvest index of Tef

	T_1	T_2	T_3	T_4	T_5	T_6	Mean
DZ-01-196	23.62^{kl}	27.89^{fghij}	31.80^{bcde}	34.07^{b}	34.09^{b}	33.91^{bc}	30.89
DZ-CR-385	24.00^{kl}	25.44^{jk}	29.57^{efg}	33.19^{bcd}	29.21^{efgh}	26.15^{ghijk}	27.92
DZ-CR-387	39.31^{a}	29.06^{efghi}	29.84^{def}	28.85^{efghij}	29.69^{def}	25.55^{ijk}	30.38
DZ-CR-409	25.75^{hijk}	29.33^{efg}	30.34^{def}	30.12^{def}	31.20^{bcdef}	25.79^{hijk}	28.74
Local Varity	21.88^{l}	29.99^{def}	29.17^{efgh}	30.48^{cdef}	29.06^{efghi}	28.90^{efghij}	28.24
Mean	26.9	28.33	29.17	31.33	30.64	28.05	29.23
LSD (5%) 3.54							
CV (%) 3.7							

3.3.5 Straw yield (kg/ha).

Application of 75% recommended dose of fertilizer through inorganic source and substitution of 25% RDF with farm yard manure resulted in significantly higher straw yield (3988.6kg ha^{-1}) than other treatments . This was followed by RDF + 5t/ha FYM (3900.9kg ha^{-1}) and 50% RDF + 50% through FYM (3765 kg ha^{-1}).The least straw production was obtained from unfertilized control (2445.1kg ha^{-1}) and the RDF through new complex fertilizer (3073.1kg ha^{-1}). Thus integration of inorganic and farmyard manure had a beneficial effect on production of biological yield of tef in comparison with use of inorganic fertilizer alone or no fertilizer application. Tef variety DZ-01-196 gave significantly higher straw yield (3725kg ha^{-1}) over other varieties. This was followed by DZ-CR-409(3539kg ha^{-1}), local variety (3399kg ha^{-1}), DZ-CR-385(3241kg ha^{-1}) and DZ-CR-387 (3080kg ha^{-1}).

Significant interaction between varieties and nutrient management elucidated that the improved variety DZ-01- 196 produced higher straw yield of 4824kg/ha^{-1} with 100% RDF + 5t/ha FYM which was comparable with 75% RDF + 25%FYM (4771kg ha)(Table 13).The variety DZ-CR-409 and DZ-CR-385 gave higher straw yield with 50% RDF + 50% FYM(4333kg ha^{-1}) and (3955kg ha^{-1}), where as DZ-CR-387with 75% RDF + 25% FYM gave 4045kg ha^{-1}.(Table 7).

3.3.6 Harvest index

Harvest index of tef was significantly higher with 75% RDF + 25%FYM (31.3) which was comparable to 100% RDF + 5t/ha FYM(30.64) and superior to the rest of the fertilizer treatments. The second best treatment was 50% RDF + 50% FYM (30.14) which in turn was superior to RDF (28.34) and RDF through complex fertilizer(28.05).The least harvest index of 26.91 was recorded with unfertilized control. Among the tef varieties, DZ-01-196 gave the highest harvest index of 30.89 which was comparable with DZ-CR-387(30.38) and superior to the other varieties .Tef variety DZ-CR-409 remaining at a par with local variety (28.24) was found superior to DZ-CR-385(27.92).

Interaction of varieties of Tef with nutrient management practice on harvest index was significant (Table8) where Tef variety DZ-01-196 with integrated nutrient management practice produced significantly greater harvest index (34.09), which was comparable with DZ-CR-385 with 75% RDF + 25%FYM (33.19) and DZ-CR-409 with 100% RDF + 5t/ha FYM (31.20).There was distinct improvement of harvest index of local variety with fertilizer use (31.33) over no fertilizer (21.88).

Plant Nutrient content of Tef

4.1 NPK concentration

Nutrient Uptake is a product of Nutrient concentration X dry biomass weight (mg/plant) .The nutrient content of grain and straw were analysed and total uptake was calculated by adding uptake in grain and in straw and expressed in kg/ha (Table 9). The nutrient concentration in grain and straw varied distinctly. Integrated nutrient management treatments had greater N, P, and K content than RDF and Control apart from complex fertilizer. The nutrient content of grain was found to be greater than that of straw .

Table 9. NPK concentration in grain and straw of of tef in relation to genotypes and nutrient management.

	Grain			Straw		
Nutrient management	**N (g/kg)**	**P(g/kg)**	**K(g/kg)**	**N (g/kg)**	**P(g/kg)**	**K(g/kg)**
Control(0-0-0)	11.20	1.32	37.45	3.5	1.35	15.78
RDF(40-60-0)	13.89	3.93	47.83	4.4	1.59	27.66
50% RDF + 50%N FYM	15.00	5.33	57.80	6.5	1.70	30.75
75%RDF + 25% FYM	14.90	5.65	61.89	7.5	1.66	32.33
100%RDF +5t/ha FYM	15.70	6.32	66.33	7.3	1.69	33.45
RDF through complex fertilizer (23-10-5NPS)	12.80	4.11	44.86	5.3	1.50	27.15
Varieties						
DZ-01-196	12.90	4.36	48.12	5.7	1.65	33.21
DZ-CR-385	14.00	4.33	46.55	5.4	1.52	34.25
DZ-CR-387	14.00	3.98	43.11	5.8	1.58	35.45
DZ-CR-409	14.20	3.35	44.21	6.0	1.59	36.66
Local Varity	14.40	3.89	40.11	5.8	1.57	28.80

Application of 100% RDF + 5t ha-1 FYM and 75% RDF +25% FYM resulted in higher nutrient contents both in grain and straw than other treatments, while the least was recorded in unfertilized control (Table 9). The local variety of tef had higher N content followed by DZ-CR-409, while the least was found in DZ-01-196 .The P,K content of grain were higher in DZ-CR-385,DZ-CR-387,DZ-CR-409 and local variety than DZ-01-196.The N,P,K content of straw were less in DZ-CR-385 compared with the rest. The K content of straw was maximum in DZ-CR-409 and DZ-CR-387.

4.2 NPK uptake as influenced by Varieties and nutrient management.

N- uptake

The uptake of N by Tef varieties varied from 6.93kg/ha-1 to 19.90kg/ha-1 in grain (Table 10). Tef varieties (DZ-01-196) had higher uptake followed by local varieties. DZ-CR-409 which were superior to DZ-CR-385 and DZ-CR-387 which showed least uptake. The N uptake in grain as influenced by nutrient management showed that application of 75% RDF +25%FYM remaining equal to 100%RDF + 5t/ha-1 FYM showed higher uptake than 50%RDF + 50%FYM,RDF,RDF through complex fertilizer, while the least uptake was with no fertilizer(control). The N uptake in straw followed similar trend as that of grain uptake in relation to varieties and nutrient management, consequently the total uptake of N by the tef followed similar trend.

P- uptake

The uptake of Phosphorus in grain and straw differed with varieties and nutrient management. Tef varieties (DZ-01-196) closely followed by DZ-CR-409 and local variety had more uptake than DZ-CR-385 and DZ-CR-387.The uptake of P in straw also followed a trend akin to that of grain of tef varieties. The uptake of P in grain was higher with 75% RDF + 25%FYM and 100% RDF + 5t/ha FYM than 50% RDF + 50%FYM, RDF, RDF through complex fertilizer and control. The uptake of P in straw as well as total uptake exhibited a trend similar to that of uptake in grain in relation to nutrient management practices (Table 1o).

K- uptake

Tef varieties differed in K uptake in grain where in DZ-01-196 followed by DZ-CR-409 and local variety was superior to DZ-CR-385 and DZ-CR-387in K uptake. The K uptake in straw also exhibited similar trend as that of grain. Different nutrient management practices influenced the K uptake in grain and straw .The K uptake in grain was found more with 75% RDF +25%FYM and 100% RDF +5t/ha FYM than other treatments ,while least was with no fertilizer control. The uptake of K in straw as well as total removal also followed the path exhibited in grain uptake of K. The total uptake of K was observed to be least with unfertilized check (Table 10).

In conclusion, varieties DZ-01-196 and DZ-CR-409 exhibited greater uptake of N, P, K than other varieties, the least being with DZ-CR-387. Among nutrient management practices, application of 75% RDF + 25% FYM closely followed by50% RDF + 50% FYM resulted in greater uptake of N, P, K than other nutrient management practices, while least being with unfertilized control and RDF through complex fertilizer (Table 10).

4.3 Post- harvest soil NPK content

The dynamics of soil nutrients in relation to varieties and nutrient management practices has been presented in Table 11. Increase in soil N content with fertilizer application over initial N status was observed. Unfertilized plots recorded lower N content than fertilized plots. The enhancement in soil N content was spectacular in 75% RDF + 25% FYM (0.95%) and 100% RDF + 5t/ha FYM (0.94%) indicating beneficial effect of farmyard manure for increasing in total N concentration of soil. Adoption of INM practices increased soil available P concentration compared with initial soil status. Integrated nutrient management showed significant increase in P content in comparison with plots receiving no fertilizer and inorganic fertilizer. Dramatic increase in soil available K content after crop harvest compared with initial soli status was observed. The increase was more with integrated fertilization than with inorganic chemical fertilizer and control (Table 11).

With regards to genotype effect, there was an increase in soil N status compared with initial soil status. With all the improved genotypes the soil N status enhanced considerably (0.83%) compared with that in Local variety (0.68) owing to more removal in the former than the latter .There has been an increase in available P content compared with initial status and the increase was more with DZ-01-196 compared with the rest of the genotypes .The soil available K content after crop harvest was more with DZ-01-196(10.8) and DZ-CR-387(10.35) and the least was with Local variety (10.1) indicating genotypic variations in extraction of

Table 10. Uptake of NPK in grain and straw of tef as influenced by varieties and nutrient management practices.

	Grain			Straw			Total Grain & Straw		
	N(kg/ha)	P(kg/ha)	K(kg/ha)	N(kg/ha)	P(kg/ha)	K(kg/ha)	N(kg/ha)	P(kg/ha)	K(kg/ha)
Control(0-0-0)	6.93	2.02	23.18	8.53	3.30	38.58	15.46	5.32	61.76
RDF (40-60-0NPK)	12.67	3.58	43.64	14.13	5.10	88.84	26.8	8.68	132.48
50% RDF + 50%N FYM	17.00	6.04	65.51	24.47	6.40	115.77	41.47	12.44	181.28
75%RDF + 25% FYM	19.38	7.35	80.51	29.90	6.61	128.92	49.28	13.96	209.43
100%RDF +5t/ha FYM	19.90	7.60	79.87	28.46	6.59	130.45	48.36	14.19	210.32
RDF through complex fertilizer (23-10-5NPS)	11.08	3.56	52.57	16.28	4.60	83.41	27.36	8.16	135.98
Genotypes									
DZ-01-196	15.11	5.10	56.39	21.23	6.14	123.69	36.34	11.24	180.08
DZ-CR-385	12.77	3.95	42.48	17.50	4.92	111.02	30.27	8.87	153.42
DZ-CR-387	12.62	3.58	38.80	17.86	4.86	109.10	30.48	8.44	147.9
DZ-CR-409	14.56	3.43	45.35	21.23	5.62	129.73	35.79	9.05	175.08
Local Varity	14.66	3.96	40.83	19.71	5.33	97.90	34.37	9.29	138.73

Table 11. Post- harvest soil NPK concentration as influenced by tef genotypes and nutrient management practices.

Nutrient management	N (%)	Ava.P(mg/g)	Ava.K(mg/g)
Control(0-0-0)	0.502	1.350	7.420
RDF (40-60-0NPK)	0.812	1.597	10.34
50% RDF + 50%N FYM	0.904	1.693	11.66
75%RDF + 25% FYM	0.950	1.664	12.24
100%RDF +5t/ha FYM	0.944	1.698	13.02
RDF through complex fertilizer (23-10-5NPS)	0.594	1.502	7.38
Genotypes			
DZ-01-196	0.7967	1.654	10.8
DZ-CR-385	0.7967	1.526	10.17
DZ-CR-387	0.8117	1.582	10.35
DZ-CR-409	0.8333	1.583	10.22
Local Varity	0.6833	1.575	10.18
Initial status	0.12	0.012mg/g	1.63mg/100g

Table12. Economics of tef production in relation to nutrient management practices.

Treatments	Total variable cost (EB ha)	Grain yield (kg ha)	Gross return (EBha)	Net return (EB ha)	MRR (%)	Benefit: cost ratio	Return/birr investment
Control(0-0-0)	0	619.2	8978.4	8978.4	----	------	--------
RDF through complex fertilizer NPS 23-10-5	870	912.4	12560.9	11690.9	312	8.45	7.45
50% RDF + 50% FYM	1532.50	1133.53	16436.1	14903.6	485	10.72	9.72
75%RDF + 25% FYM	1548.75	1300.93	18863.4	17314.7	1439	12.17	11.17
RDF (40-60-0)	1565	1204.2	13229.8	11664.80	25452.58	5.69	4.69
100% RDF + 5t/ha FYM	3065	866.27	17460.9	14395.9	10043.05	14.43	13.43

Cost of Tef grain1450 EBkg^{-1},d=dominated, Cost of Urea 740 EBkg^{-1},Cost of DAP 880 EBKG^{-1},FYM preparation cost 850 EBkg^{-1},Fertlizer application cost 1000 EBkg^{-1},Grain yield adjusted vat 10%.

soil nutrient and residual nutrient balances left in the soil (Table11).

Economic analysis

The economic analysis of tef in relation to nutrient management practices is presented in Table 12. The total variable cost ranged between 870 ETB to 1565 ETB/ha^{-1},The gross return oscillated between 8978 ETB and 18863 ETB/ha^{-1}different treatments. Application of 75% RDF + 25%FYM offered net return of 17314 ETB /ha^{-1} followed closely by 50% RDF + 50% FYM(14903ETB/ha^{-1}) and 100% RDF + 5t/ha FYM (14395ETB/ha^{-1}.) which were substantially greater than the rest of the fertilizer treatments(Table 12). The least net return of 8978 ETB/ha^{-1} was received from unfertilized control, elucidating the importance of integrated nutrient management in enhancing the net return. The application of RDF through complex fertilizer did not offer additional monetary return in comparison with RDF. The higher marginal rate of return (MRR) was obtained with application of 75% RDF + 25%FYM followed by application of 50% RDF + 50%FYM(485%) for tef production.

CONCLUSION

Field experiment was carried out during 2014 main cropping season from July to November with five varieties (DZ-01-196,DZ-CR-385,DZ-CR-387,DZ-CR-409,and local) and six levels of integrated nutrient management practices(Control(0-0-0),RDF(40-60-0,50%RDF+50%FYM,75%RDF+25%FYM,100%RDF + 5t/ha^{-1} FYM and RDF through complex fertilizer 23-10-5 NPS)with 3 replications.The results revealed that all the tef varieties showed distinct improvement in length of panicle with integrated nutrient management and application of new complex fertilizer over RDF and unfertilized plot. DZ-CR-385 and DZ-01-196 recorded lower panicle weight and significantly increased thousand seed weight over no fertilizer check. Integration of inorganic fertilizer with farm yard manure in different proportions had synergistic effect on thousand of seed weight of tef compared with sole inorganic fertilizer and unfertilized plot.

Application of 50% RDF +50%FYM resulted in improvement in grain productivity over unfertilized check and RDF through inorganic fertilizer and remained comparable with 75%RDF + 25% FYM. Integrated nutrient management with 50% RDF + 50% FYM enhanced effective tillers, panicle length, panicle weight, and thousand seed weight ultimately increasing seed yield. Application of 75% recommended dose of fertilizer through inorganic source and 25% farm yard manure resulted in significantly higher straw yield than other treatments closely followed by 100% RDF + 5t/ha FYM and 50%

RDF + 50%FYM. Harvest index was significantly higher with 75%RDF +25%FYM and 100% RDF +5t/ha FYM. The nutrient content of grain was found to be greater than that of straw. Application of 100%RDF +5t/ha^{-1} FYM and 75%RDF +25%FYM analysed higher content of NPK both in grain and straw than other treatments, ultimately resulting in greater nutrient removal than with inorganic fertilizer alone and no fertilizer check . The- post harvest available NPK content of soil in comparison with initial status was found to be higher with INM than no fertilizer and inorganic fertilizer treatments. Economic analysis showed that higher MRR, Benefit: cost ratio and return /Birr investment were accrued with 100%RDF+5t/ha FYM and 75%RDF+25%FYM when compared with inorganic fertilizer and no fertilizer check.

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REFERENCES

Abuhay Takele. (1997) Genetic variability in dry matter production, partitioning and grain yield oftef [Eragrostistef (zucc) Trotter] under moisture deficit. SINET: Ethiopi. J. Sci. 20: 177-188.

Al–Abdul Salam MA (1997) Influence of nitrogen fertilization rates and residual effect of organic manure rates on the growth and yield of wheat. Arab Gulf J. Sci. Res., 15: 647–60.

Balesh T, BerntAune J, Breland T (2007) Availability of organic nutrient sources and their effects on yield and nutrient recovery of tef [*Eragrostistef*(Zucc.) Trotter] and on soil Properties.*Journal of Plant Nutrition and Soil Science. 170:* 543–550.

Belay Shiferaw, Baker DB (1996) Agronomy and Morphological response of tef to drought .Trop.sci.36: 41-50.

Blum (1989) considerable genetic variation in grain yield and dry matter accumulation exist between and within in crop species.

Brady NC, Weil RR (2002) The Nature and Properties of Soils. 13th ed. Person Education Ltd, USA.pp:621 .

Central Statistic Authority (2008) Agricultural Sample Survey 2007/2008 (Vol.1). Report on area and production for major crops (private peasant holdings Meher season) Statistical Bulletin 417, Addis Ababa.

Day PR (1965) Hydrometer method of particle size analysis. In: Back CA (ed.),Method of Soil Analysis. Amer. Soc. Agron. Madison, Wisconsm .Agron. No 9, Part 2. Pp: 562.

DzARC (Debrezeit Agricultural Research Center). (1988) Annual research report for 1987/88.Debrezeit, Ethiopia, p. 147.

Fufa Hundera, Tesfa Bogale, Hailu Tefera, Kebebew Assefa, Tiruneh Kefyalew, Abera Debelo and Seyfu Ketema. (2001) Agronomy Research in tef. *In*: Hailu Tefera, Getachew Belay and M. Sorrels (eds.), *Narrowing the Rift:* Tef Research and Development, Proceedings of the International Workshop on Tef Genetics and Improvement, 16-19 October, 2000. Addis Ababa, Ethiopia, pp: 167-176.

Haftom Gebretsadik, Mitiku Haile, Yamoah CH. (2009) Tillage frequency, soil compaction and N-fertilizer rate effects on yield of tef (*Eragrostis tef (Zucc.) Trotter). Ethiopia Journal of Science* 1(1): 82-94.

Hailu Tefera, Seyfu Ketema. (1990) Variability and genetic advance in tef *(Eragrostis tef) cultivars*. *Tropical Agriculture* (Trinidad) 67:317-320.

Kelsa Kena. (1998) Effect of DAP and Urea fertilizers on grain yield of three tef varieties in Awassa and Areka. In: Tadele G/Selasssie and SahlemedhinSertsu (eds.).Proceedings of the Fourth Conference of the Ethiopian Society of Soil Science. Feb. 26-28, 1998, Addis Ababa, Ethiopia, pp: 122-127.

Kenea Yadeta, Getachew Ayele, Workneh Negatu. (2001) Farming Research on Tef: Small Holders Production Practices. *In*: Hailu Tefera, Getachew Belay and M. Sorrels (eds.), *Narrowing the Rift: Tef Research and Development.Proceeding* of the International Work shop on tef genetics and improvement, 16-19 October, 2000, Addis Ababa, Ethiopia.

Landon JR (1991) Booker Tropical Soil Manual: A Handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and Sub-tropics. Longman Scientific and Technical, Essex, New York. pp: 474 .

Mitiku H Fassil K (1996) Soil and moisture conservation in Semi-arid areas of Ethiopia. In: Proceedings of the Third Conference of Ethiopian Soil Science Society (ESSS). February 28-29, 1996, Addis Ababa, Ethiopia.

Mulat Demeke (1999) Agricultural Technology, Economic Viability and Poverty Alleviation in Ethiopia, Paper presented to the Agricultural Transformation Policy Workshop, 27-30 June,1999, Nairobi, Kenya.

Miller R.W, Donahue RL (1995) Soils In Our Environment. 7th ed. Prentice-Hall Englewood Cliffs, New Jersey, USA.

National Academy of Sciences. (1996) Lost crops of Africa Volume 1, Grains. Bostid NationalResearch Council. National Academy Press. Washington, D.C, USA.

NFIU (National Fertilizer and Input Unit) (1993) Agronomic feasibility of the proposed recommendation and comparison with the previous recommendation. NFIU general paper No.17. Addis Ababa.

Nelson D W, Sommers L E (1982) Total carbon, organic carbon and organic matter. In: A. L. Page R H,. Miller, Keeney DR (eds). Methods of Soil Analysis.Part 2.Agronomy 9, (2nd edn). pp. 539-579. American Society of Agronomy, Madison, USA.

Olsen S and Sommer L (1982) Phosphorus method for soil analysis; part 2.Chemical and microbiological properties. ASA Monograph number 9:403 – 430.

Piccinin Doris (2010) "More About Ethiopian Food: Teff." Ethno Med:Ethiopian food.Online. ternet.available<http://ethnomed.org/ethnomed/cultures/ethiop/teff.html> (2 Sept. 2010)

SAS Institute. (2004) JMP 5.1.1 *Users Guide*. SAS Institute Inc. Cary, NC, USA.

Steel RGD, Torrie JH (1984) Principles and Procedures of Statistics. McGraw Hill Book Co., Inc. Singapore.

Seyfu Ketema. (1993) Tef [*Eragrostis tef (Zucc.)*Trotter].Breeding, Genetic Resources, Agronomy, Utilization and Role in Ethiopian Agriculture. Institute of Agricultural Research, Addis Ababa, Ethiopia.

Seyfu Ketema. (1997) Tef [*Eragrostis tef* (Zucc.) Trotter]. Promoting the conservation and use of underutilized and neglected crops. Biodiversity institute, Addis Ababa, Ethiopia.

Tekalign Mamo. (1998) Effect of source, rate and timing of nitrogen applied to wheat on soil N level in a vertisol in central highland of Ethiopia. In: Crop Management Options to sustain Food Security. Pp: 85-100.

Tekalign Mammo, Teklu Erkossa and Balesh Tulema. (2001) Soil Fertility and Plant NutritionResearch on Tef in Ethiopia. pp. 199-200. *In:* Hailu Tefera, Getachew Belay and Mark Sorrels (eds.) *Narrowing the Rift. Tef Research and Development*, Proceedings of the International Workshop on Tef Genetics and Improvement, 16-19 October, 2000. Addis Ababa, Ethiopia, pp: 167-176.

Tareke Berhe, (2008) Increasing Productivity of Tef, *Eragrostistef*(Zucc.) Trotter: New Approaches with Dramatic results (Unpublished Report), Addis Ababa, Ethiopia.

UNDP (2002) UNDP assistance in the fifth country program to the agricultural sector.

Van Reeuwijk LP (1992) *Procedures for soil analysis* (3rd ed.). International soil reference and information center, Wageningen (ISRIC).

Warraich, EA, Ahmad, NSMA Basra, and Afzal I (2002) Effect of nitrogen on source–sinkrelationship in wheat. Int. *Journal. Agri. Biol*. 4: 300–302.

Yihenew G. (2002) Selected chemical and physical characteristics of soils of Adet Research Centre and its testing sites in north western Ethiopia*. Ethiopian Journal of Natural Resources, 4*(2): 199-215.

Yu JK, Graznak E, Breseghello F, Hailu Tefera, Sorrells ME. (2007) QTL mapping of agronomic traits in tef [Eragrostistef (Zucc) Trotter]. BMC Plant Biol. 7: 13.