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Effect of Nitrogen Fertilizer Rates and Varieties on Yield and Yield Components of Teff (*Eragrostis tef* (Zucc.) Trotter) in Abbay Chommen District, Western Ethiopia

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Abstract: Teff is a highly valued crop in the national diet of Ethiopians. However, its productivity is constrained by low plant-available soil nitrogen due to depleting soil organic matter content and minimum usage of improved variety by smallholder farmers in the area. This problem is compounded by low rates of N fertilizer applications and cultivating of local varieties teff in the country. This in view a field experiment was carried out during the 2019/2020 cropping season on farmers field in Abbay Chommen district with the objective to determine the effects of nitrogen fertilizer rates and varieties on yield and yield components. The treatments consisted of four levels of nitrogen (18, 36, 50 and 66 kg N ha^{-1}) and three varieties (Guduru, Gimbichu and Tseday). The experiment was laid out as a randomized complete block design in factorial arrangement with three replications. The main effect of N fertilizer rate significantly affected mean number of effective tillers and number of total tillers of teff. Mean number of effective tillers of teff were highly significant ($p<0.01$) affected by main effects varieties. Increasing nitrogen level beyond 50 kg ha^{-1} was increasing yield component of teff. Grain yield of teff had significantly and positive correlated with dry biomass yield (0.54) and harvest index (0.80). Dry biomass yield of teff had significantly positive correlation with straw yield (0.88). Straw yield of teff was significantly negatively correlated with harvest index (-0.50). Gimbichu and Guduru varieties of teff had responded to nitrogen rate and recommended for teff production in Abbay Chommen district and similar agroecologies.

Key words: Teff · Variety · Nitrogen · Fertilizer Rate

INTRODUCTION

Teff (*Eragrostis tef* (Zucc) Trotter) is a small seeded cereal indigenous to Ethiopia and occupies about 22.6% of the total cereals land [1]. Teff in Ethiopia stands first in area coverage and second in total annual production next to maize and ranks the lowest yield compared with other cereals grown in Ethiopia [2]. Compared to other cereals, teff has broad adaptation to the heavy, water-logging, clay soil areas of the Ethiopian highlands and teff in general is resilience to marginal areas [3]. It has the largest value in terms of both production and consumption in Ethiopia [4, 5]. Teff has both cultural and economic value for Ethiopian farmers. Currently it is among the cash crops and has been attracting an export market due to its nutritional value and is believed to be gluten free. Teff straw, besides being the most appreciated feed for cattle, is also used to reinforce mud and plaster the walls of house and local grain storage facility called *gotera* [6, 7] The teff straw is highly preferred by cattle over the straw

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of other cereals and demands high prices in the markets. It also serves to reinforce mud and plaster the wall in local house construction [8].

Teff is consumed in the form of *injera,* porridge and fermented or un-fermented non-raised breads "*kita*" and "*anebabero*"), native beer, "*talla*" and more alcoholic cottage liquor, "*katikalla*" or "*arakie*" [9]. Teff grain contains 14-15% proteins, 11-33 mg iron and 100-150 mg calcium and is rich potassium and phosphorous [10]. Furthermore, Asrat and Frew [11] reported that the carbohydrate content of teff ranges from 72.1-75.2%, protein 8.1-11.1% and ash 2.5-3.2%; the major component of ash being iron. They also reported that teff has got high lysine content compared to all cereals except rice and oats. Teff has got many prospects outside of Ethiopia due to its gluten freeness, tolerance to biotic and a biotic stress, animal feed and erosion control quality. Teff has got many prospects outside of Ethiopia due to its gluten freeness, tolerance to biotic and a biotic [12] stress, animal feed and erosion control quality [13]. Moreover, the conservation and utilization of teff genetic resources, offer a reliable basis for enhancing food security and developing crop diversification in the moisture stress and challenging agroecological areas of the country [9].

Despite its importance the productivity of teff is very low as compared its potential and research field yield due to lodging, poor crop management practices, low soil fertility, insect pests and weeds are some of the major once. Development of improved and appropriate agronomic practices (seeding rate, seeding methods, seedbed preparation, fertilizer rate and time of application) would greatly contribute for higher productivity of the crop [14]. The most common way of planting teff is by broadcasting method with higher seed rate. Tarekegne [14] reported teff yield could be improved by two to three-folds in lower seed rate levels by broadcast sowing method. . Most of the Ethiopian soils are low nutrient content due to erosion and absence of nutrient recycling. On the contrary, most of the areas used for production of grains especially teff, wheat and barley fall under the low fertility soils . Declining soil fertility has been recognized as one of the major causes for low crop productivity, especially for cereals [13]. This can be seen from the number of extension initiatives implemented and the institutional structures that have been established to promote fertilizer use in Ethiopia since 1950's, Eyasu [15].

The nitrogen use efficiency of plant depends on several factors including application time, application rate of nitrogen fertilizer, cultivar and climatic conditions [16]. The management of the time of nitrogen application is essential to ensure sustained nutrition at the end of vegetative growth. 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 [17]. Blanket recommendations, regardless of considering the physical and chemical properties of the soil as well as application of full dose at one time do not lead to increase the crop already very low productivity in the country. The crop responds differently to fertilizer rates of fertilizers depending on soil type and cultivars [18].

There are several varieties of teff cultivated in wider agroecologies of Ethiopia which could not have similar performance elsewhere. These varieties are classified as early, intermediate and late based on their maturity period. Tiruneh [19] reported that differential adaptation of teff varieties to different localities. He further stated that intermediate maturing varieties are preferred to both early and late maturing varieties in areas characterized by low moisture. Hence, varieties that perform best in highlands might not perform well in low lands and vice versa. Similarly, the performance of farmers' landraces and modern improved varieties also differ greatly. Moreover, broadcasting methods requires additional seed rate compared to row sowing method thus increases cost of production [20].

The national blanket recommendation of 64 kg N ha^{-1} fertilizer rate for Vertisols and other soil types across the country [21]. Fertilizer recommendations are dynamic and change with time due to changes in soil nutrient status [22]. Since, teff is the staple food of most Ethiopian people, the present production system cannot satisfy the consumers' demand because Ethiopian farmers use traditional and backward system which is not supported by modern technology due to small size of the grain and how easily it is lost if dropped. This means the local people use un recommended rate with a broadcasting system rather than using low seed rate with row sowing. Nitrogen fertilizer application, which is not supported by modern technology, can have adverse impacts on teff production and productivity. This is because local farmers use local teff variety with a low or maximum nitrogen fertilizer application rather than using improved variety with optimum rate of nitrogen fertilizer application. Thus, evaluating the response of teff varieties and N fertilizer application rates is necessary to limit gap in teff productivity. Therefore, this study aimed to determine the effects of nitrogen fertilizer rates on yield and yield components teff varieties in Abbay Chommen district.

MATERIALS AND METHODS

Description of Study Area: The field experiment was conducted during the 2019/2020 cropping season in Kolobo kebele, Abbay Chommen District, Horro Guduru Wollega Zone of Oromia National Regional State. Geographical it lies 10°59' 333'' N latitude and 32°28' 66'' East longitude with an altitude of 2354 meter above sea level and 8% slope. The area is characterized by Mon Modal rain fall pattern and gets rain from May to October. rain fall is 1300-1329 mm. The minimum and maximum air temperature of the area is 21 and 30°, respectively. The district is suitable for the production of different crops and livestock. The dominant crops growing around the study area are maize, teff, wheat, Niger seed, bean, field pea and barely [23].

Experimental Materials: Three teff varieties *Gimbichu* (DZ-01-899) and *Tsaday* (DZ-cr-37) and Guduru obtained from Debre Zeit research center (Table 1). Four levels of nitrogen (18, 34, 50 and 66 kg N ha^{-1}) urea source was used.

Experimental Treatments and Design: The treatments consisted of four levels of nitrogen 18 (100 kg NPS), 34 (100 kg NPS, 34.7 kg Urea), 50 (100 kg NPS, 69.5 kg Urea) and 66 (100 kg NPS , 104.3 kg Urea) N ha^{-1}) and three teff varieties (Guduru, Gimbichu and Tsaday). Four nitrogen rates were factorial combined with three varieties of teff. The total treatment combinations were 12 treatments. The experiment was laid out a randomized complete block design with factorial arrangement in three replications.

Experimental Procedure: The experimental field was prepared by using oxen plow and plowed four times, before planting. The experimental land used were cropped to Niger seed in the previous season. The experimental plot using local plow pulled by oxen according to farmers' local practice. Accordingly, the field were plowed three times before sowing and the last ploughing was done as farmers practice before sowing to make it ready for compaction and to bury early emerging weeds. After seedbeds was prepared, seeds were manually drilled.

Data Collection

Soil Sampling and Analysis: Pre-soil sampling was collected from grid of the experimental plots in a diagonal pattern from the depth of 0-20cm before planting and application of treatments. The collected soil sample was composited to one soil sample. The composited soil samples were dried, ground using a pestle and a mortar and allowed to pass through a 2 mm sieve and analyzed for the selected physicochemical properties mainly OC, TN, soil pH, available phosphorus, cation exchange capacity (CEC) and textural analysis using standard laboratory procedures. Organic carbon content was determined by the volumetric method [24] as described in Food and Agriculture Organization of the United Nations [25]. Total nitrogen was analyzed by Micro-Kjeldhal digestion method with sulphuric acid. The pH of the soil was determined according to FAO [25]. The cation exchange capacity (CEC), was measured after saturating the soil with 1N ammonium acetate (NH_4OAc) and displacing it with 1N NaOAc . Available phosphorus was determined by the Olsen's method using spectrophotometer [26]. Particle size distribution was done by hydrometer method (differential settling within a water column) according to FAO [25] using particles less than 2 mm diameter.

Crop Parameters

Panicle Length: It was 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.

Number of Total Tillers per m^2: It was counted at physiological maturity by counting all the tillers in 0.5 m length from two central rows of the net plot areas.

Number of Effective Tillers per m^2: It was counted from tillers producing panicle an area of 0.25 m x 0.25 m plants by throwing a quadrant into the middle portion of each plot.

Dry Biomass: It was measured by harvesting the whole above ground plant parts including, leaves, stems and seeds converted as kg ha^{-1}.

Grain Yield: It was measured from the grains harvested from the net plot area after threshing and sun-drying to about 12.5% moisture content. It was converted to grain in kg/ha.

Straw Yield: It was measured after threshing and measuring the grain yield by subtracting the grain yield from dry biomass yield.

Table 1: Description teff varieties used for the experiment

				Grain yield (Ku/ha)	
No	Varieties	Year of Released	Seed color	Research field	Farmers field
1	DZ-01-899(Gimbichu)	2006	White	18-20	16-18
2	DZ-CR-37(Tseday)	2005	White	16-18	14-16
3	DZ-01-1880 Guduru	2006	White	16-20	15-17

Harvest Index: It was calculated by dividing grain yield by the total above ground biomass yield and multiplying by 100.

Data Analysis: All agronomic and soil data were collected and properly managed using the Excel computer software and analyzed using SAS computer software package version 9.4 [27]. Mean separation was computed using Least Significance Difference (LSD) at 5 % probability level [28]. Pearson correlation analysis was performed to determine relations between phonological, growth parameter and yield and yield components of teff as influenced by varieties and nitrogen fertilizer rates.

RESULTS AND DISCUSSION

Pre Soil Physicochemical Properties of The Experimental Site: The pre soil physicochemical properties of the are indicated in Table 2. The pre sowing soil analysis showed that the experimental soil has a pH (H_2O) of 5 found in very strongly acidic [29]. FAO [30] reported that the preferable pH ranges for most crops and productive soils are 4 to 8. Thus, the pH of the experimental soil is within the range for productive soils. The textural class the soil of Kolobo kebele was sandy clay with composition of 27.3% clay, 14.3% silt and 58.3% sand (Table 2). The CEC of the was 18.67 cmole kg^{-1} soil found in medium range [29]. Total nitrogen and available phosphorus content of the experimental area were 0.126% and 13.11 mg kg^{-1}found in low and medium range [29]. The soil has organic carbon content of 1.97% found in low range London [29], Bruce and Rayment [31], Charman and Roper [32].

Panicle Length: Panicle length of teff is one of the yield attributes of teff that contribute to grain yield. Teff with higher panicle length could have higher grain yield. Mean panicle length of teff was significantly (P< 0.01) affected by the main effect of N fertilizer application but varieties and their interaction were non-significant(Table 3). Significantly higher (41cm) mean panicle length of teff was obtained with application of 66 kg N ha^{-1} fertilizer rate while the lowest (35 cm) mean panicle length was obtained from control. Getahun *et al.* [33] reported that the mean panicle length of teff was significantly affected by application of nitrogen fertilizer rates and longer (39.9 cm) panicle length was obtained from the application of 69 kg N ha^{-1} while the shortest (31.6 cm) was recorded from the control. They further stated that increasing N from 0 to 69 kg N ha^{-1} increased panicle length by about 26.3%, compared to the control.

Also, Mulugeta [34] reported that increased application of N caused increased panicle length of teff. Likewise, Bekelu and Arega [35] indicated that sufficient N at right time resulted in rapid growth and heading. Tamirat [36] found that application of nitrogen rate significantly affected mean panicle length of teff and maximum panicle length (44.9 cm) was recorded with application of 97.5 kg N ha^{-1} fertilizer rate, which was 23.4, 16.35 and 8.9% higher than the control treatment, 32.5 and 65 kg N ha^{-1}, respectively. He further stated that increment in panicle length due to higher N application might be the better N position of the plant during the panicle growth period. Alemu *et al.* [37] reported that the mean panicle length teff was significantly affected by NP fertilize rates and increased with increasing NP fertilizer rates with higher panicle length (34.34 cm) was recorded with application of 64/20 kg NP ha^{-1}. Awan *et al.* [38] reported the highest panicle length found in treatments receiving higher nitrogen rates.

Number of Effective Tillers: Crops with higher number of effective tillers could have higher grain yield, straw yield and biomass yield. The number of effective tillers counted at 0.0625 m2 was highly significantly ($P < 0.05$) affected by main effects N fertilizer rate, varieties and the interaction effect of the two factors es (Tables 3 and 4). The mean number of effective tillers per plant of teff was significantly increased in response to increasing rate of nitrogen fertilizer to both varieties. The maximum (22.5) number of effective tillers per plant of teff was recorded with application of 66 kg N ha^{-1} and lower (16.4) number of effective tillers per plant of teff with application of 18kg N ha^{-1} nitrogen. Similarly, Tekalign *et al.* [39],

Table 2: Pre soil physicochemical properties the experimental site

Physical and chemical properties	Values
pH(1:2.5H_2O)	5
Organic matter (%)	3.40
Organic Carbon (%)	1.97
Cation Exchange Capacity (meq/100 g soil)	18.67
Total Nitrogen (%)	0.126
Available Phosphorous (mg kg^{-1})	13.11
Sand (%)	58
Silt (%)	14
Clay (%)	27
Textural class	Sand clay

Table 3: Effects of Nitrogen fertilizer rates and varieties on panicle length, number of effective tillers and number of total tillers per m^2 Teff in Abbay Chommen District

Nitrogen ($Kgha^{-1}$)	Panicle length (cm)	Number of effective tillers per m^2	Number of total tillers per m^2
18	35.1^d	16.4^c	29.7^c
36	37.3^c	18.7^b	31.4^{bc}
50	39^b	21.4^a	33.1^{ab}
66	41.1^a	22.5^a	34.6^a
LSD(5%)	0.9	1.7	2.3
Varieties			
Guduru	34.7	17.9^b	33
Gimbichu	38.4	20.5^a	32
Tseday	38.4	21^a	31.5
LSD(5%)	NS	1.4	NS
CV(%)	2.6	8.7	7.0

Means followed by different letter(s) in a column and rows are significant at 5% level of probability, NS=non-significant

Table 4: Interaction effects of nitrogen fertilizer rates and varieties on number of effective tillers per m^2 Teff in Abbay Chommen District

	Number of effective tillers per m^2			
	Nitrogen rate (kg ha^{-1})			
Varieties	18	36	50	66
Guduru	15.33g	17.33efg	19.67de	19.33def
Gimbichu	17.33efg	19.00def	23.00ab	22.67bc
Tseday	16.67fg	20.00cde	21.67bcd	25.67a
LSD (5%)	2.9464			
CV (%)	8.7			

Means followed by different letter(s) in a column and rows are significant at 5% level of probability

Legesse [40], Haftamu *et al*. [41] reported significantly higher number of tillers in response to the application of high N rate in teff. Botella *et al*. [42] reported that stimulation of tillering with high application of nitrogen rate might be due to its positive effect on cytokinin synthesis. Tamirat [36] found that application of nitrogen fertilizer significantly (P<0.05) affected number of effective tillers of teff and successive increase in nitrogen application rates, the number of effective tillers also increased significantly and maximum numbers of effective tillers (13.79) were obtained with the application of 97.5 kg Nha^{-1}, which was higher by 56.3, 38.22 and 11.53%, over the control treatment, 32.5, and 65 kg N ha^{-1}, respectively. Okubay *et al*. [18] reported that the mean number of fertile tillers per plant of teff was increased linearly with increasing rate of applied nitrogen and lower (9) number of fertile tillers per plant without N to 22.67 with application of 69 kg N ha^{-1}. Also, Genene [43] who reported higher tillering and maximum survival percentage of tillers with increasing N application rate in bread wheat.

The number of effective tillers per m^2 of teff was significantly (P<0.05) different among varieties of teff (Table 3). Significantly higher (21 and 20.5) mean number of effective tillers per m2 of teff was obtained from Guduru and Gimbichu varieties of teff. Similarly, Amare and Adane [44] found that significant difference mean number of effective tillers m-2 of teff were observed between varieties used in black soil of Sirnka.

The number of effective tillers was significantly (P < 0.05) affected interaction effect of the varieties and nitrogen fertilizer rates (Table 4). The maximum (25.87) number of effective tillers was recorded with application 66 kg N ha from Tseday variety followed by Gimbichu variety (22.67) at the same level of nitrogen application and the lowest (19.33) number of tillers per plant of teff was recorded from Guduru variety (Table 4). Similarly, Fayera *et al*. [45] found that the highest productive tillers of teff (26 tillers per plant) under the application of 200 kg ha^{-1} NPKSZnB blended (14 N, 21 P_2O_5, 15 K_2O, 6.5 S, 1.3 Zn and 0.5 B) + 23 kg N ha^{-1} fertilizer. Also, Seifu [46] reported that the highest number of productive tillers (1189 plant m^{-2}) was obtained with the application of blended fertilizer 150 kg NPSB ha^{-1}, while the lowest number of total tillers (761 plant m^{-2}) was obtained from the control plots. In contrary, Fenta [47] stated that number of productive tillers was not significantly influenced by the main effect of cultivars as well as by interaction effects of cultivars and N fertilizer rates.

Number of Total Tillers per Plant: The total tillers per plant of teff was significantly ($P<0.05$) affected by main effects of nitrogen rates but non-significant due to varieties and their interaction of the two factors (Table 3). The highest total tillers per plant of teff was recorded with application and 50 kg N ha (Table 3) number per plant of teff increased as the rate of N increased. The increase in numbers of total tillers with the increase in N rate may be due to the enhancing capacity of N on tillering cereal crops including teff. Similarly, Kumela and Thomas [48] reported that N stimulates tillering probably due to its effect on cytokinin synthesis. Likewise, Haftamu *et al.* [41]: Bekelu and Arega [35] reported that numbers of tillers of tef increased with increased rates of N fertilizer.

Dry Biomass: The mean dry biomass yield of teff was highly significantly ($P < 0.01$) influenced by the main effect of nitrogen fertilizer rate and interaction effect of the two factors, but non-significant affected by variety (Tables 5 and 6). Dry biomass yield was generally increased significantly with the increase in the rate of nitrogen across the three varieties. Significantly higher 9926 and 9578 kg ha^{-1} dry biomass of teff were obtained with application of 50 and 36 kg N ha^{-1} fertilizer rate (Table 5). Similarly, Fenta [47] found that significantly higher fresh biomass yield (1057 and 890 g per plot) was obtained with application of 69 kg N ha^{-1} to Quncho and Jimma local varieties of teff respectively. Similarly, Legesse [40]; Mitiku [49] and Haftamu *et al.* [41] reported that further increases in N application for teff resulted in higher total biomass yield. Likewise, Tamirat [36] found that application of N fertilizer rates was highly significantly affected the mean dry biomass yield of teff and higher biomass yield (12608 kg ha^{-1}) was achieved with application of 97.5 kg N ha^{-1}while the lowest biomass (8374 kg ha^{-1}) was obtained from the control. Increasing the rate of NP from 0/0 to 64/20 kg NP ha^{-1}, the dry biomass yield was also increased to 5.274 t ha^{-1} from 2.246 t ha^{-1} indicating 135 % higher than the control [37]. Dutta *et al*. [50] found the highest biomass yield by applying higher nitrogen fertilizer rates. The increment in biomass yield might be due to high nitrogen might be high N application positively causes high vegetative growth and enlargement of stem cells that consequently increased biomass yield [36].

The interaction of varieties with nitrogen fertilizer rate was significantly affected mean dry biomass yield of teff (Table 6). The highest biomass yield (10333 and 9889 kg ha^{-1}) was obtained with application of 50 kg N ha^{-1} to Tseday and Gimbichu varieties of teff respectively. The lowest (8222 kg ha^{-1}) dry biomass was obtained from Guduru variety with application of 66 kg N ha^{-1} fertilizer rate. Thus, nitrogen application significantly enhanced biomass yield of teff. Likewise, Amanuel *et al*. [51] reported a significant increase in biomass yield of wheat because of increased rate of N application. The application of highest level of N resulted in less biomass yield (2200 kg ha^{-1}) compared to 50 kg N ha^{-1} rate applied in Guduru variety. This might be due to the effect of lodging resulted from too high amount of N fertilizer that encourage vegetative growth and height leading to lodging before the translocation of dry matter to economic yield since biomass includes the economic yield. In contrary, Haftom *et al*. [41] found the highest biomass yield of teff in response to the application of 92 kg N ha^{-1}.

Grain Yield: The mean grain yield of teff was significantly ($P<0.05$) affected by main nitrogen fertilizer rates but main effects of variety and interaction of varieties and nitrogen fertilizer rates were non-significantly affected mean grain yield of teff (Table 5). The maximum (2659 kg ha^{-1}) grain yield of teff was recorded from application of 50 kg ha^{-1}. Increased application of N up to 50 kg N ha^{-1} significantly increased grain yield but further increasing N fertilizer rates linearly decreased grain yield of teff. Nitrogen rates of 34 and 50 kg ha^{-1}, did not exhibit significant difference (Table 5). The result is also in line with Haftamu *et al.* [41] who reported application of 69 kg ha-1 gave optimum biomass and grain yields of teff. Also, Tamirat [36] found that mean grain yield teff was significantly affected by the main effects of nitrogen fertilizer rates and higher grain yield (3149 kg ha^{-1}) was obtained from application of 97.5 kg N ha^{-1} and the lowest grain yield (2066 kg ha^{-1}) was obtained from the control. Abebe *et al.* [52] found that application of N had significant ($P \leq 0.05$) effect on the combined mean grain yield of teff with a mean maximum grain yield of 1.2 t ha^{-1}. Also, NFIU [53], Tekalign *et al.* [54], Minale *et al.* [55] reported that application of nitrogen fertilizer significantly enhanced mean gran yield of teff in the highland Vertisols.

Table 5: Effects of varieties and nitrogen fertilizer rates on straw yield, dry biomass grain yield and harvest index of teff in Abbay Chommen District

Nitrogen (Kgha^{-1})	Straw yield (kg ha^{-1})	Dry biomass (kg ha^{-1})	Grain yield (kg ha^{-1})	Harvest index (%)
18	6556b	8704b	2148bc	24.72
36	7078ab	9578a	2500ab	26.17
50	7267a	9926a	2659a	26.89
66	6444b	8556b	2111c	24.63
LSD (5%)	705	737	354	NS
Varieties				
Guduru	6592	8972	2381	26.84
Gimbichu	7000	9294	2294	24.51
Tseday	6917	9306	2389	25.46
LSD (5%)	NS	NS	NS	NS
CV (%)	10.55	8.20	15.30	15.81

Means followed by different letter(s) in a column and rows are significant at 5% level of probability, NS= non-significant

Table 6. Interaction effects of nitrogen fertilizer rates and varieties on dry biomass of Teff in Abbay Chommen District

	Dry biomass (kg ha^{-1})			
	Nitrogen rate (kg ha^{-1})			
Varieties	18	36	50	66
Guduru	8444cd	9667abc	9556abc	8222d
Gimbichu	8889bcd	9511abc	9889ab	8889bcd
Tseday	8778bcd	9556abc	10333a	8556cd
LSD (5%)	1227			
CV (%)	8.20			

Means followed by different letter(s) in a column and rows are significant at 5% level of probability

Table 7: Pearson correlation between yield and yield components of teff due to varieties and nitrogen fertilizer rate in Abbay Chommen district

	PL	NTT	NET	SY	HI	DBY	GYY
PL		0.61**	0.77**	-0.06*	0.09	-0.01	0.09
NTT			0.50**	-0.11	0.07	-0.08	0.02*
NET				-0.09*	0.15	0.04*	0.16
SY					-0.50**	0.88**	0.08
HI						-0.04**	0.80**
DBY							0.54**
GYY							

* and ** = significant at the 0.05 and 0.01 probability level, NTT=Number of Total Tiller, NET= Number of Effective Tiller per plant , PL= Panicle Length, HI =Harvest Index, GY= Grain yield SY= Straw Yield, DBY= Dry biomass yield

Alemu *et al.* [37] found that grain yield of teff was significantly affected by application of NP fertilizer rates and increased with increasing rates of NP fertilizer application. The mean grain yield increased from 0.7 to 1.5 t ha^{-1} across two years with application of nitrogen fertilizer rate [52]. Fissehaye *et al.* [56] reported that higher teff grain yield with application of 69 kg N ha^{-1} on Vertisols. Minale *et al*. [55], Alemayehu *et al.* [57] recommended 60-80 kg N ha^{-1} with 18-20 kg P ha^{-1} for maximum tef production on Vertisols in Northwest Ethiopia. Wakene and Yifru [58] showed that optimal N rates for tef in Ethiopia varied from 15-90 kg ha^{-1} due to diversity in agroecology, climate and soil type and recommended 15-60 kg N ha^{-1} for Nitisols, Luvisols, Fluvisols and Andosols, but 60-90 kg N ha^{-1} for Vertisols. Bekele and Getahun [59] also reported as nitrogen fertilizer increased yield attributes and grain yields of rice.

Straw Yield: The main effects of nitrogen fertilizer rates were significantly (P<0.05) affected mean straw yield of teff but main effects of varieties and interaction of varieties and nitrogen fertilizer rate was non-significantly affected straw yield of teff (Table 5). Significantly higher 7267 and 70078 kg ha^{-1} straw yield of teff were obtained with application of 50 and 36 kg N ha^{-1} (Table 8). Tamirat [36] found that mean straw yield of teff was significantly affected by the main effects of the nitrogen fertilizer rate and higher mean straw yield (9706 kg ha^{-1}) was obtained with application of 97.5 kg N ha^{-1} and the lowest was obtained from the control. The increase in straw yield in response to the application of N fertilizer might be due to the greater availability and uptake of the nutrients by plants, the induction of vigorous vegetative growth with more leaf area and the higher photosynthesis and assimilates production for dry matter accumulation [60]. Straw yield of teff was highly significantly affected by the main effects of NP fertilizer rates application and increased with the increased rate of NP fertilize rates [37].

Harvest Index: Harvest index is the relationship of the economic yield to the total or biological yield expressed as coefficient of effectiveness. Thus, harvest index is the balance between the productive parts of the plant and the reserves, which form the economic yield. The main effects of nitrogen fertilizer rates and Varieties was not significantly affecting harvest index (Table 5). In contrary, Tamirat [36] found that mean the harvest index of teff was significantly affected by the main effects of the nitrogen fertilizer rate and higher harvest index (27.68 and 27.61%) was obtained from application of 32.5 and 65 kg N ha^{-1}, respectively while the lowest harvest index was obtained with application of 97.5 kg N ha^{-1}. Also, Alemu *et al.* [37] found that harvest index of teff was significantly affected by application of NP fertilizer rates and decrease in harvest index with increasing rates of NP fertilizer application.

Pearson Correlation of Yield and Yield Components Due to Rate of Nitrogen and Varieties: The correlation analysis between yield and yield components of teff indicated in (Table 7). Highly significantly correlation coefficients between grain yield and dry biomass yield (0.54) and harvest index (0.80). There were also highly significantly positive correlation coefficients between grain yields of teff and dry biomass yield of teff. Dry biomass yield of teff significantly positive correlation coefficients with straw yield (0.88). Straw yield of teff was significantly and negatively correlated with harvest index (-0.50).

There were highly significantly positive correlation coefficients between number of total tiller and panicle length (0.61). Similarly, Wubante *et al.* [61] reported that grain yield had significant positive correlations with total number of tillers, number of effective tillers and strong correlation with harvest index. Also, Alemate *et al*. [62] reported that grain yield was positively correlated with number of tillers per plant. Also, Hailu *et al.* [63] reported that panicle length one of the major yield attributes of teff that is positively correlated with grain yield. In contrary, Solomon [64] that indicated there is a negative and highly significant correlation between plant height and grain yield and yield components of teff had strongly positive relationship with grain yield of teff that indicated yield components of teff directly influenced the grain yield of teff.

CONCLUSION

The mean number of effective tillers of teff was significantly higher (25.67) with application 66 kg N ha^{-1} from Tseday variety as compared to Guduru and Gimbichu varieties of teff while the lowest number of effective tillers was obtained from with 18 kg N ha^{-1} fertilizer for all three varieties. The mean straw yield, dry biomass, grain yield and harvest index of teff were significantly higher with application of 50 kg N ha^{-1} fertilizer rate. The interaction of varieties with nitrogen fertilizer rate was produced significantly higher dry biomass (10333 kg ha^{-1}) from Tseday variety with application of 50 kg N ha^{-1}. Significantly higher correlation between grain yield and dry biomass yield (0.54) and harvest index (0.80). Dry biomass yield of teff significantly positive correlation with straw yield (0.88). Straw yield of teff was significantly negatively correlated with harvest index (-0.50). Therefore, application of 50 kg N ha^{-1} fertilizer rate gave agronomically higher yield and recommended for teff production in Abay Chommen district and similar agroecologies. However, to give conclusive recommendation nitrogen fertilizer rate for the teff production in the study area further research over location and years should be conducted.

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REFERENCES

1. Kebede, Z., 2009. Levels of Essential Elements in Three Teff [*Eragrostis tef* Zucc.) Trotter] Varieties. Addis Ababa University.
2. Wakjira, T., 2018. Teff Yield Response to NPS Fertilizer and Methods of Sowing in East Shewa, Ethiopia. Journal of Agricultural Sci., 13(2): 162-173.

3. CSA, 2019. Area and production of major crops. Agricultural Sample Survey 2018/19 (2011 E.C.). V 1. Statistical Bulletin. 589. Addis Ababa, Ethiopia.
4. Minten, B., T. Senesshaw, E. Ermias and K. Tadesse, 2013. The Impact of Improved Seed Development: The Success Story of the Quncho Teff Variety, International Food Policy Research Institute (IFPR) and Ethiopian Development Research Institute, Technology Business, Addis Ababa.
5. Teklay, T. and G. Grmay, 2016. Agronomic and economic evaluation of compound fertilizer applications under different Planting methods and seed rate of teff (*Eragrostis tef* (zucc) Trotter) in Northern Ethiopia. Journal of the Dry lands, 6(1): 409-422.
6. Adera, S., 2016. Response of Teff [*Eragrostis tef* (Zucc.) Trotter] to different blended Fertilizer Rates on Vertisols in Jama District, North eastern Ethiopia. M.Sc Thesis, Haramaya University, Haramaya, Ethiopia.
7. Minten, B., E. Tamru, E. Engida and K. Tadesse, 2016, Feeding Africa's cities: The case of the supply chain of teff to Addis Ababa, Econ Dev Cult Change, Forthcoming.
8. Engdawork, A., 2009. Understanding teff: a review of supply and marketing issues. Ethiopia Commodity Exchange Authority, Addis Ababa.
9. Assefa, B., M. Demeke and B. Lanos, 2015. Analysis of price incentives for Teff in Ethiopia for the time period 2005-2012 (Technical Notes Series). Rome: FAO, MAFAP.
10. NAS, 1996. 'Teff' in Lost crops of Africa, Vol. 1 Grains, pp: 215-235.
11. Asrat, W. and T. Frew, 2001. Utilization of teff in the Ethiopian diet, pp. 239-244. In: T. Hailu, B. Getachew and S. Mark (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.
12. Sahlework, Z., 2012. Sate Sahle , Effects of Sowing Methods and Types of Inorganic Fertilizers on Yield and YieldComponents of Tef [*Eragrostis tef* (Zucc.) Trotter] at Boreda District, Southern Ethiopia. M. Sc. ThesisSubmitted to the Department of Plant Sciences School of Grad.
13. Aseffa, A., 2005. Farm management in mixed crop-livestock systems in the Northern Highlands of Ethiopia., PhD Thesis. Wageningen University and Research Center.
14. Tarekegne, B., 2010. Breeding and genetic resources of Teff (*Eragrostis tef*) in Ethiopia. Institute of Agricultural Research, Addis Ababa, Ethiopia.
15. Eyasu, E., 2002. Farmers perceptions of soil fertility change and management. Paper Presented to the Evaluation in the Tropics and Subtropics.
16. Okamoto, M. and K. Okada, 2004. Differential responses of growth and nitrogen uptake to organic of nitrogen four gramineous crops. Journal Experimental Botany, 55(402): 1577-1585.
17. Bekele, H., H. Verkuijl, W. Mwangi and D. Tanner, 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.
18. Okubay, G., G. Heluf and B. Tareke, 2014. Response of teff (*Eragrostis tef*) to different rates of slow release and conventional urea fertilizers in vertisols of southern Tigray, Ethiopia. Advances in Plants & Agriculture Research, 1(5): 190-197.
19. Tiruneh, K., 2000. Genotype × Environment Interaction in Teff. pp: 145-156. In: Hailu Tefera, Getachew Belay and M. Sorrels (Eds.). Narrowing the Rift: Teff Research and Development. Ethiopian Agricultural Research Organization (EARO). Addis Ababa, Ethiopia.
20. Cheng, A., S. Mayes, G. Dalle, S. Demissew and F. Massawe, 2017. Diversifying crops for food an0d nutrition security: a case of teff. Biological Reviews, 92(1): 188-198.
21. Kenea, Y., A. Gezahegn and N. Workneh, 2001. Farming systems research on Teff: Smallholders' production Practices, pp: 9-26. In: Hailu Tefera, Getachew Belay and M. Sorrels (Eds.). Narrowing the Rift: Teff Research and Development. Ethiopian Agricultural Research Organization (EARO). Addis Ababa, Ethiopia.
22. Deckers, J., Y. Teshome, A. Negeri and K. Seyfu, 2001. Teff. In: Raemaekers, R. (Ed.), Crop Production in Tropical Africa. Directorate General for International Cooperation, Brussels, pp: 96-101.
23. ACHDANRO, 2019. Annual Report of Evaluation of Meher Crops, Report Submitted to Horro Guduru Wollega Zone Agricultural and Natural Resource Office, Shambu, Ethiopia.

24. Walkley, A. and C.A. Black, 1934. Estimation of organic carbon by chromic acid titration method. Soil Science, 37: 29-38.
25. FAO, 2008. FAO fertilizer and plant nutrition bulletin: Guide to laboratory establishment for plant nutrient analysis, FAO, Rome, Italy, pp: 203.
26. Olsen, S.R., C.V. Cole, F.S. Watanabe and L.A. Dean, 1954. Estimation of Phosphorus in soils by extraction with sodium bicarbonate. USDA, Circular 939.
27. SAS., 2012. SAS/STAT Software Syntax, Version 9.4. SAS Institute, Cary, NC. USA.
28. Steel, R.G.D., J.H. Torrie and D.A. Dicky, 1997. Principles and Procedures of Statistics, A Biometrical Approach. 3rd Edition, McGraw Hill, Inc. Book Co., New York, pp: 352-358.
29. London, J.R., 1991. Tropical soil manual: a handbook for soil survey and agricultural land evaluation in the tropics and subtropics. Longman Scientific and Technical, Longman Group, UK Ltd. A.
30. FAO, 2000. The State of Food and Agriculture . FAO Agriculture Series. No. 32. Rome, Italy, pp: 353.
31. Bruce, R. and G. Rayment, 1982. Analytical methods and interpretations used by the agricultural chemistry branch for soil and land use surveys. Queensland Department of Primary Industries, Indooroopilly, Queensland.
32. Charman, P. and M. Roper, 2007. Soil Organic Matter. pp: 276-285. In: Charman, P. and B. Murphy (Eds.). Soils, their Properties and Management, 3rd Edition, Oxford University Press, Oxford.
33. Getahun, D., A. Tigist and A. Bekele, 2018. Response of Yield and Yield Components of Teff [*Eragrostis tef* (Zucc.) Trotter] to Optimum Rates of Nitrogen and Phosphorus Fertilizer Rate Application in Assosa Zone, Benishangul Gumuz Region. Ethiopian. Journal. Agricultural. Science, 28(1): 81-94.
34. Mulugeta, G., 2003. Response of Teff [*Eragrostis tef* (Zucc.) Trotter] to applied nitrogen and phosphorus in Vertisols of Raya, Tigray. M.Sc. Thesis, Haremaya University, Haramaya, Ethiopia.
35. Bekalu, A. and A. Arega, 2016. Effect of Seed Rate on Yield and Yield Components of Teff (*Eragrostic tef*) Trotter) at Shebedino, Southern Ethiopia. Journal of Natural Sciences Research, 6(21): 1-11.
36. Tamirat, W., 2019. Effects of Nitrogen Fertilizer Rate and Inter-row Spacing on Yield and Yield Components of Teff [*Eragrostis tef* (Zucc.) Trotter] in Limo District, Southern Ethiopia. International Journal of Plant and Soil Science, 31(3): 1-12.
37. Alemu, A., T. Tamado and A. Jemal, 2016. Effects of compost and inorganic NP rates on growth, yield and yield components of teff [*Eragrotis tef* (Zucc.) Trotter] in Girar Jarso District, central highland of Ethiopia. Journal of Fertilizer and Pesticides, 7: 174. doi:10.4172/2471-2728.1000174.
38. Awan, T.H., R.I. Ali, Z. Manzoor, M. Ahmad and M. Akhtar, 2011. Effect of different nitrogen levels and row spacing on the performance of newly evolved medium grain rice variety, KSK- 133. Journal of Animal and Plant Sciences, 21(2): 231-234.
39. Tekalign, M., E. Teklu and T. Balesh, 2000. Review of soil fertility and plant nutrition research conducted on teff. pp.37-38. In: Proceeding of the International workshop tef genetics and improvement. Addis Ababa, Ethiopia.
40. Legesse, A., 2004. Response of teff [*Eragrostis tef* (Zucc.) Trotter] to applied nitrogen and phosphorus in Sirinka, North Eastern Ethiopia. MSc Thesis, Alemaya University, Alemaya, Ethiopia, pp: 71.
41. Haftamu, G., H. Mitiku and C.F. Yamoah, 2009. Tillage Frequency, Soil Compaction and N-Fertilizer Rate Effects on Yield of Teff [*Eragrostis tef* (Zucc) Trotter] in Central Zone of Tigray, Northern Ethiopia Thesis presented to Mekelle University Ethiopia. Agronomy Journal, 1(1): 82-94.
42. Botella, M.A., A.C. Cerda and S.H. Lips, 1993. Dry matter production, yield and allocation of carbon-14 assimilate by wheat as affected by nitrogen source and salinity. Agronomy Journal, 35(5): 1044-1049.
43. Genene, G., 2003. Yield and quality response of bread wheat varieties to rate and time of nitrogen fertilizer application at Kulumsa, southern Ethiopia. MSc Thesis, Alemaya University, Alemaya Ethiopia.
44. Amare Aleminew and Adane Legas, 2015. Determination of Seed Rate and Variety on the Growth and Yield of Teff in Eastern Amhara Region, Ethiopia. Journal of Biology, Agriculture and Healthcare, 5(5): 27-33.
45. Fayera, A., D. Adugna and M. Muktar, 2014. Evaluation of Teff [*Eragrostis tef* (Zuccagni) Trotter] Responses to Different Rates of NPK Along with Zn and B in Didessa District, Southwestern Ethiopia. World Applied Sciences Journal, 32(11): 2245-2249.
46. Seifu, K., 2018. Effect of rates of blended NPSB and N fertilizers on yield components and yield of teff [*Eragrostis tef* (zucc.) trotter] in Hidhebu Abote District, Central Ethiopia. M.Sc. Thesis Haramaya University, Haramaya, Ethiopia.

47. Fenta, A., 2018. Effect of Tef Variety and Rates of Nitrogen Fertilizer Application on Growth and Yield Components Under Jimma Condition. Journal of Biology, Agriculture and Healthcare, 8(11): 50-59.
48. Kumela, B. and A. Thomas, 2016. Performance of yield attributes, yield and economics of teff (*Eragrostis teff*) influenced by various row spacing, nitrogen and phosphorus fertilizers. African Journal of Plant Science, 10(10): 234-237. Paff, K. and Asseng, S. (2018). A review of teff physiology for developing a teff crop. European Journal of Agronomy, 94:5https://doi.org/ 10.1016/j.eja. 2018.01.008.
49. Mitiku, M., 2008. Effect of Seeding and Nitrogen Rates on Yield and Yield Components of Teff [*Eragrostis tef* (Zucc.) Trotter] at Adet North Western Ethiopia. M.Sc. Thesis Haramaya University, pp: 81.
50. Dutta, D., M.A.R. Sarker, M.A. Samad and S.K. Paul, 2002. Effect of row arrangement and nitrogen level and the yield and yield components of transplant a man rice. Journal of Biological Sciences, 2(10): 636-638.
51. Amanuel, G., G. Kefyalew, D.G. Tanner, T. Asefa and M. Shambel, 2000. Effect of crop rotation and fertilizer application on wheat yield performance across five years at two locations in south-eastern Ethiopia, pp: 264-274. In: The Eleventh Regional Wheat Workshop for Eastern, Central and Southern Africa. Addis Ababa, Ethiopia: CIMMYT.
52. Abebe, G., A. Samuel, T. Habtemariam, T. Tilahun, B. Seid and H. Tadesse, 2020. Fertilizer-nitrogen use optimization for Tef in South Wollo Zone of Ethiopia. African Journal of Agricultural Research, 16(6): 811-818.
53. NFIU, 1993. Wheat results of the FTS, ITS and DSFT, Addis Ababa, Ethiopia.
54. Tekalign, M., E. Teklu and T. Balesh, 2001. Soil Fertility and Plant Nutrition Research on Teff in Ethiopia, pp: 199-200. In: Hailu Tefera, Getachew Belay and Mark Sorrels (eds.) Narrowing the Rift Teff Research and Development, Proceedings of the International Workshop on Teff Genetics and Improvement, 16-19 October, 2000. Addis Ababa, Ethiopia.
55. Minale, L., A. Alemayehu, T. Tilahun and M. Abrham, 2004. The response of tef to nitrogen and phosphorus applications at Bichena and Yilmana-Denssa areas, northwestern Ethiopia, pp: 135-144. In: Asfaw Zeleke, Getachew Belay, Belay Simane, Bulcha Weyessa and Nigussie Alemayehu (Eds.). Proceedings of the Tenth Conference of the Crop Science Society of Ethiopia, 19-21 June 2001, Addis Ababa, Ethiopia.
56. Fissehaye, M., H. Mitiku, K. Fassil, T. Alemteshay and Y. Charles, 2009. Response of teff [*Eragrostis tef* (Zucc) Trotter] to phosphorus and nitrogen on a Vertisol at North Ethiopia. Journal of the Dry Lands, 2(1): 8-14.
57. Alemayehu, A., L. Minale, T. Tilahun and M. Abrham, 2007. Determination of optimum rates of nitrogen and phosphorus fertilization for tef (*Eragrostis tef*) production in different agro-ecological areas of northwestern Ethiopia, pp: 60-67. In: Ermias, A., T. Akalu, A. Alemayehu, W. Melaku, D. Tadesse and T. Tilahun. (Eds.). Proceedings of the First Annual Regional Conference on Completed Crop Research Activities, 14-17 August, 2006. Amhara Region Agricultural Research Institute. Bahir Dar, Ethiopia.
58. Wakene, N. and A. Yifru, 2013. Soil Fertility Management Studies on Teff. 121-132. In: A. Kibebew, C. Solomon and T. Zerihun (Eds.). Achievements and Prospects of Tef Improvement, Proceedings of the Second International Workshop. Debre-Zeit, Ethiopia. 7-9 November, 2011. Ethiopian Institute of Agricultural Research, Addis Ababa, Ethiopia; Institute of Plant Science, University of Bern, Switzerland.
59. Bekele, A. and D. Getahun, 2016. Influence of phosphorous and nitrogen fertilizer rate on grain yield of rice at Kamashi Zone of Benshangul Gumuz Region, Ethiopia. Journal of World Economic Research, 5: 8-14. doi: 10.11648/ j.j wer. 20160502.11.
60. Yoseftabar, S., 2013. Effects of nitrogen and phosphorus fertilizer on spikelet structure and yield in rice (*Oryza sativa* L.). International Journal of Agriculture and Crop Sciences, 5(11): 1204-1208.
61. Wubante, N., M. Ahadu and K. Mulatu, 2017. Effect of row spacing on yield and yield components of teff [*Eragrostis tef* (Zucc.) varieties in Gonji Kolela District North Western Ethiopia. Journal of Biology, Agriculture and Health Care, 7(23): 1-11.

62. Alemate, E., G. Kindu, H. Mihretab and H. Haftom, 2016. Determination of optimum population density of seedling during transplanting for the productivity improvement of teff (*Eragrostis tef* (Zucc.) Trotter). Central zone of Tigray, Ethiopia. Journal of Biology, Agriculture and Health Care, 6(1): 29-34.
63. Hailu, T. and K. Syefu, 1990. Variability and genetic advance in teff (*Eragrostis tef*) cultivars. Tropical Agriculture (Trinidad), 67: 317-320.
64. Solomon, C., 2010. Genetic analysis of agronomic traits of tef (*Eragrotis tef*) genotypes. Research Journal of Agricultural and Biological Science, 6(6): 912-916.