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Response of Teff (Eragrostistef (Zucc) Trotter) to Seeding Rate and Row Spacing at Tiro-Afeta District, Southwestern Ethiopia

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ABSTRACT

The field experiment was carried out for two (2017 and 2018) consecutive seasons at Tiro-Afeta district, Jimma Zone. The treatments consisted combinations of three row spacing (15, 20, 25 cm) and three levels of seed rate (5, 10, and 15 kg ha-1) were laid down in a randomized complete block design (RCBD) with three replications. The analysis of ANNOVA showed grain yield was significantly (P ≤ 0.001) and straw was significantly (P ≤ 0.05) affected by seed rate and row spacing. The highest grain and straw yield 1.49 and 5.42 t ha-1respectively were obtained from the application of 10 kg ha-1 seed rate with 15 and20cm row spacing. Grain yield was increased by 41.90 and 77.38 % over 5 kg ha-1 seed rate and 20 cm row space (control) and 5 kg ha-1 seed rate and 15 cm row space(lowest row spacing) respectively. In conclusion, partial budget analysis based on the field prices of inputs and tef grain yield showed, application of 10 kg seed ha-1 with 20 cm gave a highest net benefit of 29738 Ethiopian birr ha-1 from grain straw yields and also sustained acceptable even under a projected worsening trade conditions in Tiro-Afeta. Thus, it is possible to recommend that, sowing of tef (Quncho variety) with the rate of 10 kg ha-1and 20cm inter row spacing is effective in attaining higher yield and economic benefit in the study areaand similar agro-ecologies.

Keywords: *Seed rate, Row spacing, Grain yield and Economic analysis.*

INTRODUCTION

Tef [Eragrostistef (Zucc.) Trotter] is the main food crop of Ethiopia with annual cultivation of 2.8 million hectares of land and a total production of 44.7 million quintals (CSA, 2016). As compared to other cereals grown in Ethiopia, tef is the most preferred cereal by the consumers as well as the producers. Due to its source of best quality human food and animal feed, tolerance to both high and low moisture stresses, high price for its grain and straw, low-post harvest pest and disease problems and high longevity of the grain even under farmers' traditional storage conditions (Ketema, 1993, 1997; Assefa et al, 2001a) and very recently, it is also proved to be a healthy food crop since its grain is free of gluten (Spaenij-Dekking et al., 2005), making it suitable for people suffering from celiac disease. Despite the preferences and the largest area coverage of tef, its national average yield is very low as compared to other cereals.

Tef 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 (CSA, 2016; Assefa et al., 2017; Tesfahun, 2018). At Oromiya regional state the average yield was 1.37 t ha^{-1} and it is below the average yield of the country which was 1.56 t ha^{-1} (CSA, 2015/6) and recently it has been argued that the traditional sowing technology is a major constraint to increased tef productivity (Berhe et al., 2011). The cause for lower productivity is lodging, a method of planting and fertilizer application. Meantime the combined effect of those factors result up to 22% reduction in grain and straw yield (Hailu T, et al, 2001)

It's obvious that the most common way of planting the small seed like tef was broadcasting. Experiments on these alternative planting methods in controlled settings have shown large and positive impacts on tef yields (Berhe et al., 2011, Fufa et al. 2011). As a consequence, in 2013 the Ethiopian government rolled out a nationwide campaign to promote the use of improved technologies for tef production, including row planting, aiming to scale up their adoption to almost 2.5 million tef producing farmers. The row planting resulted in increased tef yields at a farm level. Moreover, due to the increased labour requirement, labour productivity decreased compared to traditional broadcast planting. As a consequence, depending on the yield increase achieved, the row planting is profitable only when the benefits associated with row planting outweigh its cost. These results seemingly explain why most farmers exposed to row planting of tef continued row planting in the year afterwards, but only on a small part of their tef lands and it became much more beneficial for farmers.

Seed rate, which is the amount of seed sown per unit area, is an important factor that affects plant density. Narrow within row spacing which results in high density, significantly increased plant height and leaf area index and consequently forage yield in maize (Mohammed, 1998). This difference in response of plant height to seed rate might be attributed to the levels of seed rates, and condition under which the crop is grown. If a manually or motor-driven broadcaster or a drill is available, a lower seed rate (about 15kg ha^{-1}) is recommended. If sowing is done by hand broadcasting, it would be difficult to evenly distribute the 15 kg ha^{-1} of seeds because of small seed size. Therefore, 25-30 kg ha^{-1} seeds are recommended for broadcast sowing. Farmer traditional practice is to broadcast tef at the rate of 40-50 kg ha^{-1} (Ketema, 1997). Seed rate broadcasted at a rate of 25 -30 kg ha^{-1} and covered lightly with soil by handheld twigs (Decker et al., 2001). Generally recommended (Stallknech, 1993).

Generally, the most common way of planting tef is by broadcasting the small seed at the rate of 25-30 kg ha^{-1} (Debebe, 2005). This sowing method results in lodging; which is the main cause for low yield of tef due to high plant density results competition to different resources and also below optimum results poor population in case of an adverse climatic condition during sowing time like no or high rainfall results in low germination and seed erosion and deposition respectively. To overcome the problem of lodging and to get optimum density to maximize yield on tef, appropriate seed rate and row planting was part of agronomic constraints regulators growth, appropriate plant population density without competition. Alternative planting methods, such as row planting seeds or transplanting seedlings, in which the seed rate is reduced and more space between plants is given, are seen as being superior to traditional broadcasting (Berhe et al. 2011, Fufa et al. 2011).

MATERIALS AND METHODS

Description of the Experimental Site

The experiment was conducted at Jimma Zone, Omonadaworeda, Tiro-Afeta district, in Oromiya region at the southwestern part of Ethiopia, during the main cropping season of 2017 and 2018.The site was located an average elevation of 2070 m amsl and average temperature is 22.5 ^{o}C and reliably receives good rain fall 2000 mm per annum cropping season.The farming system of the study site is cereal crops dominated with maize, tef, and sorghum. Also it has a convenient topography which is very suitable for all agricultural practices.

Experimental Design and Field Management

The experimental field was ploughed and harrowed by oxen to get a fine seedbed and leveled manually before the field layout was made. The treatments comprising a combination of three seed rates (5, 10 and 15 ha^{-1}) and three rows spaces (15, 20, 25cm) were arranged in a Randomized Block Design with three replications. The plot size was 5 m long and 4 m width. All other cultural practices were performed based on available recommendations for tef production. In the present study, tef varieties Quncho which adapted to the agro-ecology of the area were used. Varieties Quncho is the most promising variety released by Debrezeit Agricultural Research Centre. Phosphorus fertilizer in the form of di-ammonium phosphate (DAP) was applied by drilling in the rows at the time of sowing and incorporated into the soil before seeding. Weeds were controlled by hand to avoid competition. Harvesting at normal physiological maturity and threshing were done by hand.

Panicle Length (cm)

It was measured from the node where the first panicle branch starts to the tip of a panicle.

Number of Tillers Per Hill

Tillers were counted from five random hills of harvestable rows.

Plant Height (cm)

It was recorded from five random plants at maturity by measuring the height from ground to the tip of the panicle.

Lodging (%)

Lodging percentage was recorded at the time of harvest from harvestable rows.

Straw Yield (kg ha-1)

Tef plants in each net plot were harvested at normal physiological maturity manually, threshed separately and straw yield weighed.

Above Ground Biomass Yield (T Ha^{-1})

The central harvestable rows of the net plot plants stalk were considered for determination of above ground dry biomass weight by drying in sunlight still a constant dry weight was attained

Grain Yield (t ha-1)

It was recorded after harvesting from the central harvestable rows of the net plot.

Harvest Index

It was calculated as the ratio of grain yield to total above ground dry biomass yield multiplied by 100 at harvest from the respective treatments (Donald and Hamblin, 1976). Harvest Index = Grain yield/ above ground dry biomass yield × 100.

Economic Analysis

To assess the costs and benefits associated with different treatments Seed rate and row spacing, the partial budget technique as described by CIMMYT (1988) was applied. Economic analysis was done using the prevailing market prices for inputs at planting and outputs, at the time the crop was harvested. All costs and benefits were calculated on hectare basis of Ethiopian Birr (EtB). The inputs and/or concepts used in the partial budget analysis were the mean grain yield of each treatment in both years, the field price of Tef grain (sale price grain and straw yield minus the costs of planting, seed), the gross field benefit (GFB)/ ha^{-1} (the product of field price, straw yield and the mean yield for each treatment), the field price of seed rate kg ha^{-1} and wage rate of application, the total costs that varied (TCV) which included the sum of field cost of seed and its wage for application. The net benefit (NB) was calculated as the difference between the GFB and the TCV. Actual yield was adjusted downward by 15% to reflect the difference between the experimental yield and the yield farmers could expect from the same treatment. There were optimum plant population density, timely labor availability and better management (e.g. weed control, rainfall) under the experimental conditions (CIMMYT, 1988; Moro et al., 2008). The dominance analysis procedure as detailed in CIMMYT (1998) was used to select potentially profitable treatments from the range that was tested. The discarded and selected treatments using this technique were referred to as dominated and un-dominated treatments, respectively. The un-dominated treatments were ranked from the lowest to the highest cost. For each pair of ranked treatments, the percent marginal rate of return (MRR) was calculated. The MRR (%) between any pair of un-dominated treatments was the return per unit of investment in fertilizer. To obtain an estimate of these returns the MRR (%) was calculated as changes in NB divided by changes in cost. Thus, the MRR of 100% was used indicating for every one EtB expended there is a return of one EtB for a given variable input.

Sensitivity analysis for different interventions was also carried out to test the recommendation made for its ability to withstand price changes. Sensitivity analysis simply implied redoing the marginal analysis with the alternative prices. Through sensitivity analysis, the maximum acceptable field price of input was calculated with the minimum rate of return as described by Shah et al. (2009).

Statistical Analysis

Analysis of variance (ANOVA) for all collecteddata was computed using R software version 3.5.3 statistical software R Core Team (2019-03-11). Whenever the ANOVA results showed thesignificant differences between sources ofvariation, the means were separated usingFisher's least significant difference (LSD).

RESULTS AND DISCUSSION

Phenological and Growth Parameters

Number of Tillers Per Hill

The effect of seed rate and row spacing were showed statistically significant effect ($p<0.05$) on a number of tiller per hill. The maximum number of tiller per hill (3.67) was produced from 5 kg ha^{-1}seed rate and 15 cm row spacing while the minimum (2.33) were from 10 and 15 kg ha^{-1}seed rate and 15 cm row spacing) (Table 1). There was a negative relation with seed rate and number of tiller per hill because as seed rate increased the plant population was high and dominates the tillers initiations. The current result was in line with (M. Farooq, et al. 2006) who revealed that as the population density increased, competition for resource also increased, resulting in less tillering. Also this finding was similar to (U. A. Soomro, et al. 2009) who reported that as seeding rate increased, the numbers of total and productive tillers decreased. But it contradict with (Murtada Y. 2000) reported that the number of tillers was not significantly affected by seeding rates.

Plant Height

The tallest plant height (139.60 cm) was recorded from 10 kg ha^{-1} seed rate and 20 cm row spacing followed by (137.83 cm) from 5 kg ha^{-1} seed rate and 20 cm row spacing and had statistically ($p<0.05$) significant effect (Table 1). The above combinations of seed rate and spacing were an optimum for plant height and have appositive contribution for straw yield which is very important part of yield related. The shortest plant height (131.35 cm) was recorded from the highest 15 kg ha^{-1} seed rate x 25 cm Row spacing.Generally, the plant height was increased with seed spacing increased with the same seed rate but not with further increase in seed rate. Similarly, (S. Sahle et al 2016) reported that plant height increased as seeding rate decreased.The same result was reported by (Abraha A et al, 202), Increasing plant height with decreased seed rates with increased spacing. This could mainly be attributed to larger seed rate resulting in higher competition for nutrients while in small seed rate less plant competition for nutrients.

Table1. *Over season effect of seed rate and row spacing on growth parameters of tef at Tiro-Afeta*

Treatments	Number of Tillers per hill	Plant height (cm)	Logging %age at harvesting
5 kg ha^{-1} seed rate x 15 cm Row space	3.67	137.23	29.17
5 kg ha^{-1}seed rate x 20 cm Row space	3.33	137.83	30.83
5 kg ha^{-1}seed rate x 25 cm Row space	3.50	135.23	29.20
10 kg ha^{-1}seed rate x 15 cm Row space	2.33	134.63	30.83
10 kg ha^{-1}seed rate x 20 cm Row space	3.00	139.60	47.50
10 kg ha^{-1}seed rate x 25 cm Row space	3.00	134.87	32.50
15 kg ha^{-1}seed rate x 15 cm Row space	2.33	133.57	42.50
15 kg ha^{-1}seed rate x 20 cm Row space	2.83	133.90	45.83
15 kg ha^{-1}seed rate x 25 cm Row space	2.50	131.35	52.50
Mean	**2.94**	**135.36**	**37.12**
LSD (0.05)	**1.09**	**6.15**	**Ns**
CV (%)	**18.68**	**21.68**	**6.42**

LSD= Least significant difference; CV=Coefficient of variation; Values followed by the same letter within a column are not significantly different at $P< 0.05$.

Lodging Percentage at Harvesting

There was no significant ($p<0.05$) effect of seed rates and row spacing on logging percentage at harvest (Table 1). At the highest 15 kg ha^{-1} seed rate and 15 cm row spacing the highest logging percentage at harvest (52.50) was recordedfollowed by (47.50) from 10 kg ha-1 seed rate x 20 cm Row spacing which is the higher seed rate. While the lowest (29.17) was recorded from the lowest 5 kg ha^{-1} seed rate and 15 cm row spacing.The result showed that mostly there was a trend of increase in logging percentage at harvest with increased seed rates.It's because ofhigh plants per unit area competitions for nutrient and sun light results in plant heightand tin stem diameter leads to logging. The result was contradict with (Abraha A et al, 202)the lowest seeding rate revealed high lodging index is could be due to the plots sown with the lowest seeding rate produced high panicle length, main panicle seed weight, thousand-seed weight, and high grain yield exert a strain on the stalk and led to fall down especially under high wind or wind driven rain. The current result was agreement with(B. Abebe et al, 2015 and S. Sahle et al, 2016) reported that on which high lodging index observed from high seeding rate(25 kg/ha).

Yield and Yield Related Variables

Panicle Length

There was statistically significant ($p<0.05$) effect of seed rates and row spacing on panicle length. The longest panicle length (51.20 cm) was recorded from 5 kg ha^{-1} seed rate and 20 cm row spacing followed by panicle length (50.83 cm) at 5 kg ha^{-1} seed rate and 15 cm row spacing (Table 2). While the lowest was (47.33cm) was recorded from the highest seed rate. Similarly, (M. Melaku. 2008) revealed that there was significant increase in yield and yield components of teff with decreased seeding rate from the highest to the lowest. The optimum plant population density was crucial for growth and development; so that the above two treatment combinations were results high panicle length and grain yield. Besides this, less number of tillers has a positive contribution to panicle length and a similar report was reported by (FarooqM, et al. 2006). Also (Caliskan, et al. 2004) reported that, the number of tiller per hill negatively correlated with panicle length.

Table2. *Over season effect of seed rate and row spacing on yield and yield related parameters of tef at Tiro-Afeta.*

Treatments	**Panicle length (cm)**	**Grain yield (t ha^{-1})**	**Straw yield (t ha^{-1})**
5 kg ha^{-1} seed rate x 15 cm Row space	50.83	0.84	4.85
5 kg ha^{-1} seed rate x 20 cm Row space	51.20	1.05	4.93
5 kg ha^{-1} seed rate x 25 cm Row space	48.83	1.36	4.39
10 kg ha^{-1} seed rate x 15 cm Row space	50.50	1.49	4.72
10 kg ha^{-1} seed rate x 20 cm Row space	50.50	1.10	5.42
10 kg ha^{-1} seed rate x 25 cm Row space	50.70	1.15	4.28
15 kg ha^{-1} seed rate x 15 cm Row space	49.00	1.24	4.62
15 kg ha^{-1} seed rate x 20 cm Row space	50.20	1.14	5.18
15 kg ha^{-1} seed rate x 25 cm Row space	47.33	1.24	4.66
Mean	49.90	1.18	4.78
LSD (0.05)	3.73	0.26	0.92
CV (%)	**3.90**	**23.76**	**24.29**

LSD= Least significant difference; CV=Coefficient of variation; Values followed by the same letter within a column are not significantly different at P< 0.05.

Grain Yield

The grain yield was a significant response to seed rates and row spacing (P <0.05). The highest grain yield (1.49 t ha^{-1}) was recorded from 10 kg ha^{-1} seed rate and 15 cm row spacing (Table 2) and it was followed by (1.36 t ha^{-1}) from 5 kg ha^{-1} seed rate and 25 cm row spacing. Grain yield was increased by 41.09 and 77.38 % over 5 kg ha^{-1} seed rate and 20 cm row space (control) and 5 kg ha^{-1} seed rate and 15 cm row space(lowest row spacing) respectively. These the above two levels was an optimum combination of seed rate and spacing were the high development teffwas observed like less number of tillers and logging which has direct positive contribution to high yield.

Increase in seed rate shows gradual decline in grain yield due to decline in panicle length and also number of tillers. Similarly, the grain yield followed similar trends to that of plant height since it is the final fruit of many complex morphological and physiological processes occurring during the growth and developmentof crop (Khan HZ, et al. 2008).

The lowest grain (0.84 t ha^{-1}) was obtained from the lowest seed rate 5 kg ha^{-1} seed rate and 15 cm row space.The current results are in line with those of (Hameed et al. 2003) and (Ijaz et al. 2003), who reported that grain yield increased as the seed rate increased.

Straw Yield

The straw yield of tef has highly valuable for many purposes like animal feed, local wall making in Ethiopia. The straw yield had significantly (P=0.05) influenced by seed rates and row spacing (Table 2). There is gradual an increase in straw yield with increased seed rate especially starting from a seed rate of 10 kg ha^{-1} to its maximum seed rate of 10 kg ha^{-1} then decline with further increase. This result was in agreement with (Murtada, 2000) since higher densities contain more plants per unit area, dry matter yield per unit area increased with increasing plant density (Esechie, 1992). The highest (5.42 t ha^{-1}) straw yield was recorded at 10 kg ha^{-1} seed rate and 20 cm row spacing and followed by (5.18 t ha^{-1}) from 15 kg ha^{-1} seed rate x 20 cm row spacing. Those treatments were an optimum combinations active radiation and photosynthesis.

Above Ground Biomass Yield

The highest above ground biomass yield (5.42 t ha^{-1}) was recorded at the rate of 10 kg ha^{-1} seed rate and 15 cm row spacing followed by (5.35 t ha^{-1} at 10 kg ha^{-1} seed rate and 20 cm row spacing andnot significantly affected by seed rates and row spacing (P <0.05) (Table 3).But it shows that there was an increase in above ground biomass yield with increased seed rate from 5-10 kg ha^{-1} and 15 cm row spacing then decline with further increasedseed rates. These results were in agreement with (FekreariamA, et al 2005) who reported that relatively biomass yield was higher for the narrowest spacing (15 cm) than wider spacing since more plant stands per unit area. Also, supported by (M. Melaku. 2008) found total above-ground biomass increment with an increase in seeding rate and nitrogen fertilizer of teff.

Table3. *Over season effect of seed rate and row spacing on yield related parameters of tef at Tiro-Afeta*

Treatments	Above ground biomass (t/ha)	Harvest Index (%)
5 kg ha^{-1} seed rate x 15 cm Row space	4.70	21.93
5 kg ha^{-1} seed rate x 20 cm Row space	4.78	24.18
5 kg ha^{-1} seed rate x 25 cm Row space	4.92	30.45
10 kg ha^{-1} seed rate x 15 cm Row space	5.42	28.97
10 kg ha^{-1} seed rate x 20 cm Row space	5.35	23.04
10 kg ha^{-1} seed rate x 25 cm Row space	4.68	25.16
15 kg ha^{-1} seed rate x 15 cm Row space	5.07	25.03
15 kg ha^{-1} seed rate x 20 cm Row space	5.32	23.56
15 kg ha^{-1} seed rate x 25 cm Row space	5.23	25.90
Mean	5.05	16.68
LSD (0.05)	**Ns**	**Ns**
CV (%)	**14.44**	**16.58**

Values followed by the same letter within a column are not significantly different at P< 0.05.

Harvest Index

There was a significant (p<0.05) effect of seed rates and row spacing on harvest index (Table 3). The highest harvest index (0.30%) was recorded from lowest 5 kg ha^{-1} seed rate. and 25 cm row spacing and followed by (28.97%) obtained from 10 kg ha^{-1} seed rate x 15 cm Row spacing. It's trend was shows that decrease with increased seed rate. The current result was reveled with (Abraha A et al, 202), the higher harvest index obtained in the lowest seeding rate can be attributed to more light penetration through plant canopy and improved nutrient supply. The was in agreement with the results by (L. Zeng et al. 2000) who revealed that, at high density, carbohydrate supplywas limited because of shading among plants and the competition between shoot growth and panicle growth and also**(**Teklay T. et al 2016) reported that th**e** highest harvest index was obtained from row planted tef at 5 Kg ha^{-1} seed rate with complete fertilizer.

Economic Feasibility of Seed Rates and Row Spacing

Analysis of variance (Table 2) showed that seed rates and row spacing had a significant (P = 0.05) effect on the grain yield of tef. An economic analysis of the combined results using the partial budget technique was thus appropriate (CIMMYT, 1988). The result of the partial budget analysis and marginal rate of return (MRR %) for undominated treatments were given in (Tables 4 and 5). Dominance analysis (Table 4) led to the selection of treatments combinations 5 kg ha-1 seed rate and 25 cm row spacing, 5kg ha-1 seed rate and 20 cm row spacing and 10 kg ha-1 seed rate and 20cm row spacing ranked in increasing order of total costs that vary. Therewas no treatments having MRR below 100% was considered low and unacceptable to farmers and eliminated (CIMMYT, 1988). This was because such a return would offset the cost of capital (interest) and other related deal costs while still giving an attractive profit margin to serve as an incentive. Therefore, this investigation remained with not change and combinations 5 kg ha-1 seed rate and 25 cm row spacing, 5kg ha-1 seed rate and 20 cm row spacing and 10 kg ha-1 seed rate and 20 cm row spacing as promising new practices for farmers under the prevailing price structure since they gave more than 100% MRR. This might suggest the use of inputs that result in maximum net benefits (Bekele, 2000). Market prices are ever changing and as such is the calculation of the partial budget using a set of likely future prices i.e., sensitivity analysis, was essential to identify treatments which may likely remain stable and sustain satisfactory returns for farmers despite price fluctuations.

These price changes are realistic under the liberal market conditions prevailing in Tiro-Afeta at the time of experimentation. The new prices were thus used to obtain the sensitivity analysis (Table 6) that were above the minimum acceptable MRR of 100% for 5 kg ha-1 and 10 kg ha-1 seed rates both at 20 cm row spacing which gives 1463% and 105.6% MRR, respectively. This might suggest the use of inputs that result in maximum net benefits (Bekele, 2000). Therefore, with (5 and 10 kg ha-1) seed with 20 cm row spacing give an economic yield response and also sustained acceptable even under projected worsening trade conditions in Tiro-Afeta. On a tentative basis, farmers could thus choose any of the two new seed rates with 20cm row spacing depending on their resources.

Table4. *Partial budget analysis with dominance to estimate net benefit for application of seed rates and row spacing at current prices.*

Seed Rate (Kg ha^{-1})	Row Spacing (cm)	Adjusted Grain yield (t/ha)	Straw Yield (t/ha)	Gross Field Benefit (EtB ha^{-1})	Total Cost that Vary (EtB ha^{-1})	Net Benefit (EtB ha^{-1})
5	**25**	1.22	4.39	27378	1250	26128U
5	**20(Control)**	0.95	4.93	29457	1350	28107U
5	**15**	0.76	4.85	28458	1450	27008D
10	**25**	1.04	4.28	26217	2400	23817D
10	**20**	0.99	5.42	32238	2500	29738U
10	**15**	1.34	4.72	29511	2600	26911D
15	**25**	1.12	4.66	28512	3550	24962D
15	**20**	1.03	5.18	31050	3650	27400D
15	**15**	1.12	4.62	28296	3750	24546D

EtB = Ethiopian Birr; Wage rate = Birr 40 per day; Retail price of grain = Birr 30000 per ton.

Table5. *Partial budget with estimated marginal rate of return (%) for application of seed rates and row spacing at current prices.*

Seed Rate (Kg ha^{-1})	Row Spacing (cm)	Total Cost that Vary (EtB ha^{-1})	Net Benefit (EtB ha^{-1})	Raised Cost (EtB ha^{-1})	Raised Benefit (EtB ha^{-1})	Marginal Rate of Return (%)
5	**25**	1250	26128	-----	-----	-----
5	**20**	1350	28107	100	1979	1979
10	**20**	2500	29738	1150	1631	142

EtB = Ethiopian Birr; Wage rate = Birr 40 per day; Retail price of grain = Birr 30000 per ton.

Table6. *Sensitivity analysis of tef production after different practices based on a 15% rise in total cost and tef price of gross field benefit.*

Seed Rate (Kg ha^{-1})	Row Spacing (cm)	Total Cost that Vary (EtB ha^{-1})	Net Benefit (EtB ha^{-1})	Raised Cost (EtB ha^{-1})	Raised Benefit (EtB ha^{-1})	Marginal Rate of Return (%)
5	**25**	1438	22209	-----	-----	----
5	**20**	1553	23891	115	1682	1463
10	**20**	2875	25277	1323	1386	105

EtB = Ethiopian Birr; Wage rate = Birr 40 per day; Retail price of grain = Birr 30000 per ton.

SUMMARY AND CONCLUSION

Field experiment was conducted for the two consecutive main cropping seasons on farmer's field in jimma Zone, Tiro-Afeta district where tef is considered to be one of the major crops in the farming system. In all seasons, due sufficient amount of rainfall at sowing period, better seedling emergence and stand establishment of tef were recorded. Among the important parameters plant height, number of tillers per hill, panicle length, straw yield and grain yield showed significant differences due to the seeding of different seed rates and row spacing but harvest index, above ground biomass and lodging percentage at harvesting were not. The Partial budget analysis done by including all treatments and the highest net benefit (29738 EtB ha^{-1}) with acceptable marginal rate of return (105%). Hence, to obtain the optimum economic return from the production of tef (Quncho variety) at the study area, Application of 5 and 10 kg seed ha^{-1} with 20 cm gave the high grain yield and maximum straw yields which is almost equally important to grain to the study area but 10 kg seed ha^{-1}over came the problem of unevenly distribution of seed during sowing than 5 kg seed ha^{-1}and even thoughthey are had comparable yield and net benefit. Therefore, application of 10 kg seed ha^{-1} with 20 cm gave a highest net benefit of 29738 Ethiopian birr ha^{-1} from grain straw yields and also sustained acceptable even under a projected worsening trade conditions in Tiro-Afeta. Thus, it is possible to recommend that, sowing of tef with the rate of 10 kg ha^{-1}and 20cm inter row spacing is effective in attaining higher yield and economic benefit in the study area.

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