Journal of Plant Sciences
2025, Vol. 13, No. 3, pp. 122-131
https://doi.org/10.11648/j.jps.20251303.14

Research Article

Effect of Inter Row Spacing and Nitrogen Fertilizer on Agronomic Performance of *Teff* (*Eragrostis tef* (*Zucc.*) *Trotter*) at Burie District, Northwest, Ethiopia

Muluken Belay Yiwegu[1, *], Ahadu Menzir Anley[2], Endalkachew Baye Alemu[3]

[1]Department of Plant Sciences, Burie Poly Technic College, Burie, Ethiopia
[2]Department of Plant Sciences, Debre Markos University, Debre Markos, Ethiopia
[3]Department of Plant Sciences, Salale University, Fiche, Ethiopia

Abstract

Teff ((Eragrostis tef (Zucc.) Trotter) is one of the most important food crops in Ethiopia, has the biggest value both in production and consumption. However, due to the use of improper inter row spacing and inappropriate N fertilizer rate along with other agronomic practices, its productivity is very low. Thus, during the 2019 croping season a field experiment was conducted to study the effect of inter row spacing and N fertilizer rates on teff growth, yield components, and yield at Burie District, Northwest Ethiopia. RCBD with three replication was used for the experiment. Four levels of inter row spacing (15, 20, 25 and 30 cm) and three levels of N fertilizer (30.5, 42, and 53.5kg ha^{-1}) in combination were used as a treatment. Crop phenological, growth, yield-related and yield data were collected following the standar procedures and analyzed using SAS version 9.4. The collaboration effects of N fertilizer and inter-row spacing were not significant for the collected parameters. However, the main effects of N fertilizer and inter-row spacing showed a significant difference for all parameters except days to 50% emergence, whereas days to 90% physiological maturity and harvest index were influenced only by the main effect of inter-row spacing ($P<0.05$). The heighest and the lowest grain yield were obtained at 53.5 and 30.5 kg ha^{-1} N respectively. Based on this result, it can be concluded that 53.5 kg/ha N fertilizer and 15cm inter row spacing improves yield components and yield of teff and can be suggested for the study area and areas with similar agroecology.

Keywords

Agronomic Characterstics, GrainYield, Nitrogen, Spacing

1. Introduction

Teff (*Eragrostis tef* (*Zucc.*) *Trotter*) is one of the vital grasses in Ethiopia [32]. Its grain is used for preparing bread, injera and farm income, animal feed and building [24]. Based on the [9] report, the countrywide average yield of teff was 17.48 qt/ha. Amhara region covers 38% of the country's production. Burie District of West Gojjam Zone is one of the potentials for teff production in the region. However, its yield (15 qt/ha) is very low [8]. Factors like poor agronomic practices like sowing methods including spacing and improper fertilizer use like nitrogen contribute to this [27].

*Corresponding author: mululem21@gmail.com (Muluken Belay Yiwegu)

Received: 29 January 2025; **Accepted:** 21 May 2025; **Published:** 23 June 2025

Nitrogen is one of the produce-restraining plant nutrients [16]. There are different whole fertilizer recommendations for *teff* in Ethiopia. Consequently, Nitrogen/Posphorus recommendation rates by the Ministry of Agriculture were set at 40/35, 30/40 and 55/30 kg/ha for *teff* on Cambisols, Nitosols, and, Vertisols respectively [13]. In addition, 100 kg NPS and 50 kg/ha urea for red soil [42]. Spacing is the other factor that affects growth, yield components and yield of teff. [47] found that the number of plants/unit area is affected by both inter and intra row spacing. Closer spacing affects intercultural activity and causes resource competition among plants [19, 40]. Contrarily, the widest spacing allows resource competition among weeds and crops. According to [43], inter row spacing of 20cm is preferred for teff, while [12] recommended 15cm.

The current production system of teff cannot satisfy the consumers' demand, since many Ethiopian farmers use broadcasting over row planting and this could lead to less productivity [5]. Additionally, enough quantity of N stimulates fast growth, root growth, and increased photosynthetic activity, thus contributing to the production of high grain yield in teff [6, 44]. However, application of N not supported by modern technology has adverse influences. Hence, the aim of this field experiment was to evaluate the effect of different rates of nitrogen fertilizer and inter row spacing on teff growth, yield related traits and yield at Burie district, Northwest Ethiopia.

2. Methodology

2.1. Description of the Experimental Site

Burie District of West Gojjam Zone of Amhara Region (Figure 1) is the site where the field experiment was conducted. The field experiment was conducted during the 2019 Ethiopian rainy season. Burie is located at 10°42' N latitude and 37°4' E longitude with an altitude of 2,091 meter above sea level. The agroecology of the study site is Woyna Dega. It has minimum and maximum temperature of 17°C and 25°C, respectively, while the mean yearly rainfall is 1800 mm.

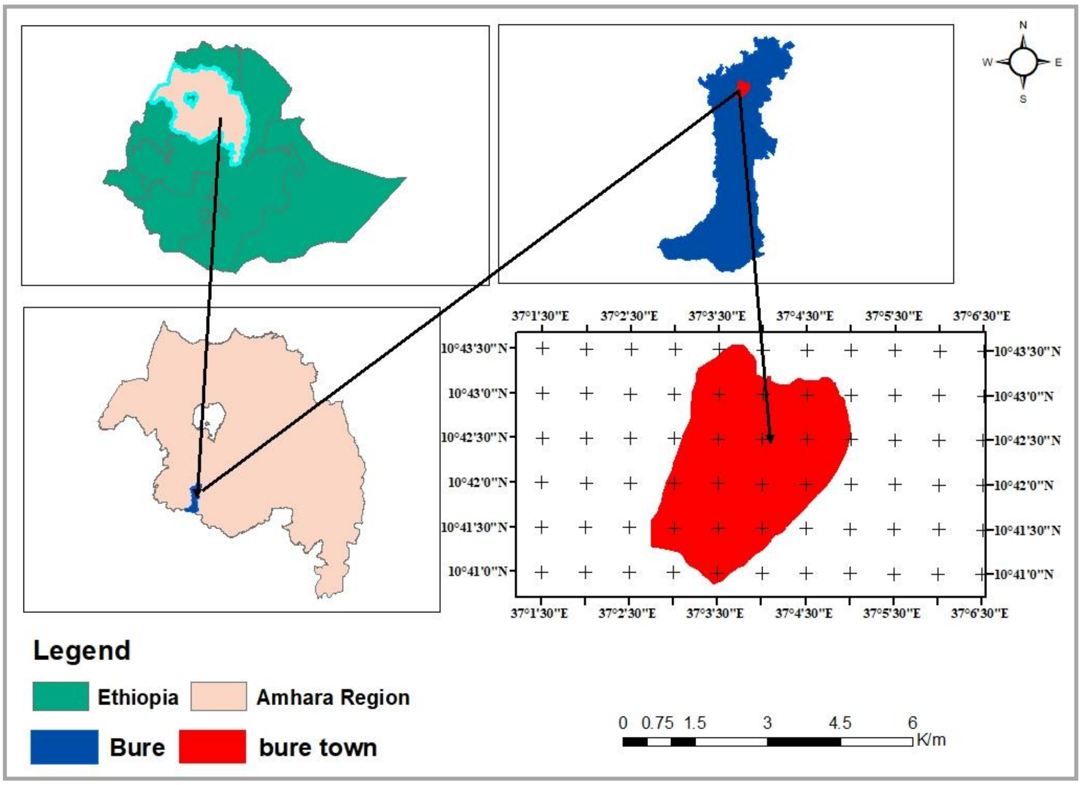

Figure 1. Map of Buire District.

2.2. Planting and fertilizer Material

DZ-Cr-37 variety of *teff which* was released by Debre Zeit Agricultural Research Center in 1984 was used. It is selected due to its' adaptability to an altitudes of 1500-2200 m. a. s. l and needs yearly rainfall of 1500-2000mm; its' productivity is 1.4-1.9 and 1.8-2.8 t/ha yields on farm and research respectively and takes 82-90 days to mature. Urea and NPS fertilizers were used as a source of N.

2.3. Treatments, Experimental Design and Procedures

The experiment was arranged with Randomized Complete Block Design (RCBD) factorial arrangement and replicated three times. Four levels of row spacing (15, 20, 25 and 30cm) combined with three rates of N fertilizer (30.5, 42 and 53.5 kg/ha) which were assigned to each plot randomly were the experimental treatments. The area of each plot was $2.4m^2$ (1.5m x 1.6m) with net plot size of 1.44, 1.2, 12, and $1.08m^2$ for 15, 20, 25 and 30cm row spacing sequentially. Spacing between plots and replications was 0.5 and 1m respectively.

Field preparation was done based on farmers' practice. Seed and fertilizer rates of 5 and 100 kg/ha respectively were used. Urea was applied in two splits (half 17 days after sowing and the remaining at tillering stage) to lessen leaching. All NPS was applied during sowing. Additional cultural follows were done based on the approval for teff.

2.4. Soil Sampling and Analysis

Soil samples were taken following a diagonal style from 0-20 cm depth and a composite of 1kg was made, dried and crushed with a pestle and mortar to pass through a 2mm size sieve. Soil texture and total N, available P, organic C, soil pH, CEC were determined using standard laboratory procedures. The soil pH was assessed at a 1: 2.5 soil-to-water ratio using a pH meter. The organic carbon content was analyzed through the Walkley and Black method [41], while available phosphorus was estimated based on the procedure outlined in [31]. Total nitrogen was determined using the Kjeldahl method, as described by Jackson in 1958.

Soil Physio-chemical Properties Before Sowing

The soil analysis revealed a texture comprising 56% clay, 24% silt, and 20% sand, classifying it as clay. The study soil was slightly acidic, with a pH of 5.9. Organic carbon content measured 1.42%, total nitrogen was 0.14%, available phosphorus (Olsen) was 27.6 mg/kg, and cation exchange capacity (CEC) was 29.3 cmol/kg. According to [26], available soil phosphorus levels below 10 mg/kg are considered low, 11-18 mg/kg as medium, and above 18 mg/kg as high; thus, the experimental site exhibited high available phosphorus. Additionally, [16] categorized total nitrogen levels as follows: very high (>1%), high (0.5-1%), medium (0.2-0.5%), low (0.1-0.2%), and very low (<0.1%). Likewise, the organic carbon content was rated as very low, aligning with [26]'s classification, which defines OC levels below 2% as very low, 2-4% as low, 4-10% as medium, and 10-20% as high.

Table 1. *Soil Physio-chemical properties before sowing.*

Texture%				pH	OM	OC	TN	AVP	CEC	EC
Class	Sand	Silt	Clay	H_2O	%			ppm	Cmol (+)/kg	Ds/m
Clay	20	24	56	5.9	2.6	1.42	0.14	N 27.6	29.3	0.145

2.5. Data Collection

2.5.1. Phenological Data

Days to 50% emergence: was documented as the duration from sowing to the point when half of the plants had emerged in each plot.

Days to 50% panicle emergence: recorded as the number of days from sowing to the date when 50% of panicles emerge from the major shoot in each plot.

Days to 90% physiological maturity: was recorded as the time from sowing until 90% of the crop's stems, leaves, and floral bracts in each plot turned light yellow.

2.5.2. Growth Data

Plant Height: was measured as the length from the base to the tip of the main panicle in ten randomly selected mother plants.

Panicle Length: was recorded by measuring the length from the node to the tip of the panicle in ten randomly chosen plants.

2.5.3. Yield Components and Yield Data

Number of total tillers/plants: recorded as the average number of tillers of ten plants from central rows by excluding the main shoot.

Number of fertile tillers/ plants: was determined by averaging the fertile tillers of ten plants from the central rows, excluding the main shoot.

Biomass Yield (kg): was determined by weighing the entire plant, including leaves, stems, and seeds, from the net area after being sun-dried for three days.

Grain yield (kg/ha): recorded by measuring the weight of the grain obtained from the net area.

Straw yield (kg): is determined by deducting the grain yield from the total biomass yield.

Harvest index: represents the ratio of grain yield to total biomass yield.

Thousand grains weight (kg): taken by measuring the weight of 1000 grains from each plot area.

Lodging index: was evaluated through visual observation using a scale from 0 to 4, where 0 represents no lodging, and 1, 2, 3, and 4 correspond to 25%, 50%, 75%, and 100% lodging, respectively [11].

2.6. Data Analysis

The gathered data underwent variance analysis using the Generalized Linear Model (GLM) in SAS software version 9.4, with interpretation based on the method outlined by Gomez and Gomez (1984). Mean differences were distinguished using the least significant difference (LSD) test at a 5% significance level.

3. Results and Discussion

The analysis of variance (ANOVA) revealed that the main effects of N fertilizer and inter row spacing significantly affected phenology, growth, yield and yield-related traits (Table 2). However, their interaction of the two don not.

Table 2. *Mean square value for effects of N fertilizer and Inter row spacing teff phonology, growth, yield and yield related traits in Burie district, Ethiopia in 2019 under Rain feed condition.*

parameters	Nitrogen Fertilizer, DF=2	Row Spacing, DF=3	Nitrogen Fertilizer * Row Spacing, DF=6
Days to 50% emergence	0.08^{ns}	0.22^{ns}	0.31^{ns}
Days to 50% panicle emergence	16.44^{**}	15.00^{**}	0.001^{ns}
Days to 90% physiological maturity	6.58^{ns}	18.92^{*}	0.47^{ns}
Plant Height (cm)	224^{**}	141.8^{*}	3.148^{ns}
Plant Panicle Length (cm)	50.44^{*}	73.86^{**}	14.48^{ns}
Number of total tillers/plants	18.46^{**}	6.09^{**}	0.91^{ns}
Number of fertile tillers/ plants	18.08^{**}	6.02^{**}	0.91^{ns}
Biomass Yield (kg)	6172772.58^{**}	16150410.36^{**}	126328.79^{ns}
Grain yield (kg/ha)	184238.42^{*}	615727.40^{**}	34015.49^{ns}
Straw yield (kg)	4254433.52^{**}	10483801.65^{**}	66772.58^{ns}
Harvest index	4.58^{ns}	12.12^{*}	3.08^{ns}
Thousand grains weight (kg)	0.0073^{**}	0.0014^{*}	0.0002^{ns}
Lodging index	919.75^{**}	1588.47^{**}	25.42^{ns}

Where: *and **, significant difference at 5% and 1% respectively; ns =non-significant; DF= Degree of freedom

3.1. Crop Phenology

3.1.1. Days to 50% Emergence

Emergence was observed within 5-6 days. The absence of significant difference in days to 50% emergence between treatments might be due to the dependency of germination on the endosperm of the seed and environmental factors like oxygen, temperature and moisture. In line with these, [2] found that embryos grow at the cost of endosperm. Likewise, [23] found that germination of sesame seeds is affected by environmental factors like temperature, O_2 and moisture and not by row spacing.

3.1.2. Days to 50% Panicle Emergence

The longest days of 50% panicle emergence (51.44days) was observed at 30cm row spacing. Whereas, the shortest (48.44days) was at 15cm. The day increased with increase in spacing (Table 3). The occurrence of panicles too early on narrow spacing may be the presence of competition between plants for nutrients, sunlight and air. Similarly, [43] indicated the increase in days to 50% panicle emergence with the increase in spacing. However, the non-significant influence of inter row spacing on days to 50% heading of wheat and *teff* crops was reported by [1, 24].

Maximum days of 50% panicle emergence (51.17) was observed from crops fertilized with 30.5kg/ha N and the earliest (48.83days) was at 53.5kg/ha N. High rate of N had a faster heading than low rate (Table 3). This may be because of the encouraging effect of highest rates of nutrients for early establishment, quick growth and development [38, 44]. Supportedly, [20, 36] reported that N enhances the uptake of other nutrients like P and K that promotes growth and development. Divergently, delayed heading at lower N rates may due to the longer time require establishing, growing and completing the vegetative growth. Contrarily, [13, 15] found a prolonged number of days to heading from higher rate of N.

Table 3. *Means of main effect of row spacing and N on days to panicle emergence, days to maturity and lodging.*

N (kg/ha)	Days to 50% panicle emergence	Days to 90% maturity	lodging%
30.5	51.17[a]	88.00[a]	37.03[c]
42	49.83[b]	88.33[0a]	41.95[b]
53.5	48.83[c]	89.42[a]	47.51[a]
LSD (5%)	0.24	Ns	3.84
Spacing (cm)			
15	48.44[d]	86.67[c]	52.07[a]
20	49.44[c]	88.33[b]	44.34[b]
25	50.44[b]	89.33[ab]	38.64[c]
30	51.44[a]	90.00[a]	33.61[d]
LSD (5%)	0.28	1.58	4.44
CV%	0.56	1.82	10.76

Note: CV= coefficient of variation, LSD= Least Significant Difference. Means in the same column followed by the same letter(s) are not significantly different at 5% level of significance.

3.1.3. Days to 90% Maturity

The shortest duration to reach 90% maturity (86.67 days) was observed at a row spacing of 15 cm, while the longest (90 days) occurred at 30 cm (Table 3). Plants grown at narrower spacing achieved physiological maturity more quickly than those at wider spacing, possibly due to heightened inter-plant competition for resources [4]. In contrast, delayed maturity in wider spacing may result from reduced competition among plants. Similarly, [34] reported that plants at the closest spacing had shorter maturity periods. According to [43], increasing row spacing from 15 cm to 30 cm extended the number of days required for 90% physiological maturity. However, [1, 24] found no significant difference in maturity duration for wheat and teff.

3.2. Lodging Percentage (%)

The highest lodging percentage 54.17 (47.51%) was recorded from 53.5kg/ha N and the lowest 36.67 (37.03%) was from 30.5 kg/ha N (Table 3). The increase in lodging percentage with the increase in N fertilizer might be due to the effect of high rate of N on increasing vegetative growth that led to bending of the stem [34]. Consistently, [15, 20] and [44] found lodged teff by the application high rate of N.

The highest lodging% 61.89 (52.07%) was recorded from plants planted at 15cm spacing and the lowest 31 (33.60%) was from 30cm spacing (Table 3). The maximum lodging percentage from narrow spacing might be the result of opaque plant population and slim stem [3, 34] and [3], (2015) also noticed effect of spacing on crop population which causes lodging. However, [24] showed the non-significant effect of spacing on loading *teff*.

3.3. Growth Parameters

3.3.1. Plant Height

The highest plant height (119.9cm) was recorded from 53.5kg/ha N while the shortest (111.78cm) was from 30.5 kg/ha N (Table 4). The occurrence of tallest plant at maximum N might be due to the encouraging effect of higher N on vegetative growth of plants which in turn produces the tallest plant. [16, 17] found the tallest *teff* plant from the higher N rate. [13, 29] also reported the taller teff plants due to the direct effect of N. Likewise, [21, 23] stated that plant height increased with an increase in the levels of N in barley and rice crops respectively.

The tallest plant (120.31cm) was obtained from inter-row spacing of 30cm, whereas the shortest (111.5cm) was from 15cm (Table 4). The increase in plant height with increase in spacing might be due to the accessibility of growth factors with increased spacing [18]. Presence of less competition between crops grown at wider spacing for nutrients that provide better environment for growth and development may be the other reason. Similarly, maximum plant height was reported from crops grown at wider inter-row spacing in teff and soybeans [10, 22]. However, closer spacing produced the tallest plants than wider spacing in wheat, rice and maize as reported by [1, 39].

Table 4. *Means of main effect of row spacing and N on plant height, panicle length, Number of Effective Tillers and Total number of tillers/plants.*

N (kg/ha)	Plant height (cm)	Panicle length (cm)	NET/plant	TNT/plant
30.5	111.78[b]	39.79[b]	4.47[b]	5.47[b]
42	118.40[a]	41.89b[a]	5.12[b]	6.03[b]
53.5	119.90[a]	43.89[a]	6.84[a]	7.84[a]
LSD (5%)	3.96	2.94	0.66	0.67
Spacing (cm)				
15	111.20[b]	38.17[b]	4.49[c]	5.49[c]
20	116.59[a]	41.91[a]	5.41[b]	6.30[b]
25	118.69[a]	42.20[a]	5.51[b]	6.51[b]
30	120.31[a]	45.16[a]	6.49[a]	7.49[a]
LSD (5%)	4.58	3.40	0.76	0.77
CV (%)	4.01	8.30	14.14	12.24

Note: CV=Coficient of variation, LSD=Least Significant Difference. Means in the same column followed by the same letter(s) are not significantly different at 5% level of significance.

3.3.2. Panicle Length

The longest panicle, measuring 43.892 cm, was observed at an application rate of 53.5 kg/ha of nitrogen, while the shortest, at 39.79 cm, occurred with 30.5 kg/ha of nitrogen (Table 4). The increase in panicle length with higher nitrogen levels may be attributed to nitrogen's role in promoting vegetative growth, leading to taller plants with extended panicle lengths [35]. Similarly, [29, 37] reported the greatest panicle lengths in plants receiving higher nitrogen levels. Consistent findings by [7, 44] also indicated that teff panicle length increased in response to maximum nitrogen application.

In case of spacing, the longest panicle (45.6cm) was obtained from 30cm while the lowest (38.17cm) was from 15cm (Table 4). Availability of growth resources from wider spacing that might increase chlorophyll formation may be the reason for obtaining long panicle from wider spacing. Consistently, [10, 34] reported that widely spaced crops are more effective in mobilizing photosynthates used for formation of longer panicles than narrowly spaced. Contrarily, [1, 28] reported about the non-significant effect of spacing on spike length of rice and wheat.

3.3.3. Total Number of Tillers Per Plant

The highest number of total tillers per plant (7.84) was recorded at an application rate of 53.5 kg/ha of nitrogen, while the lowest (5.47) occurred at 30.5 kg/ha (Table 4). The number of tillers increased progressively with higher nitrogen levels, likely due to the enhanced availability of nitrogen, which positively influenced cytokinin synthesis and cell division [37]. Similarly, [44] reported a greater number of total tillers per plant in teff when higher rates of nitrogen fertilizer were applied.

The maximum numbers of total of tillers/plant (7.48) were obtained from inter spacing of 30cm whereas the lowest (5.47) were from 15cm (Table 4). Maximum tillers/plant was obtained from wider spacing which may be due to the presence of low crop density between plants which favored more tiller number. [21, 40] also reported the highest number of total tillers/plants from widely spaced and the lowest from closely spaced rice. According to [14], this is due to enhanced access to water, light, space and nutrients in wider spacing than closer spacing. However,

3.3.4. Number of Effective Tillers Per Plant

The highest number of effective tillers per plant (6.84) was recorded at an application rate of 53.5 kg/ha of nitrogen, while the lowest (4.466) occurred at 30.5 kg/ha (Table 4). The increase in effective tillers with higher nitrogen levels may be due to nitrogen's essential role in initiating the tillering stage [5]. Additionally, [25, 37] suggest that nitrogen's widely recognized contribution to vegetative growth acceleration could also be a factor.

Regarding inter-row spacing, the highest number of effective tillers per plant (6.48) was observed at 30 cm spacing, while the lowest (4.48) was recorded at 15 cm spacing (Table 4). The greater number of effective tillers at wider spacing might be attributed to improved access to space, nutrients, water, and light. Similarly, [4] found the highest number of effective tillers per hill in rice at 30 cm spacing and the lowest at 15 cm. [1] also identified variations in the number of effective tillers per square meter of wheat across different inter-row spacing. Conversely, [24] reported no significant effect of spacing on the number of effective tillers per plant in teff.

3.4. Yield Parameters

3.4.1. Biomass Yield

The highest biomass yield (9075.1 kg/ha) was achieved with the application of 53.5 kg/ha of nitrogen, while the lowest (7743.1 kg/ha) resulted from 30.5 kg/ha (Table 5). Increased nitrogen levels promote the allocation of assimilates to leaves and stems, enhancing dry matter yield and contributing to higher biomass production [37]. Additionally, nitrogen positively influences vegetative growth and stem cell development, further boosting biomass yield [6]. Consistently, [25, 30, 46] reported that increasing nitrogen application led to higher biomass yields in barley, maize, and wheat crops.

The maximum biomass yield (10033.7kg/ha) was recorded from 15cm inter-row spacing while the lowermost (6856.1kg/ha) was from 30cm (Table 5). Widest inter-row spacing gave the minimum biomass yield than closest which may be due to the presence of more plant stands/unit area. In conformity [1, 22] reported more biomass yield from closer spacing in wheat. Contrarily, [19] found maximum biomass yield from wider row spaced rice. [34] also indicated that further increase in inter-row spacing increased biomass yield in *teff*. However, [24] reported the non-significant effect of row spacing on biomass yield of *teff*.

3.4.2. Grain Yield

The highest grain yield (2173.35kg/ha) was obtained from 53.5kg/ha N and the lowest (1937.37kg/ha) was from 30.5kg/ha N (Table 5). Likewise, [7, 37] found highest grain yield from higher rate of N, while the minimum was from low rate of N in teff. [4, 6, 20] also reported the significant effect of diverse levels of N on grain yield of teff. [4, 21, 30] also reported the highest grain yield from a higher rate of N fertilizer in maize, wheat and rice respectively.

The highest grain yield (2403.2 kg/ha) was achieved with a 15 cm inter-row spacing, while the lowest (1808.0 kg/ha) was observed at 30 cm (Table 5). According to [45], the significant increase in teff grain yield at narrower spacing can be attributed to higher plant density. Similarly, [1, 6, 39] reported greater grain yields in rice, wheat, and maize under narrow spacing compared to wider spacing. Conversely, [19, 43] found that teff grown at wider spacing produced higher grain yields.

Table 5. *Means of main effects of row spacing and N fertilizer on biomass yield, grain yield, straw yield, Harvest index and thousand Seed Weight.*

N (kg/ha)	Biomass Yield (kg/ha)	Grain Yield (kg/ha)	Straw Yield (kg/ha)	Harvest Index (%)	Thousand Seed Weight (g)
30.5	7743.1^{b}	1937.37^{b}	5800.7^{b}	25.1983^{a}	0.308750^{b}
42	7948.2^{b}	1989.84^{b}	5958.4^{b}	25.0283^{a}	0.308833^{b}
53.5	9075.1^{a}	2173.35^{a}	6901.8^{a}	24.0533^{a}	0.351583^{a}
LSD (5%)	449.15	169.66	360.63	Ns	0.0157
Spacing (cm)					
15	10033.7^{a}	2403.20^{a}	7623.8^{a}	23.9589^{b}	0.312889^{b}
20	8375.4^{b}	2022.05^{b}	6353.4^{b}	24.1178^{b}	0.316222^{b}
25	7756.7^{c}	1900.76^{b}	5856.0^{c}	24.4956^{b}	0.322333^{b}
30	6856.1^{d}	1808.08^{c}	5048.0^{d}	26.4678^{a}	0.340778^{a}
LSD (5%)	518.63	195.9	416.42	1.7955	0.0181

N (kg/ha)	Biomass Yield (kg/ha)	Grain Yield (kg/ha)	Straw Yield (kg/ha)	Harvest Index (%)	Thousand Seed Weight (g)
CV (%)	6.42	9.85	6.84	7.41	5.73

Note: CV=Coefficient of variation, LSD=Least Significant Difference. Means in the same column followed by the same letter(s) are not significantly different at 5% level of significance.

3.4.3. Straw Yield

The highest straw yield (6901.8 kg/ha) was obtained from 53.5 kg/ha N and the lowest (5800.7) was from 30.5 kg/ha N (Table 5). The increased in straw yield with an increase in N might be due to the effect of high N on the production of numerous effective tillers, increased plant tallness, and panicle length. [4, 17, 30] also found the maximum total straw yield from higher rate of N and the lowest from the control.

The highest straw yield (7623.8 kg/ha) was obtained from 15cm spacing and the lowest (5048.0 kg/ha) was from 30 cm (Table 5). Straw yields of *teff* increase as spacing decreases which might be attributed to the increased in crop population. According to [33], row spacing influenced vegetative growth of plants like plant height and number of tillers/meters which resulted in augmented straw yield. Consistently, [5, 43] reported better straw yield in rice and *teff* from closer spacing. Contradictorily, [40, 45] reported higher straw yield from wider spacing. [19, 34] also found lowest straw yield from narrow spacing.

3.4.4. Harvest Index (HI)

The maximum HI (26.47%) was obtained from 30cm inter-row spacing and the lowest HI (23.96) was 15cm (Table 5). Wider row spacing increases HI; this may be attributed to increased consumption of resource like sunlight for the production of higher dry matter and yield. In agreement, [43] reported superior and lower HI from 30 and 15cm inter-row spacing respectively. Contradictory, [6, 19] obtained higher HI from closely spaced rice.

3.4.5. Thousand Seed Weight

The uppermost thousand seed weight (0.352g) was recorded at 53.5 kg/ha N and the lowest (0.309g) was from 30.5 kg/ha N (Table 5). Heaviness in grain at higher N rates might be due to an increase in chlorophyll content of leaves which led to a high photosynthetic rate that can be accessible during grain development [5]. In line with this [21, 29, 34] reported the raise in thousand seed weight with N rates in *teff* and rice. [6] also reported maximum 1000 seed weight from higher rate of N and the minimum from the control in rice.

The highest 1000 seed weight (0.341g) was recorded from 30cm row spacing (Table 5). 1000 seed weight increase with increase in spacing which may be due to the presence of less competition for sunlight, wetness and soil nutrients in wider spacing [5, 19, and 22] also reported that 1000 seed weight increased with response to inter-row spacing in rice and soybean.

4. Conclusions

The growth, yield, and yield components of teff were influenced by the main effects of row spacing and nitrogen application. The highest grain yields (2456.6 kg/ha) were obtained with 42 kg/ha of nitrogen at 15 cm inter-row spacing, followed closely by 2429.8 kg/ha at 53.5 kg/ha of nitrogen with the same row spacing. In terms of profitability, 53.5 kg/ha of nitrogen at 15 cm spacing, followed by 42 kg/ha of nitrogen at 15 cm spacing, yielded the best economic returns with maximum grain production. However, since this study was conducted at a single location over one season, it is premature to recommend the practice. Future research should focus on validating these findings across multiple locations and seasons to establish conclusive insights on the impact of row spacing and nitrogen fertilizer rates.

Abbreviations

ANOVA	Analysis of Variance
AVP	Available Phosphorus
CEC	Cation Exchange Capacity
CV	Coefficient of Variation
CSA	Central Statistical Agency
DZAC	Debre Zeit Agricultural Research Center
EC	Electrical conductivity
LSD	List Significant Difference
OM	Organic Mater
OC	Organic Carbon
RCBD	Randomized Complete Block Design
SAS	System Analysis Software
TN	Total Nitrogen

Data Availability Statement

The data can be provided upon request.

Conflicts of Interest

The authors declare no conflicts of interest.

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