

Effect of Method of Sowing and Time of Di-Ammonium Phosphate (DAP) Fertilizer Application, on Yield and Yield Components of Tef ((Eragrostic tef) Trotter) at Shebedino, Southern Ethiopia

Bekalu Abebe[1] Tenaw Workayehu[2]
1.Arbaminch Agricultural Research Center
2.Hawassa Agricultural Research Center
*Email of the corresponding author: bekaluabebe41@yahoo.com email

Abstract
Time of DAP application and sowing method vary from farmer to farmer. Therefore, there is a need to determine time of DAP and sowing method recommendations for tef(Eragrostis tef (Zucc) Trotter). Accordingly, an experiment was conducted to evaluate the effect of sowing method and time of DAP application on yield and yield components of tef at Shebedino, Southern Ethiopia in 2012 cropping season.DZ-37 tef variety was used as a test crop. A factorial combination of planting method (row planting and broadcasting) and five times of DAP fertilize application (at planting, two, four, six and eight days before planting) was laid out in Randomized Complete Block design (RCBD) with four replications. Row sowing and DAP applied two days before planting had significantly affected days to heading and maturity, plant height , first growth rate, number of tiller and panicle, thousand seed weight, grain, straw and total biomass yields and harvest index. Days to emergence and panicle length were significantly affected by broadcasting and application of fertilizer two days before planting. Row sowing hastened heading and maturity by 1 day and increased growth rate by 23.46% than broadcasting; and DAP applied two days before planting hasten days to heading and maturity by 4 and 5 days, respectively, than DAP applied eight days before planting. Row sowing had 10, 24.8 and 23.8% more panicles, grain and biomass yields respectively, than broadcasting. DAP applied two days before sowing increased panicles, grain and biomass yields by 41.7, 62.1and 59.6% respectively, than DAP applied eight days before sowing. Interaction of row sowing and DAP applied at the time of sowing, had 54.7 and 1.07% more 1000 seed weight and harvest index respectively, than broad casting and DAP applied at the time of sowing. Row sowing was found to be economically acceptable with MRR of 627.7% with 6775.6Birr ha^{-1}more income from grain yield than broadcasting. Row sowing and DAP applied two days before planting had 80.85 Birr ha^{-1} more additional income from straw than broadcasting. Therefore, row sowing and DAP application two days before planting could be recommended as an economically feasible choice for the study area.
Keywords: sowing method, row seeding, broadcasting, time of fertilizer/DAP application before planting

1. INTRODUCTION

Tef (E*ragrostis tef* (Zucc) Trotter) is a small - seeded cereal indigenous to Ethiopia and originated in Ethiopia between 4000 and 1000 BC. Currently, tef is grown in almost all regions of Ethiopia; because it is the preferred grain crop for home consumption, market and fetches the highest grain price compared with the other cereals (Zeleke, 2009). Tef is among the major cereal crops in Ethiopia and occupies about 22.6% of the total cereals' land (about 2,731,111.67 hectares), which is more than any other major cereals such as maize (17%), sorghum (15.92%) and wheat (11.89%) (CSA, 2012). Of the total 30 million grain production,14 million tons is contributed by cereals; tef constituted about 16% (34,976,894.64 quintals), next to maize 27.77% (60,694,130.14 quintals) during the main cropping season of 20011/12.

In Ethiopia, tef performs well in '*Weina dega'* agro-ecological zones or medium altitude (1700-2400 masl). According to Haftamu *et al.* (2009), mean temperature and optimum rainfall for tef during growing season range from 10 to 27 ^{o}C and 450 to 550mm, respectively. Tef withstands low moisture conditions and has the ability to tolerate and grow on Vertisols having a drainage problem, which make it a preferred cereal by farmers.

The length of growing period (LGP) considering rainfall of 450 to 550 mm and evapo-transpiration of 2-6 mm day^{-1}, ranges from 60 to 180 days. Depending on variety and altitude, tef requires 90 to 130 days for growth (Haftamu *et al*., 2009).

Ethiopian farmers grow tef for a number of merits; which are mainly attributed to the socioeconomic, cultural and agronomic benefits (Hailu and Seyfu, 2001); although it ranks the lowest in terms of yield from of all cereals grown in Ethiopia.

The lower productivity of tef might be due to its confinement to Ethiopia in terms of origin and diversification, which limits the chance of improvement like other cereals of international importance (Kebebew *et al.,* 2001). Other factors contributing to its low in productivity are lodging, method of planting and fertilizer application; the combined effect of those factors result up to 22% reduction in grain and straw yield (Hailu and Seyfu, 2001).Therefore, further improvement of product and productivity of tef is highly needed; as even improved varieties of tef are reported to yield only up to 2.2 t ha^{-1} on farmers' field (Hailu and Seyfu, 2001) and the national average yield is 1.17 t ha^{-1} (CSA 2012).

The most common way of planting tef is by broadcasting the small seed at the rate of 25 - 30 kg ha^{-1} (Tareke and Nigusse, 2008). This sowing method results in lodging; which is the main cause for low yield of tef due to high plant density (Tareke, 2009). To minimize the problem of lodging on tef, low seed rate, row planting, late sowing and application of plant growth regulators were used (Fufa *et al.,* 2001).

High rate of nutrient depletion in Ethiopia; due to lack of adequate synthetic fertilizer input, limited return of organic residues and manure, high biomass removal, erosion, and leaching (Balesh.*et al.*, 2007). The solution for these would be selecting combinations of nutrient source, appropriate rate and timing of fertilizer application; that would optimize fertilizer use efficiency and increases economic return (Grant *et al.*, 2002).

Especially, application of nutrients before peak crop nutrient demand is critical; and adequate nutrients early in the growing season are necessary to maximize yield. Mainly, N and P are ensuring good grain or seed fill (Clain Jones, 2011). According to Clain (2011), there are many advantages from early application, like increased nutrient use efficiency and reduced adverse environmental effects.

Though there is much advantage from early application, time of fertilizer application before planting is not known; due to limited research work on early application. Therefore, there are controversies regarding appropriate time of DAP fertilizer application before planting. Some farmers prefer to apply DAP four days before planting, while others prefer to apply three days before planting, the remaining prefers to apply two and one day before planting; which might result on loss of fertilizer and reduction in yield.

Majority of the farmers believes for longer time, to higher productivity on tef, broad casting all over the field is necessary. So they faced productivity problem for longer time due to, difficulty to mange weeds and lodging (Jim, 2011).

To improve production and productivity of tef planting methods (such as planting in rows rather than broadcasting) and optimum time of fertilizer application should be considered (ATA, 2012). Hence, this study was initiated with the following objectives:

- To evaluate the effect of sowing method and time of Di-Ammonium Phosphate **(**DAP) fertilizer application on growth and yield of tef.
- To see the interactive effect of sowing method and time of DAP fertilizer application on growth and yield of tef.
- To identify the optimum sowing method & time DAP fertilizer application in tef production

2. MATERIALS AND METHODS

2.1 Site Description

This study was conducted at Taremessa Kebele of Shebedino Woreda, in Sidama Zone. The site is located 27 km south of Hawassa and situated at 7^0 4'N and 44^0E with an elevation of 1900-2600 masl. The mean annual rain fall varies from 900-1500 mm, with two rainy seasons (bimodal); the belg (short rain from Feb-April) and meher (main season from June- October).

The dominant crops growing around the experimental area are enset (*Enset ventricosum*), maize (*Zea mays* L.), tef, different vegetables and Chat (*Catha edulis*). Specifically the study site has an altitude of 1980 masl with clay loam textural soil and considered as representative of the Woreda's cool sub humid (Weyna Dega) agro climatic zone (SWRDO, 2013, unpublished).

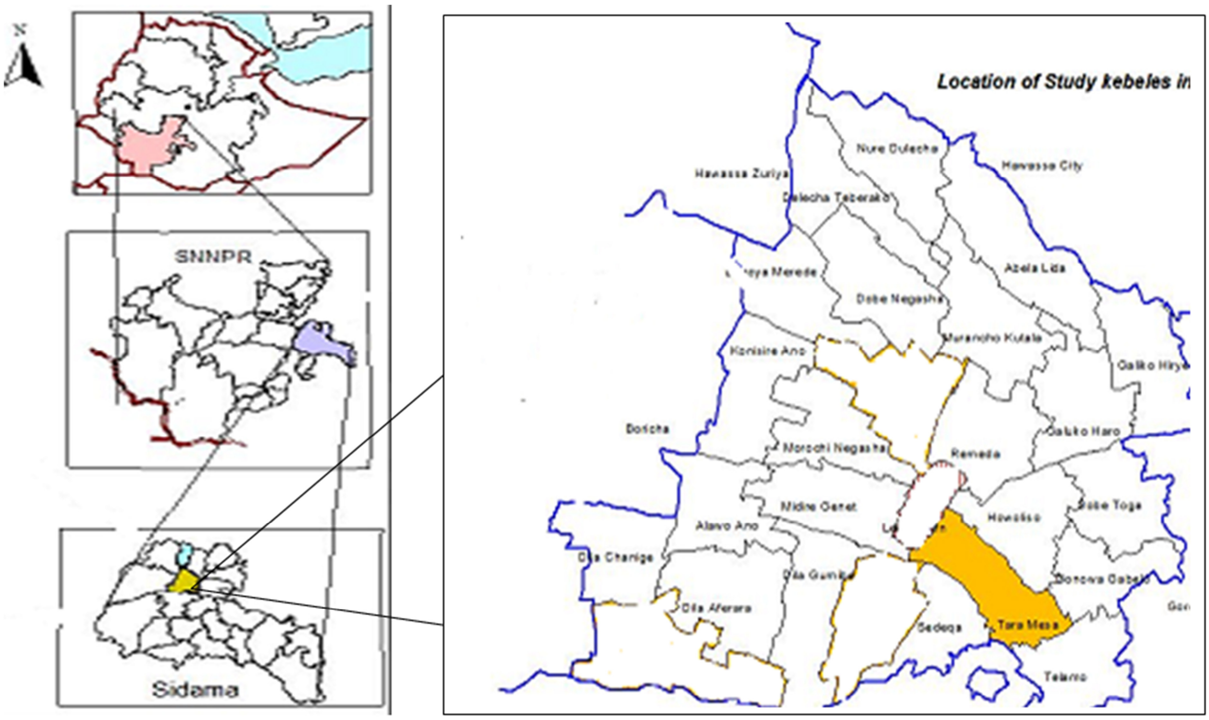

Fig1:- Location of the study site

Based on ten years (2003 to 2012) meteorological data, the average annual rainfall of the study area was 798 mm; with a range of 704.3 mm to 1197.9 mm per year. The total rainfall of the growing year was 922.8 mm with a range of 0.2 to 193.6 mm per month. The total rainfall of the growing season was 590.4 mm with a range of 5.5 to 155.2 mm per month; which are ideal for the production of tef (Appendix Table1).

The average annual minimum and maximum temperatures are 13.3 °C and 27.5 °C, respectively. The mean minimum and maximum temperatures of the growing year were 13.5 °C and 27.8 °C, respectively. The mean minimum and maximum temperatures of the growing season were 14.5 °C and 26.3 °C, respectively. Generally the Woreda consist of two agro climatic zone, namely cool sub humid (Weyna Dega (90%)) and cool and humid (Dega (10%)) (SWRDO, 2013) (unpublished).

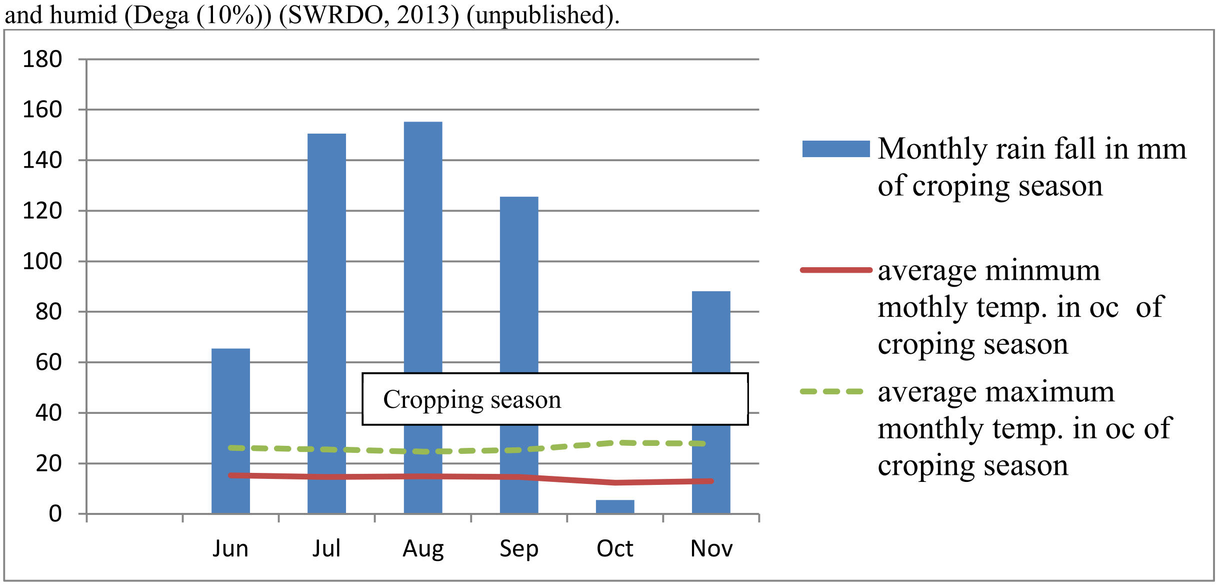

Fig2:- Monthly rainfall, Average minimum and maximum temperature of cropping season.

2.2. Experimental Treatments and design

The experiment consisted of two factors, method of sowing and time of fertilizer application; arranged in randomized complete block design (RCBD). Times of fertilizer (DAP) application (0, 2, 4, 6 and 8 days before planting) and methods of sowing (broad casting and row sowing), were arranged as factorial with four replications.

2.3. Experimental Procedure
Tef variety, DZ-Cr-37 (Tsedeay) released in 1984 was used as a test crop; which is most widely grown variety in the relatively low altitude and moisture prone areas (Truneh *et al.*, 2000).
The experimental field was prepared by using oxen plow and plowed four times, before planting. Plowing started at the end of June and the fourth plowing was done in the middle of August 2012. The experimental plot size was 2 m x 2.5 m (5 m^2) and the space between plots was 0.5 m; which had 0.2m intra row space.
DAP fertilizer was used at the rate of 100 kg ha^{-1} as source of N and P; and Urea was applied at the rate of 50 kg ha^{-1}; in which 1/3 at planting and 2/3 at stem elongation. The seed rate of tef used was 25 kg/ha for both sowing methods; and all necessary cultural practices were applied.

2.4. Soil Sampling and Analysis
Sixteen random soil samples (0-20 cm depth) from the experimental field were thoroughly mixed to make a composite. The sample was air dried and ground to pass 2 mm sieve and necessary parameters such as soil texture, available P, pH and CEC were determined. For the determination of OC and N 1mm sieve was used. Soil texture was analyzed by Bouyoucos hydrometer method (Day, 1965). Available P was extracted with a sodium bicarbonate solution at pH 8.5 following the procedure described by Olsen *et al.* (1954).The pH of the soil was measured potentiometrically in the 1:2.5 soil: water mixture by using a pH meter and organic carbon was determined following Walkely and Black wet oxidation method (Walkely and Black, 1934).Cation Exchange Capacity (CEC) was determined by Ammonium Acetate method (Jackson, 1973).

2.5. Data Collection
2.5.1. Phenological data
Days to 50% emergence: number of days from sowing up to the date when 50% of the plants emerged in a plot.
Days to 50% heading: number of days from sowing up to the date when the tips of the panicles first emerged from the main shoot, on 50% of the plant in a plot
Days to 90% maturity: number of days from the date of sowing up to the date when 90% of the crop stands in a plot changed to light yellow color.
2.5.2. Growth data
Plant height (cm): - It was taken at an interval of 20 days; by taking six randomly selected plants and measured from the base of the main stem to the tip of the panicle.
Growth Rate: - It was the ratio of the differences between two consecutive plant heights measured at difference time [GR= $\Delta H \div \Delta T$] (Watson, 1952).
Growth rates (GR_1, GR_2 and GR_3) were calculated according to Watson (1952), as following:-

$GR_1 = [H_2-H_1] \div [T_2-T_1]$ $GR_2 = [H_3-H_2] \div [T_3-T_2]$ $GR3 = [H_4-H_3] \div [T_4-T_3]$

Where,
GR_1 = First growth rate T_1 = 20 days after emergence
GR_2 = Second growth rate T_2 = 40 days after emergence
GR_3 = Third growth rate T_3 = 60 days after emergence
H_1 = Height of plant at time t_1 T_4 = 80 days after emergence
H_2 = Height of plant at time t_2
H_3 = Height of plant at time t_3
H_4 = Height of plant at time t_4
Tillers number (m^{-2}): - to determine the capacity of tillering per 1m^2, 10 cm X 20 cm area was demarcated and the number of plants existed in that area were counted. Then recounting was done after at flowering on demarked area; because maximum tillers produced during vegetative phase and senescence occurs at maturity (Lafarge *et al.,* 2004). Finally the difference between the first and second count was converted into 1m^2.
Panicles per plant: - six plants were randomly taken and the average number of panicles per plant was considered.
Panicle length (cm): - length of the panicle was measured by selecting six plants randomly and measuring from the node (the first panicle branch started) to the tip of the panicle.
2.5.3 Yield and yield components
Total above ground biomass (kg):- was measured after sun-drying for two days.
Straw yield (kg): - was measured by subtracting grain yield per plot from the total above ground biomass.
Grain yield (kg ha^{-1}):- yield from every plot
Thousand seed weight (g): - the seeds were taken from each plot and 1000 seeds counted by hand and then weighted.

Harvest index: - the ratio of grain yield to the above ground (shoot) biomass. [HI= Grain yield/Total biomass].

2.6. Economic Analysis

For economic analysis, a simple partial budget analysis was employed using CIMMYT approach (CIMMT, 1988). For partial budget analysis, the factors with significant effect were considered. The yield was adjusted by subtracting 10 % from average gain yield. Than after, gross yield benefit was obtained by multiplying the adjusted yield by the price of grain (13 birr kg^{-1}). Net benefit was calculated, by subtracting labor cost from gross yield. Finally marginal rate of return (MRR) was obtained, by dividing marginal net benefit to the marginal cost and expressed as percentage (CIMMT, 1988). The mean market price of tef was obtained by assessing the market at harvest (2012 cropping season).

2.7. Data Analysis

The various agronomic data were analyzed using the general linear model (GLM) procedures of the SAS statistical software (SAS Institute, 2000) to evaluate the effect of sowing method and time of fertilizer application and their interaction. Least Significant Difference (LSD) test at $P \leq 0.05$ was used to separate means whenever there were significant differences.

3. RESULTS AND DISCUSSION

3.1. Physicochemical Properties of the Experimental Soil.

The analytic results indicated that the experimental soil was clay loam textured; having organic carbon content (OC) of 2.54 % (Table 1). The soil had high OC in accordance with Sahlemedhin (1999), who rated OC between 1.74-2.90% as high. The CEC of the soil was 23.87 cmol kg^{-1}, which could be considered as medium (Landon, 1991). According to Olsen *et al*. (1954) P rating (mg kg^{-1}), P content of < 3 is very low, 4 to 7 is low, 8 to 11 is medium, and > 11 is high. Thus, the experimental site of available P content is high. The pH of the soil was 4.98, which is within the range of 4 to 8 suitable for tef production (FAO, 2000).Total N of the soil (0.16 %), is medium; as rated by Havlin *et al*., (1999) who rated total N between 0.15 to 0.25% as medium.

Table 1: - Physio-chemical properties of the experimental soil.

Depth (cm)	pH (H_2o)	CEC (cmol kg^{-1})	OC (%)	Total N (%)	Av.P (mg kg^{-1})	Particle size distribution (%)			Textural
						sand	clay	silt	Class
0-20	4.98	23.87	2.54	0.16	27.4	32	30	38	Clay loam

CEC= Cation Exchange Capacity, OC= Organic Carbon, Av.P= Available phosphorous.

3.2. Crop Phenology

3.2.1. Days to emergence

Days to 50% crop emergence was significantly affected both by method of sowing and time of fertilizer application ($P \leq 0.001$). However, their interaction did not have any significant effect on crop emergence (Appendix Table 4).

Broadcasting shortened days to emergency by 3-days than row sowing (Table 2). The result agrees with the finding of Klosterboer and Turner (2002), who indicated rice in the broadcast emerges earlier than row sowing. The row sown tef was placed relatively deeper than that of broadcasted tef; and the finding was in contrast to the report of Evert *et al.* (2008),who found earlier emergence of tef on the surface compared to deeper planted tef; because of poor seed to soil contact.

Fertilizer applied eight days before sowing delayed emergency by 2-days than that applied two days before sowing (Table 2). This might be attributed to the high loss of DAP fertilizers from the earlier application before it is used by the plant; especially N, which is highly soluble and may be lost from the soil-plant system by leaching, de-nitrification, volatilization and erosion (Vaughan *et al*., 1990).

Table2:- Effect of method of sowing and time of DAP application on the days to emergence, heading and maturity of tef.

Treatments	50% Emergence	50% Heading	90 % Maturity
Method of sowing			
Broad casting	7b	46a	68a
Row sowing	10a	45b	67b
LSD (5%)	**0.24**	**0.55**	**0.80**
CV (%)	**4.32**	**1.87**	**1.84**
Time of fertilizer application			
At planting	8c	45cd	66cd
2-DBP	8c	44d	65d
4-DBP	9b	46bc	67bc
6-DBP	9b	47b	68ab
8-DBP	10a	48a	70a
LSD (5%)	**0.54**	**1.25**	**1.80**
CV (%)	**4.32**	**1.87**	**1.84**

DBP=Days Before Planting, the same letter in a column of each factor shows a non-significant difference at 5% probability level.

3.2.2. Days to heading

Both method of sowing and time of fertilizer application had a significant ($P \leq 0.001$); but interaction did not have a significant effect on days to heading (Appendix Table 4). Row sowed tef was head 1-day earlier than broadcasted (Table 2), which may be due to little weed competition and efficient use of fertilizer than broadcasted one (Mehdi, 2010).

Days to heading was enhanced by 4 days on DAP applied two days before sowing, compared to that of DAP applied eight days before sowing (Table 2).Thus days to heading for application of DAP two days before sowing is smaller; due to minimum loss fertilizer contributes for growth of crop (Brady and Weil, 2002).

3.2.3. Days to maturity

Days to 90% maturity were significantly ($P \leq 0.001$) affected by both sowing method and time of fertilizer application; but their interaction not significant (Appendix Table 4).

Row sowed tef matured 1-day earlier than broadcasted (Table 2).The result is in line with Delesa (2007), who reported rice planted by broadcasting matured later than rows. The possible reason is that, less weed infestation and better use of fertilizer in row planting as compared to broadcast (Farooq *et al*., 2006); specially P enhanced maturity (Brady and Weil, 2002). Application of fertilizer at planting resulted in 1-day delay and 4-days earlier mature compared to those applied two and eight days before sowing, respectively (Table 2). Thus, applying fertilizer two days before sowing enhanced maturity and this was because of time of application is one of the factor influencing crops phonology and growth (Mugwe *et al.,* 2007).

3.3. Growth Parameters

3.3.1. Plant height

Both sowing method and time of fertilizer application had very high significant ($P \leq 0.001$) effect on plant heights, except the effect of planting method on plant height (ph_1) which was highly significant ($p \leq 0.01$). However interaction effect of time of fertilizer application with planting method did not significantly affect plant height (Appendix Table 5).

Row sowing had batter heights, at all of four measurements (PH_1, PH_2, PH_3 and PH_4) than broadcasting and also contributed for 15, 24, 12 and 3% increments in plant heights, respectively (Table 3). These are due to smaller space among plants in broadcast resulting in higher competition for nutrients; while in row sowing there was wider space and thus relatively less plant competition for nutrients (Henderson *et al.,* 2000). Also, Caliskan *et al.* (2004), reported taller and more branched plants at the lower plant densities of sesame.

Application of fertilizer two days before sowing had 25% more plant height than DAP applied at sowing on the first measurement. Whereas application of fertilizer two days before sowing had 42, 25.6 and 8.7% higher plant height than that of applied eight days before sowing on PH_2, $PH_3$and PH_4, respectively. The results are in line with the report of Taylor and Francis (2005) and Vaughan *et al.* (1990), who indicated maximum use of N and P with minimum loss resulting in maximum growth in height on lentil and wheat, respectively.

Table3:- Effect of time of DAP application and sowing method on growth of tef.

Treatments	PH_1	PH_2	GR_1	PH_3	GR_2	PH_4	GR_3	PL	PN
Method of sowing									
Broad casting	11.54b	29.80b	0.98b	67.84b	1.89	94.00b	1.32	20.79a	9b
Row sowing	13.56a	39.17a	1.28a	77.30a	1.90	97.32a	1.50	18.51b	10a
LSD (5%)	**1.14**	**3.39**	**0.23**	**3.66**	**0.21**	**1.58**	**1.04**	**2.31**	**0.34**
CV (%)	**14.00**	**15.13**	**31.30**	**7.78**	**17.54**	**2.54**	**11.3**	**5.86**	**5.54**
Time of fertilizer application									
At planting	11.48b	38.16ab	1.32	77.95ab	2.00	97.77ab	2.69	23.75a	11b
2-DBP	15.40a	43.00a	1.38	84.00a	2.05	100.15a	1.34	20.61b	12a
4-DBP	14.60a	35.80ab	1.05	71.50bc	1.78	95.45bc	1.20	18.94bc	10c
6-DBP	11.37b	30.58bc	0.96	66.90cd	1.82	93.75cd	0.82	17.63c	8d
8-DBP	9.89b	24.97c	0.90	62.50d	1.87	91.40d	1.01	17.33c	7e
LSD (5%)	**2.58**	**7.63**	**0.51**	**8.24**	**0.48**	**3.56**	**2.33**	**1.68**	**0.77**
CV (%)	**14.00**	**15.13**	**31.30**	**7.78**	**17.54**	**2.54**	**11.3**	**5.86**	**5.54**

DBP= Days Before Planting, PH = Plant Height (PH_1- was measured 20 days after emergence; PH_2-measured 40 days after emergence; PH_3-measured 60 days after emergence and PH_4- was measured 80 days after emergence),GR= Growth Rate (GR_1-calculated from PH_1& PH_2, GR_2-calculated from PH_2& PH_3, GR_3-calculated from PH_3& PH_4), PL= Panicle Length and PN= Panicle Number. The same letter in a column of each factor shows a non-significant difference at 5% probability level

3.3.2. Growth rate

Sowing method, time of fertilizer application and their interaction were not significant on all growth rates; except method of sowing had significant ($P \leq 0.05$) on the first growth rate (Appendix Table 5). Row sowing had 23% more fast growth than broadcasting on first growth rate (Table 3). The result is in line with the finding of Thakur *et al*.(2004) who reported row sown rice had fast growth than broadcasted. The non significant effect on others growth rate were due to efficient utilization of applied DAP fertilizer at earlier growth stage. Especially N is a constituent of chlorophyll, proteins and nucleic acids, which are essential for plant growth (Rashid *et al*, 2007).

3.3.3. Panicle length

Sowing method and time of fertilizer application significantly ($P \leq 0.001$) affected panicle length, but their interaction was not significant (Appendix Table 5). Broadcasting increased panicle length by 11% more than row sowing (Table 3). Because less tillering on broadcasting due to many plant density (Farooq *et al*., 2006), which contributes to growth of panicle length due to minimum competition for nutrients among tillers. This is in line with Caliskan *et al.* (2004), who reported number of tiller negatively correlated with panicle length on sesame.

Fertilizer applied two days before sowing had 16% more and 13% less panicle length than fertilizer applied eight days earlier sowing and at time of sowing, respectively. This might be due to maximum utilization of nutrients on fertilizer applied two days before sowing and at the time of sowing; because time and rate of fertilizer application has significant effect on both growth and yield (Lloveras *et al*., 2001).

3.3.4. Panicle number

Sowing method and time of fertilizer application significantly ($p \leq 0.001$) affected number of panicles per plant; but their interaction was not significant (Appendix Table 5). Row sown had 10% more panicle numbers than broadcasted (Table 3), because of better root growth in the case of row planting; which favors the growth (Mugwe *et al.,* 2007) and contributes to panicles per a plant (Blaise *et al.,* 2003).

Application of DAP eight days before sowing and at time of sowing had 42 and 8% less panicle number, respectively, than applied two days before sowing (Table 3). This result is in line with the finding of Genene (2003) who reported time of fertilizer application, particularly those containing N and P affects panicle number of wheat.

3.3.5. Tillers

Sowing method, time of fertilizer application and their interaction significantly ($P<0.001$) affected the number of tillers (Appendix Table 5).

The interaction of row sowing and DAP applied two days before sowing had 5% more tillers than the interaction of row sowing and DAP applied at the time of sowing. Whereas the interaction of broadcasting and DAP applied eight days before sowing has delayed the growth by 83% compared with interaction of row sowing and fertilizer applied at sowing (Table 4).These might be due to the reduction of productive tillers by broadcasting (Delesa, 2007), together with maximum loss of N when DAP was applied eight days earlier to sowing, which could result to less tillering (Lloveras *et al*., 2001). Because N stimulates tillering due to its' effect on cytokinin synthesis (Mengel and Kirkby, 1996)

Table 4:- Interaction effects of time of fertilizer application and sowing method on tef tillering.

Time of fertilizer application	Number of tillers	
	Broad casting	Row sowing
At planting	20.4	43.2
2DBP	26.1	45.6
4DBP	15.0	18.9
6DBP	8.7	14.4
8DBP	7.2	9.3
LSD (5%)	**5.21**	
CV	**17.09**	

. DBP= Days before Planting, LSD= Least Significant Difference and CV= Coefficient of Variations.

3.4. Yield and yield components

3.4.1. Total biomass

Sowing method and time of fertilizer application significantly ($p \leq 0.001$) affected biomass yield; although their interaction was not significant (Appendix Table 6). Row sowed tef yielded 23.8% more biomass than broadcasted (Table 5), because of better growth in row sowing; due to easy absorption of photo synthetically active radiations (Ahmad *et al*., 2002).

Application of DAP at the time of sowing resulted in 52.5 % more biomass than the treatment with DAP applied eight days prior to sowing. Whereas applying of DAP at the time of sowing 15 % less biomass than DAP applied two days before sowing (Table 5), this might be due to maximum use of applied fertilizer on fertilizer applied two days prior sowing; because efficient utilization of applied fertilizer increased vegetative growth, which resulted for higher biomass production (Wakene 2010).

Table:- 5 Effects of time of DAP application and sowing method on yield and yield components of tef.

Treatments	TBM	SY	GY
		Kg ha^{-1}	
Sowing Method			
Broad casting	1092.5b	97.05	995.45
Row sowing	1432.5a	108.5	1324.0
LSD (5%)	**97.0**	**11.6**	**149.9**
CV (%)	**19.5**	**17.4**	**19.9**
Time of fertilizer			
At planting	1525.0ab	110.0ab	1415.0a
2-DBP	1793.8a	117.5a	1676.3ab
4-DBP	1331.3b	101.3ab	1230.0b
6-DBP	937.5c	95.0ab	842.5c
8-DBP	725.0c	90.1b	634.9c
LSD (5%)	**359.9**	**26.1**	**337.5**
CV (%)	**19.5**	**17.4**	**19.9**

DBP= Days before Planting, CV= Coefficient of Variations, TBM = Total Bio Mass, SY = Straw Yield and GY = Grain Yield.

4.4.2. Straw yield

Time of fertilizer application significantly ($p \leq 0.5$) affected biomass yield; although sowing method and interaction of time of fertilizer application and sowing method were not significant (Appendix Table 6).
Application of DAP at the time of sowing and two days before sowing resulted in 18 and 23.3% more straw yield, respectively than the treatment with DAP applied eight days prior to sowing (Table 5). This might be due to maximum use of applied fertilizer, with little loss on applied at the time of sowing and two days prior to sowing; because efficient utilization of applied fertilizer increased vegetative growth, which contribute to higher straw yield (Alam *et al*., 2005).

4.4.3. Grain yield

Sowing method and time of fertilizer application ($P<0.001$) had significant effect on grain yield; but no interaction effect (Appendix Table 6). Row sown increased grain yield by 24.8% over broadcasted (Table 5).This might be uneven seed distribution on broadcasting, which results in excess nutritional competition at certain areas and no competition on other areas of the field and thus less grain yield productivity (Delassa,2007). Application of DAP two days before sowing increased grain yield by15.6% over DAP applied at the time of sowing, whereas DAP applied eight days before sowing decreased grain by 55.1% compared to application at sowing (Table 5).These could attributed by minimum loss through leaching and volatilization on DAP applied two days before sowing and which resulted in better growth (Erkossa & Teklewold, 2009)

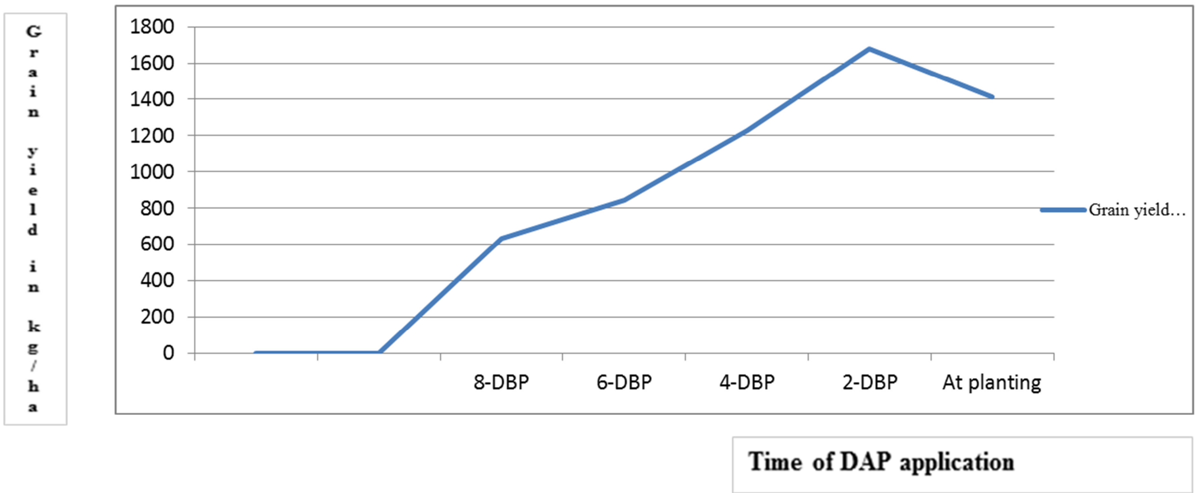

Fig 3:- Effect of time of DAP application on Grain yield of tef

4.4.4. Thousand Seed weight

Sowing method, time of fertilizer application and their interaction had significant ($p \leq 0.001$) effect on thousand seed weight (Appendix Table 6). Interaction effect of row sowing and DAP applied two days before sowing had 26.7% more thousand seed weight than interaction of row sowing and DAP applied at sowing. Whereas as the interaction of broad casting and DAP applied eight days prior sowing was weighted 82.4% less compared in weight to row sowed and DAP applied at sowing (Table 6). These might be because of combined effect of row sowing, which enhances efficiently utilization of applied fertilizer (Minale *et al.,* 1999) and appropriate rate of N fertilizer at correct time, which optimizes grain yield and quality (Abdo, 2009).

Table:-6 Interaction effects of method of sowing and time of DAP application on thousand seed and harvest index of tef.

Time of fertilizer	TSW(g)		HI	
	Broadcasting	Row sowing	Broadcasting	Row sowing
At planting	0.67	1.48	0.92	0.93
2-DBP	1.19	2.02	0.93	0.93
4-DBP	0.44	0.85	0.91	0.92
6-DBP	0.25	0.36	0.88	0.90
8-DBP	0.26	0.32	0.77	0.90
LSD	**0.12**		**0.05**	
CV	**10.53**		**4.3**	

DBP= Days before Planting, LSD= Least Significant Difference and CV= Coefficient of Variations CV = Coefficient of Variation, TSW = Thousand Seed Weight and HI= Harvest Index

4.4.6. Harvest index

Main effects and their interaction had significant effect on harvest index (Appendix Table 6).

Combined effect of row sowing and fertilizer application two days before sowing had 17.2% more harvest index than interaction of broadcasting and application of DAP eight days prior to sowing (Table 4). These might be due to, row sowing had less weed competition and efficient use of applied fertilizer (Thakur *et al*., 2004); and increment vegetative growth by applied N, which in turn increase grain yield by improving cumulative solar radiation intercepted by the crop (Osman *et al*., 2001).

4.5. Association of Grain Yield with Yield and Yield Components

Stepwise multiple linear regressions analyses were carried out using treatment means to determine the effects of method of sowing and time of fertilizer on the grain yield formation. Grain yield considered as dependant, whereas plant height, growth rate, tillers, panicles, panicle length, thousand seed weight, straw yield, total biomass and harvest index were taken as explanatory variables (Table 7).

Grain yield was positively and significant ($P < 0.001$) associated with plant heights taken at four different times, first growth rate, number of tillers and panicle, panicle length and thousand seed weight, r=0.60, 0.69, 0.72, 0.70, 0.51, 0.8,0.6 and 0.81, respectively. Similar correlations were reported in barley by Mekonnen (2005) and Alam *et al.* (2005). On the other hand, grain yield was associated negatively with thrid growth rate ($r=^{-}0.69^{***}$) and panicle length ($^{-}0.75^{***}$); which was in line with the report of Getachew (2004) on bread wheat.

Table 7:- Correlation between yield and yield components of tef.

	PH1	PH2	PH3	PH4	GR1	GR2	GR3	TN	PN	PL	TSW	GY	SY	TBM	HI
PH1	1.0	0.56***	0.80***	0.82***	0.81 ns	-0.09ns	-0.75***	0.48**	0.64***	-0.49**	0.59***	0.60***	0.14***	0.56***	0.43**
PH2		1.0	0.80***	0.82***	0.82ns	-0.09 ns	-0.75***	0.78***	0.76***	-0.71***	0.79***	0.69***	0.30*	0.62***	0.52***
PH3			1.0	0.94***	0.59***	0.51***	-0.98***	0.84***	0.83***	-0.69**	0.89	0.72***	0.37 *	0.66***	0.48**
PH4				1.0	0.59***	0.39*	-0.84***	0.78***	0.81***	-0.68***	0.82***	0.70***	0.34*	0.22***	0.49
GR1					1.0	-0.19 ns	-0.56***	0.62***	0.49**	-0.49**	0.60***	0.51***	0.29 ns	0.53***	0.01 ns
GR2						1.0	-0.55***	0.28 ns	0.29 ns	0.38**	0.35*	0.21 ns	0.18 ns	0.63 ns	0.06 ns
GR3							1.0	-0.83***	-0.79***	0.66***	-0.88***	-0.69***	-0.37*	-0.64***	-0.43*8
TN								1.0	0.86***	-0.77***	0.93***	0.80***	0.31*	0.75***	0.49**
PN									1.0	-0.49	0.59***	0.60***	0.14ns	0.56***	0.43***
PL										1.0	-0.71	-0.75***	-0.22 ns	-0.69***	-0.62***
TSW											1.0	0.81***	0.42 ns	0.76***	0.45 ns
GY												1.0	0.43 ns	0.97 ns	0.52***
SY													1.0	0.46 *	0.04*
TBM													1.0	0.46 *	0.04*
HI															1.0***

ns = not significant, * ** &*** significant at 0.05, 0.01and 0.001 respectively, $PH_{1,}$ $PH_{2,}$ PH_3 &PH_4= first, second, thread & fourth Plant Height respectively, $GR_{1,}$ GR_2 & $GR_{3=}$ first, second & third growth rates, respectively, TN= Tillers in Number, PL= Panicle Length TBM = Total biomass, GY = Grain Yield, SY = straw yield, TSW = Thousand Seed Weight and HI= Harvest Index.

4.6. Partial Budget Analysis

The return obtained from row planting was above the minimum acceptable marginal rate of return (100%) (CIMMYT, 1988), which is 627.7% and contributes to 6775.6 Birr ha^{-1} more income as compared to broadcasting. The combination of row sowing and fertilizer applied two days prior to sowing had increased straw yield 60% more than broadcasting and application of DAP eight days before sowing (Table 6), which contributed more 80.85 birr ha^{-1}.than broad casted and eight days earlier applied. Thus, in order to obtain benefit from straw and grain, row sowing and fertilizer application two days before sowing could be recommended for farmers in this area.

Table 8:- Partial budget analysis of tef as influenced by sowing method.

reatment	Av.Y (q ha^{-1})	ADTY (q ha^{-1})	GFB (birr ha^{-1})	Total Variable cost (birr ha^{-1})			Net benefit (birr ha^{-1})	MRR (%)
				DFM	Unit labor cost	Total labor cost		
Method of sowing	-	-	-	-	-	-	-	_
Broad casting	19.87	17.88	23,244	90	12 birr	1,080	22,164	_
Row planting	26.58	23.92	31,098.6	180	12 birr	2,160	28,938.6	627.7

Av.Y= Average Yield, ADTY=adjusted yield, GFB= Gross Field Benefit, DFM=Days of Farm Management, MRR=Marginal Rate of Return.

6. REFERENCES

Abdo Woyema.2009. Effect of different rate of Nitrogen on yield, yield related trait and quality of durum wheat (Triticum turgidum L.Var Durum) cultivars in the highland of bale. MSc. Thesis, Alemaya University. 53 pp.

Ahmad,R., Mahmood.T., Farrukh,M.S. and Ahmad.S.2002. Comparative performance of two sesame (*Sesamum* *indicum* L.) varieties under different row spacing. *Asian J.Plant Sci*.1(5): 546-547

Alam,M. Z., Haider,S. A. and Paul.N. K., 2005. Effects of sowing time and nitrogen fertilizer on barley (*Hordeum vulgare* L.). *Bangladesh Journal Boanyt* 34: 27-30.

ATA (Agricultural Transformation Agency), 2012. Innovations to help our country grow. (http://www.ata.gov.et/ programs/value-chain-programs/tef/) (Accessed on March 2013).

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

Brady.N. C. and Weil,R. R. 2002. The Nature and Properties of Soils (13 th ed.) Pearson Education Ltd., USA. 621 pp.

Caliskan.S , Arslan.M, Arioglu.H and Isler.N, 2004. Effect of planting method and plant population on growth and yield of sesame (*Sesamum indicum* L.) in Mediterranean type of environment. *Asian J. Plant Sci*. 3 (5) 610-613

*C*entral Statistical Agency (CSA), 2012. Agricultural sample survey 2007/2008. Report on Statistical Bulletin, 417. Addis Ababa, Ethiopia. 45 pp.

CIMMYT (International Maize and Wheat Improvement center).1988. An Economic Training Manual: from agronomic data recordation. CYMMT. Mexico. 79 pp.

Clain.J. 2011. Nutrient Uptake Timing by Crops to assist with fertilizing decisions. *Book of Soil Science.* Montana State University. pp 67-78.

Day.P. R. 1965. Hydrometer method of particle size analysis. In: Back, C.A. (eds.), Method of Soil Analysis. Amer. Soc. Agron. Madison, Wisconsm . Agron. No 9, Part 2. pp.562.

Dekking.L.S. and Koning, K. 2005. The Ethiopian Cereal Tef in Celiac Disease. The New England Journal of Medicine 353;16.

Delassa Angassa. 2007. Effect of sowing method and seeding rate on yield and yield components of rain fed rice (*Oryza sativa* L.) varieties in Woliso, South west Shoa of Oromia region. MSc. Thesis, Haramyaya University, Haramaya. pp 56-60.

Erkossa,T. and Teklewold, H. 2009. Agronomic and Economic Efficiency of Manure and Urea Fertilizers Use on Vertisols in Ethiopian Highlands. *Agricultural Science in India 8*(3): 352

Evert.S, Staggenborg.S and Olson. L.S. 2008. Soil temperature and planting depth effects on tef emergence. Short Communication. *Journal of Agronomy and Crop Science*, ISSN 931:789.

Farooq.M., Shahzad.M.A., Basra.A.S. and Basharat. A. S, 2006. Direct seeding method popular among rice farmers, DAWN Group of News letter, Sri Lanka. 89 (2): 11-28.

Food And Organization (FAO). 2000. Fertilizers and Their Use 4th ed. International fertilizer industry association, FAO, Rome, Italy.34pp.

Fufa Hundera, Tesfa Bogale, Hailu Tefera, Kebebew Assefa, Tiruneh Kefyalew, Abera

Debelo and Seyfu Ketema. 2001. Agronomy research on tef. pp. 167-176. Tef Research and Development. Proceedings of the International Workshop on Tef Genetics and Improvement, Debre Zeit, Ethiopia, 16-19 October 2000.

Genene Gezu. 2003. Yield and quality response of bread(*Triticum aestivum* L.) Varieties to rate and time of Niterogen fertilizer application in Kulumsa, South eastern Ethiopia. M,Sc. Thesis, Alemaya University, School of Graduate Studies. pp48-53.

Getachew Fisseha. 2004. Soil characterization and bread wheat (*Triticum aestivum* L.) Response to N and P fertilization. M.Sc.Thesis. Haramyaya University, Haramaya.65p.

Grant.C. A., Peterson, G. A., and Campbell, C. A. 2002. Nutrient considerations for diversified cropping systems in the northern Great Plains. Agron. J. 94:186-198.

Haftamu Gebretsadik, Mitiku Haile and Yamoah.C.F. 2009. Tillage frequency, Soil Compaction and N-Fertilizer Rate Effects on Yield of Tef (*Eragrostis tef* (Zucc) *Trotter)* in Central Zone of Tigray, Northern Ethiopia. *Agron.J* 1 (1): 82 – 94.

Hailu Tefera and Seyfu Ketema. 2001. Production and importance of tef in Ethiopian agriculture. In

Henderson T.L., Johnson,B.L. and Schneiter.A.A. 2000. New crops row spacing, plant population, and cultivar effects on grain amaranth in the Northern Great Plains. *Agron. J*.92: 329-336.

Havlin.J.L., Beaton .J.D, Tisdale .S.L and Nelson W.L.1999.Functions and forms of N in plants. In Soil Fertility and Fertilizers. 6thEd.Prentice Hall, New Jersey.

Henderson T.L., Johnson.B.L., and A.A.Schneiter.2000. New crops row spacing, plant population, and cultivar effects on grain amaranth in the Northern Great Plains. *Agron. J*. 92: 329-336.

Jim Carrey's Better U Foundation and Cornell International Institute for Food, Agriculture and Development, 2011. System of Tef Intensification (STI) - SRI Concepts and Methods Applied to Other Crops. (http://sri.ciifad.cornell.edu/aboutsri/othercrops /tef/index.html) (Accessed on March 2013).

Janckson,M.L. 1973. Soil Chemical Analysis.Prentice-Hall of India, New Delhi.

Kebebew Asefa, Syefu Ketema, Hailu Tefera, Fufa Hundera and Tiruneh Kefyalew, 2001. Genetic diversity for agronomic traits in tef. pp. 33-47. *In:* Hailu Tefera, Getachew Belay and Mark Sorrels (eds.). Narrowing the Rift. Tef Research and Development. Proceeding of the International Workshop on Tef Genetics and Improvement, Debre Zeit, Ethiopia, 16-19 October 2000.

Klosterboer,A.D. and Turner.F. T. 2002. Rice production guidelines. Texas Cooperative Extension, USA.63 pp.

Lafarge.T, Tubana.B and Pasuquin.E.2004.Yield advantage of hybrid rice induced by its higher control in tiller emergence. In: proceedings of the 4th International Crop Science Congress. May 2004, pp. 16-17, Brisbane, Australia.

Lloveras.J, Lopez.A , Ferran.J, Espachs .S and Solsova.J. 2001. Bread making quality of wheat and soil nitrate as affected by nitrogen fertilization in irrigated Mediterranean conditions. *Agron. J.* 93: 1183-90.

Mehdi.P.K., Roghayyeh.Z.M., Shahzad.J.S.and Ajid.K. 2010. Interaction effect of plant densities and nitrogen fertilizer on durum Wheat. *American-Eurasian J. Agric. & Environ. Sci*., 9 (3) 263-268, 2010.

Mekonnen Asrat. 2005. Response and uptake of barley (*Hordem irregulare* L.) to Different Rates of organic P and N fertilizer. M.Sc. Thesis. Haramaya University. Haramaya. 63p

Minale Liben, Alemayehu Asefa, Tanner.D. G. and Tilahun Tolessa, 1999. The response of bread wheat to N and P application under improved drainage on Bichena Vertisols in North-Western Ethiopia *Agronomy Journal*, 94 : 1-6

Mugwe.J., Mugendi.D., Kungul.J. and Mucheru.M. 2007. Effect of plant bio mass,manure and inorganic fertiliser on maize yield in the central highlands of Kenya. *African Crop Science Journal 15* (3): 111 - 126.

Osman.A, Coverdale.S.M., Ferguson.R, Watson.K, Fox.G, Hamilton.S.E. and Dersey.J. 2001. The causes of low barley protein modification. Proceedings of the 10th Australian Barley Technical Symposium, 15 November 2001, Canberra, Australia.

Rashid.A, Khan.U.K. and Khan.D.J. 2007. Comparative effects of verities and fertilizer levels on barley (*Hordum vulgare* L.). ISSN: 1814-9596, Pakistan.

Shebedino Woreda Agriculture and Rural Development Office (SWARDO), 2013.Unpabelished

Tareke Berhe and Nigusse Zena, 2008. Results in a trial of System of Tef Intensification (STI) at Debre Zeit. In: Proceedings of Annual Research Review Workshop, May 2008, pp. 16-17, Debre Zeit, Ethiopia.

Tareke Berhe. 2009. Recent Developments in tef, Ethiopia's most important cereal and gift of the world. CIIFAD Forum Seminar, 15 November 2009, 23 pp, Addis Abeba.

Taylor and Francis. 2005. Root Growth, Nodulation, Grain Yield, and Phosphorus Use Efficiency of Lentil as Influenced by Phosphorus, Irrigation, and Inoculation. *Saskatchewan Journal of Food and Agriculture.*89 (2): 13-14.

Thakur.A.K., Roychowdhury.S, Kundu.D.K. and Singh.R. 2004. Evaluation of planting methods in irrigated rice.Water technology centre for Eastern Bhubaneswar Orissa, India. *Journal of Agricultural Sci*ence 50(6): 31-49.

Tiruneh, K. 2000. Genotype × Environment Interaction in Tef. In: Hailu,T., Getachew, B. and Sorrells,M.(eds.). Narrowing Rift: Tef Research and Development. *Proceeding of International Workshop on Tef Genetics and Improvement*, October 2000, 45pp, Addis Ababa, Ethiopia.

Vaughan.B., Westfall.D.G . and Barbarick .K.A. 1990. Nitrogen rate and timing effects on winter wheat grain yield, grain protein, and economics. *Prod. Agric. J.* 3:324-328.

Wakene Tigre. 2010. The effect of NP fertilizers on yield and yield components of barley (*Hordeum vulgare* L.). MS.c. Thesis. Hawasa University, Hawasa.66p.

Walkley.A and Black.A. 1934. An examination of Degtjareff Method for Determine Soil Organic Matter and Proposed Modification of the Chromic Acid Titration Method. Soil Science 37:29-38.

Watson D.J**.** 1952. The physiological basis of varieties in yield. *Adv. Agron*., 4:101-145.

Zeleke Kebede.2009. Effect of the Levels of essential elements in three tef [*Eragrostis tef* (*Zucc*.) Trotter] varieties. Annual Research Review Workshop, June 2009, pp 36-40, Addis Ababa University, Addis Ababa, Ethiopia.

7. APPENDIX

Appendix Table 1:- Mean monthly total rainfall (mm) of Shebedino, 2003 – 2012.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean	Total
2003	52.5	2.4	129.1	119.6	85.2	91.7	76.6	190.4	83.2	37.3	0.0	51.5	76.6	**919.5**
2004	30.4	2.0	78.2	179.1	40.4	110.5	107.8	76.1	85.5	53.4	6.2	51.8	68.5	**821.4**
2005	46.2	94.2	42.0	83.1	81.5	75.7	75.4	114.9	116.0	57.1	94.2	15.3	74.6	**895.6**
2006	81.1	7.7	120.9	156.0	144.5	73.2	150.9	61.3	117.2	28.4	46.0	10.4	83.1	**997.6**
2007	1.7	9.0	139.2	145.9	74.4	108.0	171.1	169.3	194.9	56.9	79.2	48.3	99.8	**1197.9**
2008	18.0	55.0	76.4	112.0	166.1	225.4	129.1	104.3	233.8	32.7	3.7	0.0	96.4	**1156.5**
2009	33.7	8.3	3.4	57.8	121.0	118.2	120.5	123.5	160.0	66.1	97.1	5.8	76.3	**915.4**
2010	32.8	9.0	60.3	45.6	103.1	51.6	92.6	112.0	81.7	41.6	4.1	69.9	58.7	**704.3**
2011	26.6	58.4	124.8	96.1	173.5	53.1	132.5	136.6	96.1	53.1	32.0	56.0	86.6	**1038.8**
2012	2.3	7.1	55.5	73.7	193.6	65.5	150.5	155.2	125.5	5.5	88.2	0.2	76.9	**922.8**
Mean	**32.5**	**25.3**	**83.0**	**106.9**	**118.3**	**97.3**	**120.7**	**124.4**	**129.4**	**43.2**	**45.1**	**30.9**	**79.7**	**957.0**

Source: National Meteorology Agency Hawassa Branch, 2013.

Appendix Table 2:- Monthly average minimum temperature of Shebedino, 2003– 2012

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Mean**
2003	12.4	11.8	14.0	13.5	14.8	14.5	14.3	14.2	13.4	12.8	9.8	13.2	**13.2**
2004	11.8	11.6	13.2	14.3	14.2	14.3	14.6	14.7	14.0	11.9	11.2	10.4	**13.0**
2005	12.9	11.5	12.2	14.7	13.2	13.9	14.0	14.3	13.6	11.5	11.6	11.4	**12.9**
2006	11.3	11.4	13.8	14.0	15.0	14.6	14.2	14.7	14.4	13.1	9.5	7.8	**12.8**
2007	11.8	12.4	13.8	14.6	13.9	14.3	15.0	14.7	14.5	14.2	11.4	12.4	**13.6**
2008	12.7	12.9	12.4	14.2	14.8	15.0	14.8	14.6	14.3	11.1	10.9	9.0	**13.1**
2009	10.5	11.6	11.4	14.1	14.6	14.4	14.9	14.5	14.2	13.0	11.1	10.3	**12.9**
2010	11.8	12.4	12.9	14.3	14.4	13.9	14.2	14.7	14.8	13.2	10.7	13.6	**13.4**
2011	13.0	15.3	14.7	15.6	16.3	15.1	15.2	15.3	14.4	13.5	11.1	10.9	**14.2**
2012	12.6	11.8	13.4	14.3	15.1	15.3	14.7	14.9	14.7	12.3	13.0	10.0	**13.5**
Mean	**12.1**	**12.3**	**13.2**	**14.4**	**14.6**	**14.5**	**14.6**	**14.7**	**14.2**	**12.7**	**11.0**	**10.9**	**13.3**

Source: National Meteorology Agency Hawassa Branch, 2013

Appendix Table 3:- Monthly average maximum temperature of Shebedino, 2003 – 2012

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
2003	28.2	30.9	28.8	28.6	27.6	25.7	26.3	25.3	26.1	28.3	29.8	28.2	27.8
2004	28.4	31.3	30.6	28.1	28.3	25.6	24.2	24.9	26.0	28.2	29.3	27.2	27.7
2005	28.9	28.7	30.2	27.3	28.6	25.9	25.3	25.5	25.5	26.7	28.6	28.6	27.5
2006	28.9	31.5	30.0	29.4	25.9	25.6	24.6	25.7	26.0	27.3	28.0	28.5	27.6
2007	30.1	31.3	29.3	27.3	27.7	26.2	24.5	24.7	25.2	26.7	27.6	27.5	27.3
2008	28.5	29.2	30.0	28.2	27.7	25.3	24.6	24.2	25.1	26.7	27.8	27.9	27.1
2009	29.5	29.4	31.5	29.4	26.3	25.6	24.4	24.8	25.7	26.6	26.6	27.8	27.3
2010	28.4	30.0	31.3	29.2	29.0	27.7	26.0	26.0	26.3	27.5	29.5	28.1	28.3
2011	28.5	28.4	27.7	28.0	26.9	26.2	24.4	25.0	25.3	27.7	28.7	28.2	27.1
2012	28.7	30.6	30.2	30.7	27.6	26.2	25.6	24.6	25.3	28.2	27.8	27.6	27.8
Mean	**28.8**	**30.1**	**30.0**	**28.6**	**27.5**	**26.0**	**25.0**	**25.1**	**25.6**	**27.4**	**28.4**	**28.0**	**27.5**

Appendix Table 3:- Monthly average maximum temperature of Shebedino, 2003 – 2012

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
2003	28.2	30.9	28.8	28.6	27.6	25.7	26.3	25.3	26.1	28.3	29.8	28.2	27.8
2004	28.4	31.3	30.6	28.1	28.3	25.6	24.2	24.9	26.0	28.2	29.3	27.2	27.7
2005	28.9	28.7	30.2	27.3	28.6	25.9	25.3	25.5	25.5	26.7	28.6	28.6	27.5
2006	28.9	31.5	30.0	29.4	25.9	25.6	24.6	25.7	26.0	27.3	28.0	28.5	27.6
2007	30.1	31.3	29.3	27.3	27.7	26.2	24.5	24.7	25.2	26.7	27.6	27.5	27.3
2008	28.5	29.2	30.0	28.2	27.7	25.3	24.6	24.2	25.1	26.7	27.8	27.9	27.1
2009	29.5	29.4	31.5	29.4	26.3	25.6	24.4	24.8	25.7	26.6	26.6	27.8	27.3
2010	28.4	30.0	31.3	29.2	29.0	27.7	26.0	26.0	26.3	27.5	29.5	28.1	28.3
2011	28.5	28.4	27.7	28.0	26.9	26.2	24.4	25.0	25.3	27.7	28.7	28.2	27.1
2012	28.7	30.6	30.2	30.7	27.6	26.2	25.6	24.6	25.3	28.2	27.8	27.6	27.8
Mean	**28.8**	**30.1**	**30.0**	**28.6**	**27.5**	**26.0**	**25.0**	**25.1**	**25.6**	**27.4**	**28.4**	**28.0**	**27.5**

Source: National Meteorology Agency Hawassa Branch, 2013

Appendix Table 4:- Analysis of variance for crop phenology of tef.

Source	DF	Days 50% emergence	50% Head	90%Maturity
Rep	3	0.18^{ns}	0.03^{ns}	0.81^{ns}
Sm	1	683.45***	25.01***	7.91**
Ft	4	54.83***	26.21***	17.42***
Sm*Ft	4	2.48^{ns}	0.48^{ns}	0.56^{ns}
Error	27	76.10	6.85	6.85
CV		4.32	**1.87**	**1.84**

** and *** significant at 0.01 and 0.001 Probability level, respectively. Sm= sowing method, Ft = Time of Fertilizer,

Appendix table 5:- Analysis of variance for growth of tef

Source	DF	PH_1	PH_2	GR_1	PH_3	GR_2	PH_4	GR_3	NT	PL	PN
Rep	3	0.57^{ns}	0.13^{ns}	0.20 ns	0.32^{ns}	0.42 ns	0.28^{ns}	0.95^{ns}	1.02^{ns}	0.53^{ns}	0.09^{ns}
Sm	1	13.04**	31.6***	7.14*	28.10***	0.01 ns	17.55***	0.12^{ns}	91.51***	39.02***	84.52***
Ft	4	14.09***	14.3***	2.95 ns	18.48***	0.92 ns	15.63***	1.71 ns	94.98***	41.75***	138.74***
Sm*Ft	4	1.51^{ns}	0.60^{ns}	1.10 ns	1.38^{ns}	0.65 ns	0.92^{ns}	1.24^{ns}	14.47***	3.27^{ns}	3.39^{ns}
Error	27	6.43	7.63	0.63	2.00	0.63	7.05	1.23	54.44	18.39	54.4
CV		**14.00**	**15.10**	**31.28**	**7.77**	**17.54**	**2.54**	**11.3**	**17.09**	**5.86**	**5.54**

*, **&*** significant at 0.05, 0.01 and 0.001 Probability level, respectively. Ns= non significant, Sm =Sowing method Ft = Time of fertilizer application, CV= Coefficient of Variations, PH1= Plant Height 20 days after emergence PH_2= Plant Height 40 days after emergence, $PH_{3=}$ Plant Height 60 days after emergence and $PH_{4=}$ Plant Height 80 days after emergence, $GR_{1=}$ first growth rate, $GR_{2=}$ second growth rate, $GR_{3=}$ thread growth rate, NT= Number of Tillers, PL= Panicle Length and PN=Panicle Number.

Appendix Table 6:- Analysis of variance for yield and yield components of tef

Soure	DF	TBM (Kg ha^{-1})	SY(Kg ha-^{1})	GY (Kg ha^{-1})	TSW(g)	HI
Rep	3	0.27^{ns}	0.39^{ns}	0.26^{ns}	0.21^{ns}	0.97^{ns}
Sm	1	19.03***	4.09^{ns}	20.21***	285.46***	7.66*
Ft	4	24.71***	3.07*	26.70***	360.10***	8.57***
Sm*Ft	4	1.81^{ns}	1.09^{ns}	1.90^{ns}	39.38***	3.67*
Error	27	10.49	1.83	11.28	157.00	4.96
CV		**19.5**	**17.41**	**19.93**	**10.5**	**4.3**

,* ** &*** significant at 0.05 and 0.01 Probability level, respectively and ns= non significant. Sm =Sowing method, Ft = Time of fertilizer application, TBM = Total biomass, SY = straw yield ,TSW = Thousand Seed Weight, GY = Grain Yield and HI= Harvest Inde