
Effect of Seed Rate and Row Spacing on Tef (*Eragrostis tef* (Zucc.) Trotter) Production at Central Highlands of Ethiopia

Almaz Meseret Gezahegn*, Serkalem Tamiru

Ethiopian Institute of Agricultural Research, Debre Zeit Agricultural Research Center, Debre Zeit, Ethiopia

Email address:

almimeseret@gmail.com (A. M. Gezahegn)

*Corresponding author

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Abstract: Field experiments were conducted for three consecutive years (2012-2014) to determine optimum seed rate and row spacing for increasing productivity of tef at central highlands of Ethiopia. The experiment was designed in a randomized complete block design with a factorial combination of three levels of seed rates (5, 10 and 15 kg/ha) and three rows spaces (15, 20, 25cm) with three replications in a factorial arrangement. One satellite treatment of broadcasting of 25 kg/ha seed rate was included. Results revealed that plant height and number of tillers were not significantly affected by a combination of seed rate and row spacing, however, panicle length was significantly affected by a combination of seed rate and row spacing. The lowest seed rate (5kg/ha) with 25 cm row spacing gave the highest panicle length. Yield and yield components of tef were also significantly affected by a combination of seed rate and row spacing at both locations. At both locations, 10 kg/ha seed rate with 20 cm and broadcasted with 25kg/ha seed rate gave significantly higher grain yield, but were not significantly different from other treatments except 5 kg seed rate with 25 cm row spacing. The Partial budget analysis revealed that highest net benefit was recorded from 10 kg/ha seed rate with 20 cm row spacing. Therefore, a seed rate of 10 kg/ha with 20 cm row spacing can be recommended for higher and economic yield of tef at central highlands of Ethiopia.

Keywords: Net Benefit, Row Spacing, Seed Rate, Tef, Yield

1. Introduction

Tef (*Eragrostis tef* (Zucc.) Trotter) is a staple food for the majority of Ethiopian population and adapted to a wide range of environment including situation which is unfavorable to the production of different crops [1]. The crop prefer to grow by Ethiopian farmers due to multiple advantages such as low risk crop, low postharvest management cost, high market value, and straw of tef is the best feed for animal feed as compared to different cereal crops, [2]. Tef straw, other than being the foremost acknowledged feed for cattle, it is additionally utilized to strengthen mud and mortar the dividers of tukuls and nearby grain capacity offices called gottera [3, 4]. Currently, the crop is getting worldwide consideration among money crops and has been drawing in an send out advertise owing to its wholesome and health-related benefits [5], particularly due to its gluten free property [6, 7].

Tef has the significance value in terms of both production

and consumption in Ethiopia. It positions first in area coverage and second in total annual production following to maize, and positions the bottommost yield compared with other cereals grown in Ethiopia [8, 9]. Tef covers for about 22.6% of the total area and 16% of the total crop production of the main cereals produced in Ethiopia [8]. Tef production and request has been expanding from year to year in both country and urban ranges of Ethiopia. In spite of the abovementioned importance and huge area coverage, its productivity is very low with a national average yield of 1.71 t/ha [8]. The low productivity of tef in Ethiopia is largely attributed to its susceptibility to lodging, its small seed size, moisture stresses [10], and poor agronomic management practices, such as lack of appropriate sowing method and optimum seeding rate [11].

Seed rate is one of the significant factors in attaining optimum level of plant density and has substantial effects on growth and yield of the crops. It also highly affects crop productivity when combined with planting method. In

Ethiopia, there is inconsistency in using improved agronomic practices like seeding rate and planting methods and results in low yield of tef [12]. The most common method of sowing is broadcasting at a rate of 25-50 kg/ha which is conventional and greatly reduces the amount of tef grain yield due to higher competition for resources and causes lodging [4]. Alternatively, row planting keeps uniform population per unit area and offers easy accessibility for completing management practices though needs extra time, energy, and cost [13]. Similarly, using of optimum seed rate allows boosting production and productivity of tef through reducing of lodging percent [14]. However, in Ethiopia particularly in study area, farmers practice broad casting methods of sowing tef with higher seed rate. Therefore, the study was conducted to determine the optimum seed rate and appropriate row spacing for increasing productivity of tef in central highlands of Ethiopia.

2. Materials and Methods

2.1. Description of the Study Area

The experiments were conducted at Debre Zeit Agricultural Research Center (DZARC) station and Ude farmer field during 2012-2014 cropping season under rain-fed condition. Debre Zeit Agricultural Research Center and Ude are located in East Shewa Zone of Oromia Regional State. Debre Zeit agricultural research center is located an altitude of 1,900 m above sea level and 8°44' N latitude and 38°58' E longitude. While Ude is located at 9°5'52.8" N latitude and 36°58'37.2" E longitude with an altitude of 1970 meter above sea level. Those areas are typical of the rain-fed tef-growing regions of Ethiopia with average annual rainfall of 912 mm and 826 mm at DARC and Ude, respectively. The dominant soil types of the areas are heavy Vertisol. Monthly total rainfall and average minimum and maximum temperature of DZARC and Ude over the 3-year study periods are presented in Figures 1 and 2, respectively.

2.2. Experimental Design and Treatments

Table 1. Treatment combinations.

Treatment no.	Treatment combinations
1	5 kg/ha x Row space 15 cm
2	5 kg/ha x Row space 20 cm
3	5 kg/ha x Row space 25 cm
4	10 kg/ha x Row space 15 cm
5	10 kg/ha x Row space 20 cm
6	10 kg/ha x Row space 25 cm
7	15 kg/ha x Row space 15 cm
8	15 kg/ha x Row space 20 cm
9	15 kg/ha x Row space 25 cm
10	25 kg/ha at broad casting

The experiment was designed in a randomized complete block design with three replications. The treatment comprised with a factorial arrangement of three levels of seed rates (5, 10 and 15 kg/ha) and three rows spacing (15,

20, 25cm). One additional plot of broadcast of tef seed at 25 kg/ha seed rate for each replication was considered as a standard check. The treatment combination is presented in Table 1. The plot size of 4m x 5m (20 m²) was used. The spacing between plots and blocks were 0.5m and 1m, respectively.

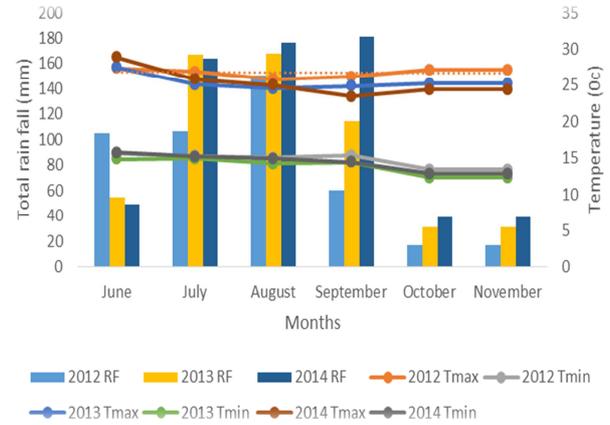


Figure 1. Total rainfall, minimum and maximum Temperature for the cropping season during 2012-2014 at Debre Zeit.

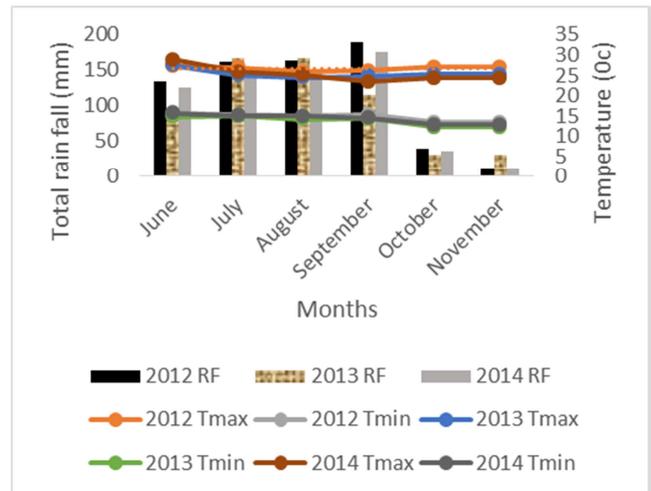


Figure 2. Total rainfall, minimum and maximum Temperature for the cropping season during 2012-2014 at Ude.

2.3. Crop Management and Data Collection

The experimental site was ploughed by tractor to a fine till at DZARC and by oxen 4 times before final preparation of seed beds at Ude. Urea (46% N) at a rate of 100 kg/ha and DAP (18% N, 48% P₂O₅) fertilizer at rate of 100 kg/ha were used as a source of nitrogen, and phosphorus, respectively. Full dose of DAP was applied at planting, while urea fertilizer was applied in two equal splits, the first portion 15 days after planting and the remaining amount being top dressed at tillering stage. Other agronomic practices were applied based on local research recommendations. The first weeding was done 30-35 days after planting and the second weeding was carried out a month after the first weeding.

Plant height was measured from the surface ground to the tip of the panicle at maturity time. Panicle length was measured the node (the first panicle branch started) to the tip of the panicle. Number of tillers per plant was determined by counting the number of additional plants growing from the main stem. The samples for the above parameters were taken from 10 randomly taken plants. Above ground biomass was determined by taking the total weight of the harvest including the grains from each net plot area. Straw yield was measured by subtracting grain yield per net plot from the total above ground biomass. Grain yield (kg/ha) was measured after threshing the grains harvested from each net plot. Harvest index was calculated by the ratio of grain yield to above ground biomass.

2.4. Economic Analysis

To compare the economic feasibilities of different treatments, partial budget analysis and Marginal rate of return were done as described by CIMMYT [15]. The average grain and straw yield was adjusted downwards by 10% to reflect the difference between the experimental yield and the expected yield of farmers from the same treatment. The costs that vary were calculated by adding costs of seed and other costs were constant for each treatment. The mean market price of tef grain (40 Birr/kg) and straw cost (3Birr/kg) were used.

2.5. Statistical Analysis

The data were subjected to combined analysis of variance (ANOVA) over years after confirmation of homogeneity of error variance using SAS software program. Separate analyses were conducted for each location because of heterogeneity of error variance. The means were compared by list significant difference (LSD) method at 0.05 probability level.

3. Result and Discussion

3.1. Growth Parameters

The result indicated that seed rate and row spacing had not significant effect ($p > 0.05$) on plant height and number of productive tillers of tef at both locations (Table 2). However, panicle length of tef was significantly affected by ($p > 0.05$) combination of seed rate and row spacing. Panicle length is one of the major yield attributes of tef that is positively correlated with grain yield. The highest panicle length was obtained when the crop was planted at 5 kg/ha seed rate with 15 cm row spacing, but was not significantly different ($P > 0.05$) from 5 kg seed rate by 20 and 25 cm row spacing, 10 kg seed rate by 20 cm row spacing and 15 kg seed rate by 15 cm row spacing at Ude. At Debre Zeit, the highest panicle length was obtained when tef was planted at seed rate of 5 cm with 25 and 20 row spacing, but were not significantly different ($P > 0.05$) from other seed rate planted in row. In contrast, the lowest panicle length was obtained when the crop was broadcasts at the rate of 25 kg/ha at both locations. The increment of panicle length in the case of row space increment as well as decreasing seed rate might be resulted due to extra space given for the crop to utilize additional growth resources by reducing competition between plants. The lower panicle length at higher seed rate might be due to the higher intra-specific competition between plants for the resources. Plants grown with a lower plant density had more area of land around them to utilize more resources such as nutrient, water and solar radiation on individual plant basis than those established at higher plant density because of competition. This result is in agreement with Kitata et al. [16] and Sahle et al. [17], who reported higher panicle length in lower seed rate and vice versa. Reda et al. [18] also reported that the performance of the individual tef plant grown under low plant density was better as compared to the tef plant with lower plant density.

Table 2. Effect of seed rate and row spacing on growth parameters of tef at Ude and Debre Zeit.

Treatments	Ude			Debre Zeit		
	PH (cm)	NT	PL(cm)	PH (cm)	NT	PL(cm)
5 kg/ha x Row space 15 cm	93.17	3.7667	45.44abcd	106.67	4.73	37.67ab
5 kg/ha x Row space 20 cm	103.00	3.2333	45.30abcd	107.00	5.167	39.73a
5 kg/ha x Row space 25 cm	108.67	3.1667	48.79a	111.17	4.77	40.53a
10 kg/ha x Row space 15 cm	98.00	3.3667	43.59cd	118.17	3.70	35.93ab
10 kg/ha x Row space 20 cm	95.33	3.7333	47.83ab	112.67	5.57	36.13ab
10 kg/ha x Row space 25 cm	95.50	3.7667	42.50cd	110.00	4.27	36.48ab
15 kg/ha x Row space 15 cm	97.33	3.4333	46.39abc	107.33	4.00	34.87ab
15 kg/ha x Row space 20 cm	96.50	3.4333	44.83bcd	106.67	4.82	36.80ab
15 kg/ha x Row space 25 cm	97.50	3.1667	43.52cd	110.17	4.73	36.80ab
25 kg/ha at broad casting	114.33	2.9667	42.23d	116.00	4.33	34.40b
LSD ($P > 0.05$)	ns	ns	3.89	ns	ns	4.7
CV	25.25	22.91	7.44	17.7	10.2	15.2

PH=plant height, NT=number of productive tillers, PL= panicle length.

3.2. Yield and Yield Components

The combination of seed rate and row spacing had a significant effect ($P < 0.05$) on biomass yield, and grain yield at both locations and on straw yield at Debre Zeit. However,

harvest index of tef was not significantly affected ($P > 0.05$) by combination of seed rate and row spacing. At Ude, the highest biomass yield (5916.7 kg/ha) was obtained in the control plot, which was broadcasted at 25 kg/ha seed rate, but was not significantly different ($P > 0.05$) from other treatments

except 5 kg/ha seed rate with 20 and 25 cm row spacing. On the other hand, at Deber zeit the highest biomass yield (9333kg/ha) and straw yield (7634 kg/ha) were obtained when tef was planted at 15 kg/ha seed rate and 25 cm row spacing. In contrast, the lowest biomass yield and straw yield were obtained when tef was planted at a seed rate of 5 kg/ha with 25 cm row spacing at both locations and at Debre zeit, respectively. This implies that the biomass yield increases as the seed rate or planting density increase. This is due to the fact that the seed rate increase, the number of plant establishment, the plant height and number of plants per unit area increases, which substantially increases the biomass of the plant. The result is in line with Reda et al. [18] and Lakew and Berhanu [19] who reported the highest biomass yield of tef at higher seed rate.

The highest grain yield was obtained at seed rate of 10 kg/ha with 20 cm and 25 cm row spacing, 15 kg/ha with 15 cm and control plot or broadcasted at 25 kg/ha seed rate

(1525.4 kg/ha, 1417.7 kg/ha, 1407.1kg/ha and 1523.5kg/ha, respectively) at Ude. Similarly, at Debre Zeit, seed rate of 10 kg/ha with 15 and 20 cm row spacing and broadcasting tef with 25 kg/ha seed rate were gave highest grain yield (1820 kg/ha, 1875/kg/ha and 1833 kg/ha, respectively), but were not significantly different from other treatments except 5 kg/ha seed rate with 25 cm row spacing. At both locations, the lowest grain yield was obtained at 5 kg/ha seed rate with 25 cm row spacing. The result indicated that there was a slightly increment of grain yield as the seed rate increased. This might be due to number of plants per meter square is the main determinants of yield. Similarly, Lakew and Birhanu [19] reported that 15 kg seed rate gave higher grain yield of tef than 10 and 5 kg/ha. Further the result showed that row spacing didn't increase grain as well as biomass yield of tef over broadcast. In contrary to this result, Mihretie et al. [20] reported that row planting gave greater (30%) grain yield of tef than broadcasting.

Table 3. Effect of seed rate and row spacing on yield and yield component of tef at Ude and Debre Zeit.

Treatments	Ude				Debre Zeit			
	SY (kg/ha)	BY (kg/ha)	GY (kg/ha)	HI (%)	SY (kg/ha)	BY (kg/ha)	GY (kg/ha)	HI (%)
5 kg/ha x Row space 15 cm	3778.5	5083abc	1305ab	0.26	4694b	6083ab	1389ab	0.23
5 kg/ha x Row space 20 cm	3486.4	4833bc	1347ab	0.28	5350ab	6875ab	1525ab	0.26
5 kg/ha x Row space 25 cm	3651.3	4792c	1140b	0.24	4729b	5833b	1105b	0.18
10 kg/ha x Row space 15 cm	4058.8	5417abc	1358ab	0.25	7181ab	9000ab	1820a	0.19
10 kg/ha x Row space 20 cm	4349.6	5875ab	1525a	0.26	7083ab	8958ab	1875a	0.21
10 kg/ha x Row space 25 cm	3957.3	5375abc	1418a	0.26	6401ab	7958ab	1557ab	0.18
15 kg/ha x Row space 15 cm	4134.6	5542abc	1407a	0.25	7391ab	9125ab	1735ab	0.19
15 kg/ha x Row space 20 cm	4221.2	5333abc	1112b	0.21	7373ab	8833ab	1460ab	0.16
15 kg/ha x Row space 25 cm	3866.5	5167 abc	1300ab	0.25	7634a	9333a	1700ab	0.18
25 kg/ha at broad casting	4393.2	5917a	1523a	0.26	6918ab	8750ab	1833a	0.22
LSD (P>0.05)	ns	1048	265.09	ns	2712	3345	667.9	ns
CV	19.86	16.93	17.00	15.31	4694b	6083ab	1389.4ab	0.23

SY= straw yield, BY= biomass yield, GY=grain yield, HI= harvest index.

3.3. Economic Analysis

Partial budget analysis at Ude showed that the highest net benefit (66225 kg/ha) was obtained when tef was seeded at a rate of 10 kg/ha with 20 cm row spacing, followed by broadcasted 25 kg/ha seed rate (Table 4). Similarly, at Debre Zeit, the highest net benefit was obtained at 10 kg/ha seed rate with 20 cm row spacing followed by 10 kg/ha seed rate

with 15 cm row spacing (Table 5). This finding is in line with Lakew and Brehanu [19] who stated that an combination of 15kg ha⁻¹ seed rate with 20cm row spacing gave higher net benefit than that of broadcasting with higher seed rate. Abebe and Abebe [21] also reported that tef sown with 5 kg/ha is economically beneficial for farmers compared to broadcasting with higher seed rate.

Table 4. Partial budget analysis for seed rate and row spacing at Ude.

Treatment	GY (kg/ha)	SY (kg/ha)	Adj.GY (kg/ha)	Adj.SY (kg/ha)	GB (ETB)	TVC (ETB)	NB (ETB)
5 kg/ha x Row space 15 cm	1305	3779	1174	3401	57175	200	56975
5 kg/ha x Row space 20 cm	1347	3486	1212	3138	57902	200	57702
5 kg/ha x Row space 25 cm	1140	3651	1026	3286	50913	200	50713
10 kg/ha x Row space 15 cm	1358	4059	1222	3653	59843	400	59443
10 kg/ha x Row space 20 cm	1525	4350	1373	3915	66658	400	66258
10 kg/ha x Row space 25 cm	1418	3957	1276	3562	61722	400	61322
15 kg/ha x Row space 15 cm	1407	4135	1266	3721	61819	600	61219
15 kg/ha x Row space 20 cm	1112	4221	1001	3799	51433	600	50833
15 kg/ha x Row space 25 cm	1300	3867	1170	3480	57247	600	56647
25 kg/ha at broad casting	1524	4393	1371	3954	66708	1000	65708

*GY=grain yield, SY=straw yield, Adj. GY= Adjusted grain yield, Adj.SY=adjusted straw yield, GB= gross benefit, TVC= total variable cost, NB= net benefit, ETB= Ethiopian Birr

Table 5. Partial budget analysis for seed rate and row spacing at Debre Zeit.

Treatment	GY (kg/ha)	SY (kg/ha)	Adj.GY (kg/ha)	Adj.SY (kg/ha)	GB (ETB)	TVC (ETB)	NB (ETB)
5 kg/ha x Row space 15 cm	1389	4694	1250	4225	62692	200	62492
5 kg/ha x Row space 20 cm	1525	5350	1373	4815	69359	200	69159
5 kg/ha x Row space 25 cm	1105	4729	994	4256	52534	200	52334
10 kg/ha x Row space 15 cm	1820	7181	1638	6463	84894	400	84494
10 kg/ha x Row space 20 cm	1875	7083	1688	6375	86639	400	86239
10 kg/ha x Row space 25 cm	1557	6401	1402	5761	73346	400	72946
15 kg/ha x Row space 15 cm	1735	7391	1561	6652	82401	600	81801
15 kg/ha x Row space 20 cm	1460	7373	1314	6636	72474	600	71874
15 kg/ha x Row space 25 cm	1700	7633	1530	6870	81802	600	81202
25 kg/ha at broad casting	1833	6918	1649	6226	84647	1000	83647

GY=grain yield, SY=straw yield, Adj. GY= Adjusted grain yield, Adj.SY=adjusted straw yield, GB= gross benefit, TVC= total variable cost, NB= net benefit, ETB= Ethiopian Birr

4. Conclusions

Based on the study, a combination of seed rate and row spacing had a significant effect on grain and biomass yield of tef at Ude and Debre zeit. The highest grain yield of tef were obtained at 10 kg/ha seed rate with 20 and 25 cm row spacing, but was not significantly different from 25 kg of seed rate with broadcasting. Partial budget analysis showed that, at both locations, 10 kg/ha seed rate with 20 cm row spacing gave the highest net benefit. Therefore, based on highest grain yield and economic advantage, 10 kg/ha seed rate with 20 cm row spacing is recommended for the study areas.

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