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Grain Yield, Nitrogen Use Efficiency and Economic Benefits of Tef [Eragrostis tef (Zucc.) Trotter] Production as Influenced by Nitrogen Split Application Timing in Central Highlands of Ethiopia

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Abstract
Tef [Eragrostis tef (Zucc.) Trotter] is among the major cereals of Ethiopia and occupies the largest cultivated land more than any other cereals. This experiment was initiated to evaluate the appropriate nitrogen fertilizer split application timing for Quncho tef variety. The experiment was done at Holeta Agricultural Research center, West Shoa, Ethiopia. The split nitrogen application times involved in the study were 1/2 at sowing + 1/2 at mid tillering, 1/2 at sowing +1/2 at anthesis, nil at sowing + 1/2 mid tillering + 1/2 at anthesis, nil at sowing + full at mid tillering, nil at sowing + full at anthesis, 1/3 at sowing + 2/3 at mid tillering, 1/3 at sowing + 1/3 mid tillering + 1/3 at anthesis, nil at sowing + 1/3 mid tillering + 2/3 at anthesis, 2/3 at sowing + 1/3 mid tillering, 2/3 at sowing + 1/3 at anthesis, full at sowing and negative control. The experimental design used was completely randomized block design with three replications. Yield and yield components of tef crop studied includes Grain and biomass yields, plant height, panicle length and Harvest index. Timing of nitrogen fertilizer application has significant effect on yield and yield components of tef. Timing of nitrogen fertilizer 1/3 at sowing + 2/3 at mid tillering gave the highest tef plant height, panicle length, biomass yield, grain yield and harvest index compared with other nitrogen timing. It also gives the height Agronomic Nitrogen Use Efficiency and highest economic return.
Keywords: Split application timing, Nitrogen fertilizer, Grain yield, Nitisols, Tef

1. Introduction

Teff *[Eragrostis teff (zucc) Trotter]* is a cereal crop that belongs to the family Poaceae, sub family Eragrostidae, tribe Eragorsteae and genus Eragrostis. It is a self pollinated annual cereal (Seyfu, 1993) and is indigenous to Ethiopia (Vavilov, 1951). Ethiopia is the origin and the first domesticator of this unique crop (Vavilov, 1951). Also, it is thought to have been spread to Europe through the Portuguese contact in the 16th century (Taddesse, 1975). According to Costanza *et al*. (1979) tef was distributed to several countries in the 19th century, and now it is cultivated as a forage grass in Australia, India, Kenya, and South Africa.

In Ethiopia, tef is primarily grown for its grain that is used for preparing *injera* (Abel, 2005), which is a staple and very popular food in the national diet of most Ethiopians. It can also be used in many other food products such as *kitta* (unleavened bread), *anebaberro* (double layered injera), porridge, and local alcoholic beverages such as *tella* and *katikala* (Asrat and Frew, 2001; Hailu *et al*., 2003; Seyfu, 1993). Tef grains and flour do not contain gluten (Spaenij-Dekking *et al*., 2005) and are rich in minerals, especially iron (Yewlsew *et al*., 2007). These two characteristics make tef flour a desirable ingredient in health products. Tef grain contains 14-15% proteins, 11-33 mg iron, and 100-150 mg calcium and is rich potassium and phosphorous (National Academy of sciences, 1996). Furthermore, Asrat and Frew (2001) reported that the carbohydrate content of tef ranges from 72.1-75.2%, protein 8.1-11.1% and ash 2.5-3.2%; the major component of ash being iron.

Tef production has been increasing from year to year and so does the demand for it as staple grain in both rural and urban areas of Ethiopia (Mitiku, 2008). Although tef is found in almost all cereal growing areas of Ethiopia, the major areas of production are Shewa, Gojam, Gonder, Wellega and Wello with central highlands of the country (Doris-Piccinin, 2010). It occupies about 3 million hectares (24.02% of the grain crop area) of land which is more than any other major cereals such as maize (16.8%), sorghum (14.58%) and wheat (13.25%) (CSA, 2014). Despite the fact that tef has widely grown under a wide range of altitudes (300 to 2800m above sea level), climate conditions, and soil types including which are marginal to most other crops (Seyfu, 1997; Hailu and Seyfu, 2001), the average grain yield in Ethiopia according to the central statistic agency (CSA, 2014) is about 15.75Q ha^{-1}. This average tef grain yield is low compared to other cereals, which is attributed to nutrient limitations, drought and water logging (Tulema *et al.,* 2005). By improving management practices and using improved cultivars, however, tef can yields up to 2500 kg ha^{-1} (Tefera and Belay 2006), while the yield potential under optimal management and when lodging is prevented, is as high as 4500 kg ha^{-1} (Teklu and Tefera 2005). Lower tef grain yield is mainly attributed to low soil fertility, especially, nitrogen and phosphorus deficiencies (Fassil and Charles, 2009).

Nitrogen (N) is one of the most yield-limiting nutrients for crop production in the world. It is also the nutrient element applied in the largest quantity for most annual crops (Huber and Thompson, 2007). Its contribution for the grain yield and biomass yield productivity is well known. For environmental and economic reasons, nitrogen fertilizers should be utilized as efficiently as possible in agriculture. The nitrogen use efficiency of plant depends on several factors including application time, application rate of nitrogen fertilizer, cultivar and climatic conditions (Okamoto and Okada, 2004). The management of the time of nitrogen application is essential to ensure sustained nutrition at the end of vegetative growth. Therefore, the total amount of N should be divided into suitable fractions to be applied to best satisfy the requirement of the growing tef crop. The aim is to avoid increasing early vegetative growth and to encourage the development of the upper most green parts to directly involved in grain formation. Too late application, may lead to N starvation whereas too early supply may also increase tillering and vegetative density. On completion of tillering phase and at the onset of stem elongation it is important to eliminate any possibility of nitrogen starvation by applying the fertilizer in such a way that it can make tiller vigour, enables a high proportion of tillers to produce ears and extensive development of uppermost green tissue, good ear fertility and sufficient filling of the grain.

In simple terms, efficiency is ratio of output (economic yield) to input (fertilizers) for a process or complex system. Commonly used practice to improving the N use efficiency of crops are split application of fertilizers, selection of crop growth environment (soil type and climate), management practices (sowing date and rate of N application), and crop breeding. Obtaining a high N-use efficiency generally requires splitting the N between a starter-band application and a side/top-dress application. Delaying nitrogen application for 4 to 6 weeks after planting will avoid early season nitrogen losses by leaching and volatilization and provide available fertilizer nitrogen to the crop when it needs it most. The timing of side/top-dress nitrogen applications is critical. Crop yields are more often limited by inadequate supplies of nitrogen than by deficiencies of other essential nutrients. This is because losses of applied nitrogen can occur during the growing season by leaching, denitrification, or volatilization. Farmers in Ethiopian highlands apply N fertilizer in the form of urea at sub-optimal blanket rates mostly only once at the time of sowing, and this limits the potential productivity of cereal crops (Bekele *et al*. 2000). Thus, it is important to determine plant nitrogen requirements and to use effective management practices to minimize losses of applied nitrogen. Timing of nitrogen fertilizer application is an important factor affecting the efficiency of fertilizer nitrogen, because the time interval between application and crop uptake determines the length of exposure of the fertilizer nitrogen to loss processes such as volatilization, denitrification and leaching (De Datta and Patrick, 1986; IRRI, 1990). So, this research was designed to determine the appropriate application time of nitrogen fertilizer for tef crop in central high-lands of Ethiopia.

2. Materials and Methods

2.1 Study area

The experiment was conducted for two years (2015 and 2016 main cropping seasons) at Holeta, West Shoa, in the central high lands of Ethiopia. Holeta is located between 09^0 03' N latitude and, 38^0 30' E longitude, 30 km west of Addis Ababa, at an altitude of about 2400m above sea level. The long-term average annual rainfall of the area is 1100 mm. The average minimum and maximum air temperatures are 6.20^0c and 22.1^0c respectively. The environment is seasonally humid and the soil type was Eutric Nitisol. The soil of the area is slightly acidic with low total nitrogen content and medium available P and less organic matter content.

2.2 Design, treatments and data analysis

The experiment was carried out during the main rainy season of two years (2015-2016) to determine the appropriate application time of nitrogen fertilizer for tef crop in central high-lands of Ethiopia. The experimental plot size was $5m^2$. The tef variety named Quncho (DZ-Cr-387-RIL 355), which was developed and released by Debrzeit Agricultural Research Centre in 2006 was used for the experiment. Quncho is a high yielding white-seeded cultivar adapted to a wide range of altitudes (MoARD, 2008). Recommended Nitrogen and Phosphorous fertilizers were used for the trial in which, triple-super phosphate (TSP) was used as a source of phosphorus fertilizer applied at planting time and Urea as a source of Nitrogen fertilizer using split-application as stated in treatments. Design of the experiment was RCBD with three replication. The treatments tasted were eleven different times of nitrogen fertilizer application in which T_1 = 1/2 at sowing + 1/2 at mid tillering, T_2 = 1/2 at sowing + 1/2 at anthesis, T_3 = nil at sowing + 1/2 at mid tillering + 1/2 at anthesis, T_4 = nil at sowing + full at mid tillering, T_5 = nil at sowing + full at anthesis, T_6 = 1/3 at sowing + 2/3 at mid tillering, T_7 = 1/3 at sowing + 1/3 mid tillering + 1/3 at anthesis, T_8 = nil at sowing + 1/3 mid tillering + 2/3 at anthesis, T_9 = 2/3 at sowing + 1/3 mid tillering, T_{10} = 2/3 at sowing + 1/3 at anthesis, T_{11} = full at sowing and T_{12} = negative control (No input)). The same rate of N, 60 N kg ha-1, was splitted and used in all cases. All recommended cultural practices were adopted to manage the experimental field. All the data were subjected to analysis of variance (ANOVA) using the GLM procedure of SAS. The LSD test was used to separate significantly differing treatment means after they were found significant at $P \leq 0.05$. Economic analysis was performed to investigate the economic feasibility of the time of N applications following the CIMMYT partial budget methodology (CIMMYT, 1988). The average open current market price (Birr 20 kg-1) for tef and the official prices of N and P fertilizers were used for economic analysis. The prevailing labor cost for sowing, weeding and harvesting for the area in Ethiopian Birr 30 per man day was assumed as total variable cost for the economic analysis. Agronomic Nitrogen Use Efficiency (NUE) was calculated as extra kilogram of grain per extra kilogram of N applied (Hatfield and Prueger, 2004).

3. RESULTS AND DISCUSSION

3.1 Weather

The total rainfall amount and precipitation pattern for 2016 was significantly higher compared with long-term average and 2015 (Figure 1). The rainfall amounts recorded for July and September were considerably higher in 2016 than in 2015. When compared with a 30 year average, rainfall in July 2016 was higher by 70 mm but lower by 167 mm in 2015. Rainfall in September 2016 and 2015 was lower by 9 and 69 mm, when compared with a 30 year average, respectively. Which entails average moisture received in 2016 was conducive for tef growth and development. On the contrary, since rainfall received in 2015 was much lower it was not suitable for growth and development of tef relatively. Moisture deficiency in July seriously affects tillering while in September and October it critically affects grain filling.

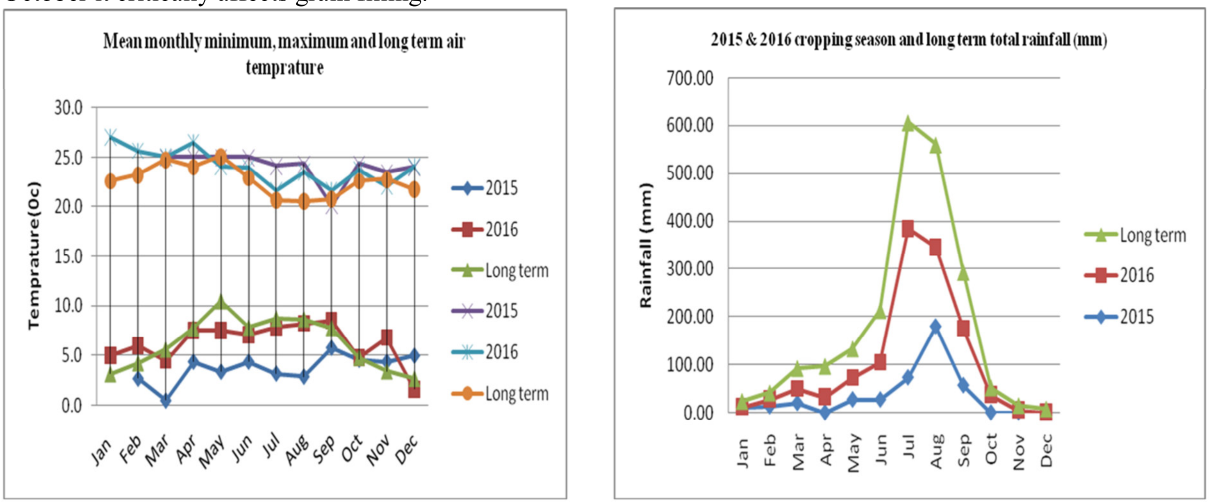

Figure 1. Mean monthly maximum, minimum air temperatures and monthly total rainfall for 2015 and 2016 cropping seasons, and the 30-year average rainfall at Holeta Research Center.

3.2 Yield and yield components

3.2.1 Plant height and Panicle length

The analysis of variance showed that plant height was affected highly significantly (P< 0.01) by timing of nitrogen fertilizer application (Table 1). Out of the tasted treatments split application of nitrogen fertilizer 1/3 at planting and 2/3 at stem elongation stage gives the tallest plant height (69.13cm) followed by split application of nitrogen fertilizer 1/2 at planting and 1/2 at stem elongation stage (67.2cm) as indicated in table 2. While the smallest plants were recorded at zero level of nitrogen (45.4cm). Panicle length was also highly significantly (P< 0.01) affected by timing of nitrogen fertilizer application (Table 1). Out of the tasted treatments split application of nitrogen fertilizer 1/3 at planting and 2/3 at stem elongation stage gives the tallest panicle length (37.06cm) followed by split application of nitrogen fertilizer 1/2 at planting and 1/2 at stem elongation stage (32.56cm). While the smallest panicle length of plants (14.4cm) were recorded at zero level of nitrogen (Table 2). This is because of N fertilizer has plays vital role in vegetative growth and resulted for significant influence on plant height (Haftom *et al,;* 2009) and panicle length in the same way. But non optimal application of N, resulted in significantly reduction on heights (Zewdu *et al,;* 1992: Alcoz *et al,;*1993) and in the same way on panicle length.

3.2.2 Biomass yield

The analysis of variance revealed that biomass yield of tef was highly significantly (P<0.01) influenced by time of nitrogen fertilizer application (Table 1). Out of the tasted treatments split application of nitrogen fertilizer 1/3 at planting and 2/3 at stem elongation stage gives the highest biomass yield (7038.9 kg/ha) followed by split application of nitrogen fertilizer 1/2 at planting and 1/2 at stem elongation stage (6363 kg/ha). While the smallest biomass yield (1169.6 kg/ha) were recorded at zero level of nitrogen (Table 2).

3.2.3.Grain yield

The analysis of variance indicated that grain yield of tef was highly significantly (P<0.01) influenced by time of nitrogen fertilizer application (Table 1). Out of the tasted treatments split application of nitrogen fertilizer 1/3 at planting and 2/3 at stem elongation stage gives the highest grain yield (2451.68 kg/ha) followed by split application of nitrogen fertilizer 2/3 at planting and 1/3 at stem elongation stage (2022.87kg/ha) which is statistically not different with a yield (1974.54kg/ha) recorded by application of nitrogen fertilizer 1/2 at planting and 1/2 at stem elongation (Table 2). While the smallest grain yield were recorded at zero level of nitrogen (188.7 kg/ha). Temesgen (2001) also reported that application of different levels of N significantly affected grain yield of tef on farmer's field. Other Investigetors (Shiferaw and Tewdroa, 2016) also reported that split apploication of Nitrogen fertilizer half at sowing and half at planting gave high tef grain yield than non splitting N fertilizer.

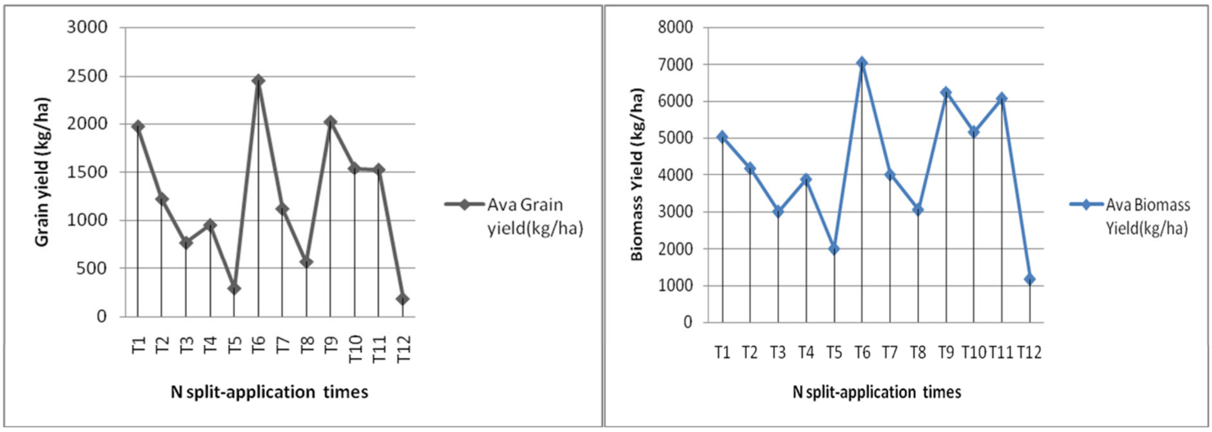

Fig 2: Effect of Nitrogen split-application time difference on grain and biomass yield of tef.

3.2.4 Harvest index

Statistical ANOVA revealed that time of nitrogen application was highly significant ($P < 0.001$) in affecting tef harvest index (the ratio of the economic yield to the biological yield) based on this study data (Table 1). Significantly greater harvest index (0.34) was obtained with the application of 1/3 at planting + 2/3 at mid tillering but the lowest harvest index (0.15) was recorded with the application of nil nitrogen at sowing and full application of nitrogen at anthesis stage (Table 2).

3.3 Economic analysis

Nitrogen split-application was also observed to be economically advantageous. The economic analysis revealed that N fertilizer application 1/3 at sowing + 2/3 at mid tillering was the appropriate time of N application due to the fact that it gave the highest net economic benefit of 37904.4 Birr/ha than application of 1/2 at sowing + 1/2 at mid tillering (29554.28 Birr/ha) which is the usual practice for tef crop in the study area (Table 3). Based on the analysis application of 1/3 N at sowing + 2/3 at mid tillering was more economically beneficial than other split-applications studied (Table 3).

3.4 Nitrogen Use Efficiency

Nitrogen Use Efficiency is explained as grain production per unit of N applied. Nitrogen fertilizer applications that exceed crop N requirement lead to environmental pollution including nitrate Nitrogen leaching and Nitrogen gaseous emissions. As a result, it is so essential to determine the plant response to N fertilization. Splitted N applications might have decreased the loss of N applied at due to denitrification, leaching and runoff and improved the agronomic NUE. Based on this research work (Table 4) tef had the highest NUE when the Nitrogen was applied in split of 1/3 at sowing + 2/3 at mid tillering. Similar to this finding, numerous reports indicate increase in NUE with split N applications. Since leaching is one of the main challenges for N loss in especially in high rainfall areas (Chikowo, et al., 2004; Fageria and Baligar, 2005; Ali, 2010).

4. CONCLUSION AND RECOMMENDATIONS

Tef is among the major cereals and is an indigenous cereal crop to Ethiopia. Ethiopian farmers grow tef for a number of merits, which mainly attributed to the socio-economic, cultural and agronomic benefits. Both its grain and straw obtain relatively higher price than other cereal crops. Tef has got many prospects outside Ethiopia due to its gluten-free grains, tolerance to biotic and abiotic stresses, animal feed value and erosion control quality. Regardless of its high area coverage, adaptation to different environmental conditions and importance as a staple food in Ethiopia, the yield of tef grain is relatively low as compared to other major cereals. Its low productivity may be attributed due to several production problems like growing on marginal soils which are old method of cultural practices, low application of fertilizers, and soil-related constraints.

This research work was designed to determine appropriate Nitrogen split application time for optimum tef yield production on high-land areas of Ethiopia. This study indicated that timing of nitrogen fertilizer has significant effect on the yield and yield component of tef. According to this research work, N split application of 1/3 at sowing and 2/3 at mid tillering was most effective time in improving grain yield nitrogen use efficiency and economical benefit than other N split application-times studed. Generally the two year data indicated that timing of split nitrogen fertilizer one third at sowing plus two third at mid tillering gave the highest number of Harvest index (0.34), plant height (69.13 cm), panicle length (37.06 cm), biomass (7038.9 kg/ha) and grain yield (2451.68 kg/ha) of tef followed by application of 1/2 at sowing plus 1/2 at mid tillering. Proper nitrogen management is important for rain fed agriculture specially in high-land areas having high rain fall (like the current study area) at sowing which causes high loss of Nitrogen fertilizer. In other case application of Nitrogen fertilizer at anthesis growing stage may be good for tef crop but there is a moisture limitation at this time for fertilizer uptake so further study will be needed on time of Nitrogen split application based on weather condition for rain fed agriculture and also for irrigation Agriculture there may not be moisture deficiency on anthesis stage and as a result appropriate time of Nitrogen split - application may be different and need further study.

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REFERENCES

Abel Debebe. 2005. Performance of F4 progenies and association among yield and yield related traits in tef (*Eragrostis tef* (Zucc) Trotter). M.Sc. Thesis, Alemaya University, Ethiopia.

Alcoz, M., Frank, M. and Haby, V. 1993. Nitrogen fertilizer timing effect on wheat production, nitrogen uptake efficiency, and residual soil nitrogen. *Agronomy Journal* 85: 1198-1203.

Ali, E.A. (2010). Grain yield and nitrogen use efficiency of pearl millet as affected by plant density, nitrogen rate and splitting in sandy soil. *American-Eurasian Journal Agriculture and Environmental Science*, 7(3), 327-335. Ali, H., Shakeel, *and Plant Disease*, L. E. Datnoff, W. H. Elmer, and D. M. Huber (eds) 31–44. St. Animal and Plant Health Regulatory Directorate, Addis Ababa, Ethiopia, June 2008.

Asrat Wondimu and Frew Tekabe. 2001. Utilization of tef in the Ethiopian diet, pp. 239-244.

Bekele, HK., Verkuijl, H., Mwangi, W. and Tanner, D. 2000. Adoption of Improved Wheat Technologies in Adaba and Dodola Woredas of the Bale Highlands, Ethiopia. Second National Maize and Wheat Workshop.12-16 November 2000; Addis *Ababa*. International Maize and Wheat Improvement Center) and Ethiopian Agricultural Research Organization (EARO). Addis Ababa, Ethiopia.

Chikowo, R., Mapfumo, P., Nyamugafata, P., and Giller, K. E. (2004). "Mineral N dynamics, leaching and nitrous oxide losses under maize following two-year improved fallows on a sandy loam soil in Zimbabwe" . *Plant and Soil*, 259 (1-2), 315–330.

CIMMYT (International Maize and Wheat Improvement Center) (1988) From agronomic data to farmer recommendations: An economic workbook, Mexico, D.F.

Costanza, S.H., DeweJ, M. T. and Harlan, J.R. 1979. Literature review and numerical taxonomy of Eragrostis tef(Tef). Econ Bot 33(4): pp. 413-424.

CSA (Central Statistic Authority) 2013/14. Agricultural Sample Survey 2013/2014. Report on area and production for major crops (private peasant holdings Meher season), Addis Abeba, Ethiopia.

De Datta, S.K. and Patrick, Jr. W. H. 1986. Nitrogen Economy of Flooded Rice Soils.

Doris-Piccinin, M.S.D. 2010. More about Ethiopian Food: Tef; Department of Nutrition and Food Science, University of Washington, America. *Euphatica*, 131: 91-96.

Fageria, N.K. and Baligar, V.C. 2005. Enhancing nitrogen use efficiency in crop plants.*Advanced Agronomy*. 88:97–185.

Fassil Kebede and Charles Y. 2009. "Soil fertility status and Numass fertilizer recommendation of Typic Hapluusterts in the Northern Highlands of Ethiopia," *World Applied Sciences Journal*, vol. 6, pp. 1473–1480, 2009.

Haftom Gebretsadik, Mitiku Haile and 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 and Seyfu Ketema. 2001. Production and importance of tef in Ethiopian Agriculture pp.3-7 In: Hailu Tefera , Getachew Belay and Mark Sorrels (eds.). Narrowing the Rift: Tef Research and development. Proceedings of International Workshop on Tef Genetics and Improvement, 16-17 October 2000. Addis Ababa, Ethiopia.

Hailu Tefera, Kebebew Assefa, Fufa Hundera, Tiruneh Kefyalew and Tesfaye Teferra. 2003.

Hatfield, J.L. & Prueger J.H. (2004). Nitrogen Over-use, Under-use, and Efficiency. "New directions for a diverse planet". Proceedings of the 4th International Crop Science Congress, 26 Sep – 1 Oct 2004, Brisbane,Australia. pp 21-29. Heritability and genetic advance in recombinant inbred lines of tef (*Eragrostis tef*).

Huber, D. M. and Thompson, I. A. 2007. Nitrogen and plant disease. *In*: *Mineral Nutrition*

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.

IRRI. 1990. Annual report. International rice research institute, Lose Banos, Philippines. Jackson, M. L. 1973. Soil Chemical Analysis. Prentice Hall Grice. Englewood Cliffs, USA. 284pp.

Mitku Melaku. 2008. Effects of seeding and nitrogen rates on yield and yield components of tef [*Eragrostis tef* (Zucc.) Trotter]. M.SC. Thesis, Haramaya University, Haramaya, Ethiopia.

MoARD. 2008. Ministry of Agriculture and Rural Development. Crop Variety Register,

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

Okamoto, M. and Okada K. 2004. Differential responses of growth and nitrogen uptake to organic of nitrogen four gramineous crops. *Journal. Exp. Bot.* 55 (402): 1577 – 1585.

Seyfu Ketema (1993): Tef (*Eragrostis tef*): breeding, genetic resource, agronomy utilization and role in Ethiopia agriculture. Institute of Agricultural Research, Addis Ababa. 147p.

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

Spaenij-Dekking, L, Kooy-Winkelaar, Y, Koning, F. The Ethiopian cereal tef in celiac disease. The New England journal of medicine, 2005. 353(16): p. 1748-9.

Shiferaw Tolosa and Tewodros Ayalew, 2016. “Response of Tef [*Eragrostis tef* (Zucc.) Trotter] to time of nitrogen application and variable seed rates at Dilla district, southern Ethiopia”, *International Journal of Current Research,* 8, (03), 28047-28052.

Tadesse Ebba. 1975. Tef (*Eragrostis tef*) cultivars: Morphology and Classification, Part II. Experimental Station Bulletin 66, Addis Ababa University, College of Agriculture, Dire Dawa, Ethiopia. 73pp

Tefera H, Belay G. 2006: Eragrostis tef (Zuccagni) Trotter. [Internet] Record from Protabase. In: Brink M, Belay G (eds) PROTA (Plant Resources of Tropical Africa/ Ressources ve´ge´tales de l’Afrique tropicale), Wageningen.http://database.prota.org/search.htm (December, 2010).

Teklu Y, Tefera H 2005: Genetic improvement in grain yield potential and associated agronomic traits of tef (Eragrostis tef). Euphytica, 141, 247–254.

Temesgen Kassa. 2001. Effect of sowing date and nitrogen fertilization on yield related traits of tef (*Eragrostis tef*) on vertisols of Kobo area, North Wollo. M.Sc. Thesis presented to AlemayaUniversity. 67p.

Tulema B, Zapta F, Aune JB, Sitaula B 2005: N fertilization, soil type and cultivars effects on N use efficiency in tef(Eragrostis tef (Zucc.) Trotter). Nutr. Cycling Agroecosyst., 71, 203–211.

Vavilov N.I (1951): The origin, variation, immunity and breeding of cultivated plants PP.37-38. Roland press, New York.

Yewlsew Abebe, Alemtsehay Bogale, Hambidge KM, Stoecker BJ, Bailey K and Gibson RS. 2007. Phytate, zinc, iron and calcium content of selected raw and prepared foods consumed in rural Sidama, Southern Ethiopia, and implications for bioavailability. *Journal of Food Composition and Analysis 20:* pp.161-168.

Zewde, L., Yilma, Z., Tanner, D. G., & Elias E. (1992). The effects of N fertilizer rates and applications timing on bread wheat in Bale region of Ethiopia. pp. 495-502. In: Tanner, D. G. and W.

Table 1: Means of Effect of Time of N fertilizer application on yield and yield components of tef in 2015 and 2016

Parameters	Year (Y)	Time of N application (TN)	Y x TN	Mean	CV(%)
Grain yield(kg/ha)	**	**	ns	1220.3	14.17
Above ground biomass yield(kg/ha)	ns	**	ns	4334.9	15.5
Plant height(cm)	**	**	ns	58.75	11.27
Panicle length (cm)	**	**	ns	26.68	14.64
Harvest Index (HI)	**	**	*	0.262	18.5

Notes. Significant at *P<0.05, **P <0.01, ns, not significant

Table 2: Effects of year, time of Nitrogen application and their interaction on yield and yield components of Tef 2015 and 2016

Factor Year	Grain yield (kg ha-1)	Above ground Biomass yield (kg ha-1)	Harvest index (%)	Plant height (cm)	Panicle length (cm)
2015	1148.8	4261.6	0.24	56.66	22.48
2016	1292.04	4408.4	0.27	60.8	30.8
LSD(0.05)	81.62	318.15	0.023	3.12	1.84
Time of N application					
T1=1/2 at sowing + 1/2 at mid tillering	1974.53	6363	0.311	67.2	32.56
T2=1/2 at sowing + 1/2 at flower initiation	1222.23	4179.6	0.293	58.8	26.3
T3= nil at sowing + 1/2 at mid tillering +1/2 anthesis	770.77	3001.9	0.262	52.7	26.3
T4= nil at sowing + full at mid tillering	953.18	3872.2	0.249	60.26	26.4
T5= nil at sowing + full at anthesis	296.81	2001.9	0.156	49.33	20.11
T6=1/3 at sowing + 2/3 at mid tillering	2451.68	7038.9	0.348	**69.13**	**37.06**
T7=1/3 at sowing + 1/3 at mid tillering +1/3 at anthesis	1121.66	4005.6	0.282	58.9	23.76
T8= nil at sowing + 1/3 at mid tillering + 2/3 anthesis	570.27	3053.7	0.180	54.83	25.4
T9=2/3 at sowing + 1/3 at mid tillering	2022.87	6111.1	0.334	65.43	28.9
T10=2/3at sowing + 1/3 at anthesis	1541.5	5159.3	0.305	63.3	28.3
T11= full at sowing	1529.5	6063	0.254	59.66	30.3
T12=Negative Control(no input)	188.7	1169.6	0.166	45.4	14.4
LSD(0.05)	199.9	779.3	0.056	7.65	4.5
CV(%)	14.17	15.5	18.5	11.27	14.64

Table 3: Economic analysis for split application of N fertilizer application

No.	Treatments	12.5 % Adjusted Grain Yield (kg ha- 1)	Total Variable Cost (Birr/ha)	Gross profit (Birr/ha)	Net benefit (Birr/ha)
T1	1/2 at sowing + 1/2 at mid tillering	1727.71	5000	34554.28	29554.28
T2	1/2 at sowing + 1/2 at flower initiation	1069.45	5000	21389.03	16389.03
T3	nil at sowing + 1/2 at mid tillering + 1/2 at flower initiation	674.424	5000	13488.48	8488.475
T4	nil at sowing + full at mid tillering	834.033	4700	16680.65	11980.65
T5	nil at sowing + full at flower initiation	259.709	4700	5194.175	494.175
T6	1/3 at sowing + 2/3 at mid tillering	2145.22	5000	42904.4	37904.4
T7	1/3 at sowing + 1/3 at mid tillering + 1/3 at anthesis	981.453	4700	19629.05	14929.05
T8	nil at sowing + 1/3 at mid tillering + 2/3 at anthesis	498.986	5000	9979.725	4979.725
T9	2/3 at sowing + 1/3 at mid tillering	1770.01	5000	35400.23	30400.23
T10	2/3 at sowing + 1/3 at anthesis	1348.81	5000	26976.25	21976.25
T11	Full at sowing	1338.31	4700	26766.25	22066.25

Table 4: Agronomic Nitrogen Use Efficiency of tef as affected by split N fertilizer application

No.	Treatments	Agronomic Nitrogen Use Efficiency
T1	1/2 at sowing + 1/2 at mid tillering	32.90883
T2	1/2 at sowing + 1/2 at flower initiation	20.3705
T3	nil at sowing + 1/2 at mid tillering + 1/2 at flower initiation	12.84617
T4	nil at sowing + full at mid tillering	15.88633
T5	nil at sowing + full at flower initiation	4.946833
T6	1/3 at sowing + 2/3 at mid tillering	40.86133
T7	1/3 at sowing + 1/3 at mid tillering + 1/3 at anthesis	18.69433
T8	nil at sowing + 1/3 at mid tillering + 2/3 at anthesis	9.5045
T9	2/3 at sowing + 1/3 at mid tillering	33.7145
T10	2/3 at sowing + 1/3 at anthesis	25.69167
T11	Full at sowing	25.49167