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Economic Analysis of Tef Yield Response to Different Sowing Methods and Seed Rates in Eastern Amhara, Ethiopia

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Abstract. The study was conducted in 2019/2020 for two years in Habru, Kobo, and Dawa Chefa districts of the Eastern Amhara with the main objectives of evaluating and validating the productivity, evaluating economic feasibility and selecting the best performing sowing method and seed rate of tef technologies under farmers condition. The districts were selected based on their representativeness for the growth of tef. Three treatments were used for the study namely row planting with 5kg.ha^{-1}, row planting with 10kg.ha^{-1}, and hand broadcasting methods. Tef (Zoble variety) was used for the study purpose. Based on the data obtained, the highest yield was obtained from the hand broadcasting (25kg.ha^{-1}) and the lowest yield was from the row planting (5kg.ha^{-1}). The mean yield of tef from the hand broadcasting (25kg.ha^{-1}) was 16.5% higher than the row planting (5kg.ha^{-1}). Similarly, the labor utilization has increased from hand broadcasting 25kg.ha^{-1}to row planting of (5kg.ha^{-1}) and 10kg.ha^{-1}. The labor cost for row plantings of tef was also higher, whereas the hand broadcasting (25kg.ha^{-1}) consumed the least labor. This study therefore has proved that hand broadcasting is both high yielder and economically feasible in the Eastern Amhara. In addition to this, the study suggests that there should be additional seed rate study on broadcasting In order to gain optimum tef yield with feasible economic advantage.
Keywords: hand broadcasting; marginal rate of return; row planting; zoble tef

INTRODUCTION

In Ethiopia about 12 million smallholder households account for approximately 95 percent of agricultural GDP and 85 percent of employment. Nearly 55 % of all smallholder farmers operate on one hectare or less (Jobie, 2015). Tef [*Eragrostis tef* (Zucc.) Trotter] is the most important crop in Ethiopia and is well-adapted to different environments, but grain yields are low. The government is therefore promoting the adoption of improved varieties, inorganic fertilizers and new planting techniques (Abraha et al., 2017; Tehulie et al., 2021). Tef is used in various forms by Ethiopians.

The dominant form of usage is *injera*, an unleavened pancake made of tef flour, which is the mainstay of the Ethiopian diet. It is also consumed in the form of porridge and bread. Its straw is a nutritious and highly preferred feed for livestock compared to the straw of other cereals particularly during dry season. Besides its local use, it is the major cash earning crop for the farming community as market price for both its grain and straw is higher compared to other cereal crops. It is grown well at middle elevations between 1,400 and 2,200 meters above sea level and in regions that have adequate rainfall. Compared to other cereals, tef is considered a lower risk crop as it can withstand adverse weather conditions. And water stress during seed germination, establishments, flowering and maturation affected the tef population and the total grain and straw yields adversely ((Mengistu & Mekonnen, 2012; Siyum et al., 2022; Zewde & Purba, 2022).

Labor intensiveness was clearly observed in transplanting and row planting methods as compared to the hand broadcasting methods ((Tesfay et al., 2015). The impacts of the widespread promotion campaign of row planting of teff, in particular, on land and labor productivity are unknown. This is mainly due to a lack of reliable and objective farm level data. Moreover, no systematic effort has yet been put into examining farmers' perceptions after they experimented with the new sowing techniques (Vandercasteelen et al., 2014). It is not only the biological yield that matters for the smallholder farmers but also the amount of labor consumed during the implementation of each technological options. Experience has shown that farmers are much more likely to

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adopt new practices in small steps rather than in complete packages. For this partial budget analysis is a way of evaluating the changes from one technology to another by comparing the changes in costs and net benefits associated with each treatment (CIMMYT, 1998). Mindful with the above facts, the experiment was conducted to generate evidence on economic advantage of different tef sowing methods in order to solve problems related to labor for tef production. The objectives of this research are a) to evaluate and validate the productivity of the technologies under farmers' condition; b) to evaluate economic feasibility of the technologies; c) to select the best performing sowing method and seed rate technologies with farmers' participation.

METHODS

Description of the study area

The experiment was conducted in Raya Kobo, Habru and Dawa Chefa districts (fig. 1). The overall agro ecological description of the Districts were summarized as follows in table 1 and summary of treatments (tabel 2).

Table 1. Description of the study area

Zone	Districts	altitude (masl)	Mean temp. ℃		Mean annual RF mm
			min	max	
N. Wollo	Raya Kobo	1468	14	34	815
N. Wollo	Habru (Sirinka)	1850-1889	12.8	31.8	1199.8
Oromo nation	Dawa Chefa	1640-1669	12.7	29.9	1027.3

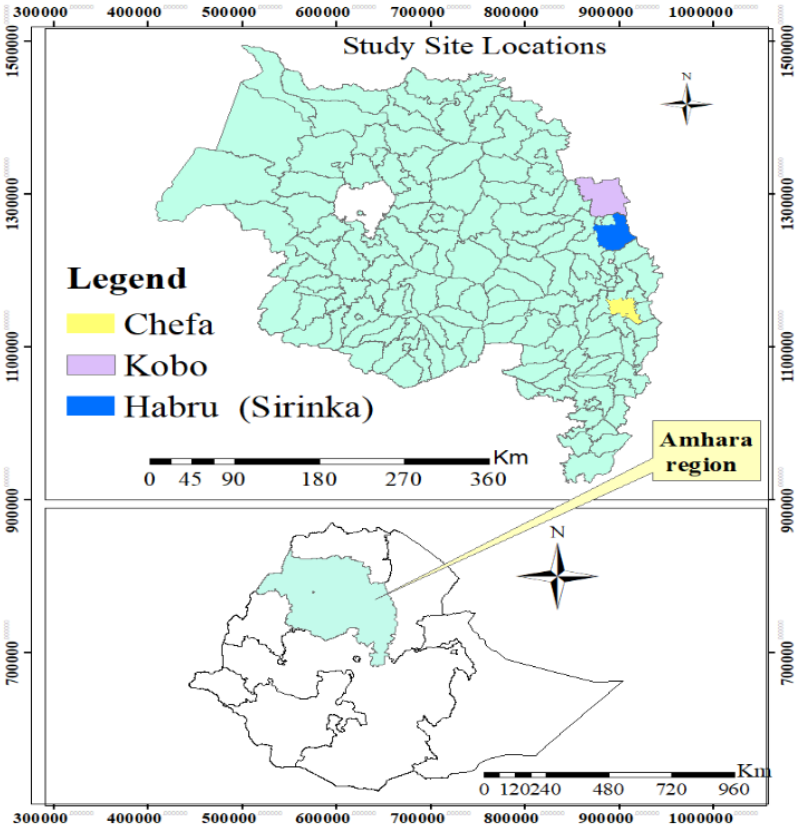

Fig. 1. The study site location.

Table 2. Summary of treatments used for the evaluation of seed rate and sowing methods

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Tr. No.	Sowing methods	Fertilizer rate(kg.ha^{-1})	Seed rate(kg.ha^{-1})
1	Row planting	121 NPS and 39 urea	5
2	Row planting	121 NPS and 39 urea	10
3	Hand broadcasting	121 NPS and 39 urea	25

Method of data analysis

The data obtained was analyzed using the economic evaluation comprising a partial budget with dominance and marginal analysis as it was described by CIMMYT (1998) as the best method of data analysis for this kind of experiment. Economic analysis was done using the prevailing local market price for inputs at planting/sowing season and for outputs at the time the crop was harvested. All costs and benefits were calculated on hectare basis in Ethiopian birr (Birr/ha). The Dominance analysis procedure was used to select potentially profitable treatments. This helps to eliminate those treatments costing more but producing a lower Net Benefit than the next lowest cost treatment. Then the selected treatments (un-dominated treatments) were used for the next step while the rejected (Dominated) treatment was rejected from the next step. For each pair of ranked un-dominated treatments, a percentage marginal rate of return (% MRR) was calculated. The percent MRR between any pair of un-dominated treatments denotes the return per unit of investment in crop management practices expressed as percentage. To obtain an estimate of these returns we calculated the MRR, which was given by the following formula:

$$MRR\ (\%) = (NB/\ TVC) * 100 \quad \ldots\ldots\ldots (1)$$

RESULTS AND DISCUSSION

During the experiment with sowing methods, the agronomic performance of tef across the treatments was found to be varied considerably (table 2). The mean grain yield of tef was highest on the hand broadcasting (25kg.ha^{-1} seed rate) and the lowest for the row planting (5kg seed rate). The yield gained from the hand broadcasting was 16.6% and 7.2% higher than the row planting method (5kg.ha^{-1} and 10 kg.ha^{-1} seed rates) respectively. This amount of yield reduction by using improved technology (row planting with minimum seed rates) occurred due to highest pest prevalence i.e. disease and insects were severing and susceptibility nature of row planting for pests by its lower seed rates in the study area. This idea is supported by authors Reda et al. (2018), who assessed the grain yield obtained from plants established at the seed rate of 25kg.ha^{-1} exceeded the grain yields obtained from plants raised at the seed rates of 20, 15, 10, 5, and 2.5 by 14, 10, 52, 61 and 75% respectively (Gemechu, 2018).

The severity of the tef leaf rust disease was sever in the row planting treatments than the broadcasting and this may be because of the row planting were easily attacked by insects, and susceptible to diseases. Insect pests known to attack germinating tef seeds and seedlings include the tef shoot fly (Atherigona hyalinipennis), Wollo bush-cricket (Decticoides brevipennis), the red tef worm (Mentaxya ignicollis), grasshoppers, ants and termites (Mamo, 2019), and also observed beetles where the study was conducted; striped blister beetle (Epicauta Vittata) locally known as “Genbo” it was highly infested and caused damage on teff seedlings in low land areas of Eastern Amhara. Bayeh et al. (2009) study result shown us, the Entomology of Tef 179 incidence of shoot fly in GubaLafto, Habru, Sirinka and Ziquala areas of North Wollo Zone, the level of tef seedling infestation ranged from 5 to 6% at seedling and 2 to 5% at heading stage. The other major challenge for producing tef was drought. It affects adversely tef production from seed germination to the final seed setting and maturity. The experiment has also indicated;

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the labor utilization has increased in row planting from row making to harvesting was observed to be the highest while the hand broadcasting consumed the least labor.

Table 3. Result of partial budget analysis for tef experiment at Sirinka, Kobo and Chefa (combined) (variety = Zoble)

Parameters	2018-2019 - combined		
	Row pl.(5kg)	Row pl. (10kg)	Broad. (25kg)
Average grain yield (qtl/ha)	10.36	11.53	12.41
Adjusted grain yield	9.32	10.37	11.17
Average of tef straw yield (qt/ha)	6.80	7.07	8.26
Adjusted straw yield qt/ha	6.12	6.30	7.43
Gross field benefit of tef grain/ha (Birr)	32,620.00	36,295.00	39,095.00
Gr. field benefit of tef straw /ha (Birr)	20,398.00	20,998.00	24,764.00
Total Gr. Fi. Benefit-TGFB (Birr/ha)	53,018.00	57,293.00	63,859.00
Field cost of seeds (Birr/ha)	143.75	287.50	718.75
labor cost of weeding (Birr/ha)	2,398.00	2,305.67	2,197.33
labor cost threshing	1,418.00	1,430.00	1,260.00
Labor cost of harvesting (Birr/ha)	1,933.67	1,946.67	1,820.67
Labor cost of fert. appln. (Birr/ha)	1,689.67	1,688.33	505.00
Labor cost of row making/ha	2,908.00	2,902.33	0
Labor cost of tef sowing per ha	1,931.67	1,923.67	207.67
Labor cost of seed covering /ha	445.67	445.67	481
Total labor cost Birr/ha	12,724.33	12,635.67	6,472.33
Total variable cost (TVC) (Birr/ha)	12,868.08	12,923.17	7,191.083
Net benefits (Birr/ ha)	40,149.92	44,369.83	56,667.9

Note: *100kg tef straw price on average =3333.00 ETB*
**1qt tef price on average =3500.00 ET*
*Man-day wage rate = 42 birr at Sirinka, 50 birr at Kobo and 50 birr at Chefa *based on the SARC wage rate*

As indicated on table 3, the net benefit from row planting (5kg.ha^{-1}) was 29.15% lower than the net benefit obtained from hand broadcasting (25kg.ha^{-1}). Similarly, the net benefit obtained from the row planting (10kg.ha^{-1}) was higher than the net benefit obtained from row planting (5kg.ha^{-1}) by more than 9.5%.This result is confirmed the finding of (Vandercasteelen *et al*, 2016) who used an innovative randomized controlled trial set-up, and shown that the implementation of row planting at the farm level significantly increases total labor use, but not teff yields relative to broadcast planting.

The Dominance analysis procedure was indicated that the most profitable treatment was hand broadcasting(25kg.ha^{-1}) due to its highest Net benefit 56,667.9 Birr/ha than that of net benefit obtained from row planting with 5kg.ha^{-1} 40,149.92 birr/ha and row planting 10kg.ha^{-1} 44,369.83 birr.ha^{-1} (table 4).

Table 4. Dominance analysis in varied cost

Treatments	Total Variable Cost	Net benefit	Dominated
25 kg.ha^{-1} HBC	7,191	56,668	no
05 kg.ha^{-1} Row	12,868	40,150	Yes*
10 kg.ha^{-1} Row	12,923	44,370	no
Dominance *			

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The row method of 5kg /ha was dominated due to lack of proportional increase in net benefit as compared to the costs that vary and excluded from marginal analysis (table 5). By switching from dominance analysis is done by sorting the technologies, including the current the producer is using, on the basis of costs, listing them from the lowest to the highest, together with their respective net benefit. In moving from the lowest to the highest, any technology that costs more than the previous one but yields less net benefits is said to be "dominated" and can be excluded from further analysis (Evan, 2020).

Table 5. Result of marginal analysis

Treatment	*TVC birr*	*MC birr*	*NB birr*	*MC birr*	*MRR*
*10kg.*ha^{-1} *Row*	12,923		44,370		
*25kg.*ha^{-1} *HBC*	7,191	5732	56,668	12,298	214 %

Note: *The row method having 05kg.ha^{-1} seed rate was eliminated for the marginal analysis since it was not passed dominance analysis.*
TVC=total variable cost MC=marginal cost NB=net benefit MB=marginal benefit MRR marginal rate of return (the ratio of the marginal revenue to the marginal cost)

Treatment 25 kg.ha^{-1} hand broadcasting method is more varied than the alternative. The partial budget and marginal analysis for economic analysis experiment has indicated that the treatment 25kg.ha^{-1}hand broadcasting method show the highest net benefit and the MRR for this treatment (214%) implied that for each birr invested in the hand broadcasting method, the producer can expect to recover the one birr invested plus an additional return of 2.14 birr (table 3).

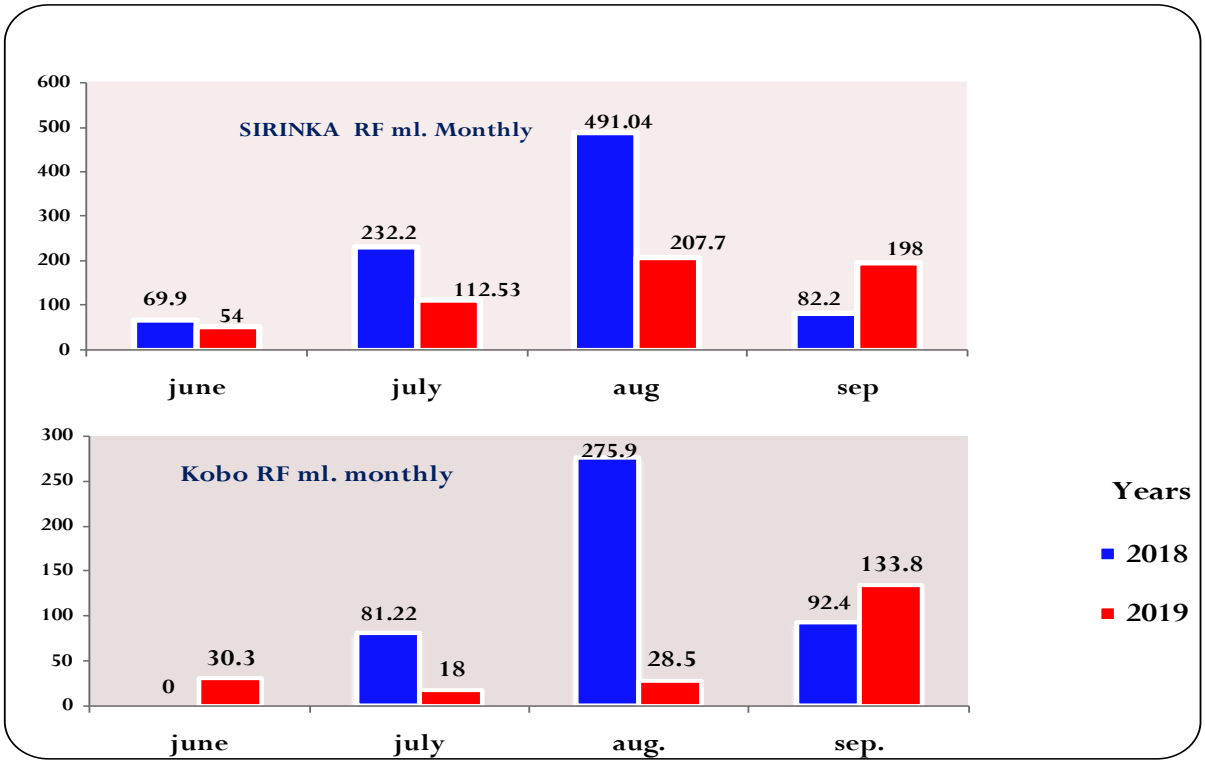

Fig. 2. Monthly rain falls at Sirinka and Kobo

Early season drought could delay sowing and /or causes poor germination of sown crops as soil moisture content is the major environmental factor affecting crop germination and its establishment (Mengistu & Mekonnen, 2012). As it is indicated in fig.

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2, monthly rain falls at Sirinka and Kobo were very low at planting of tef in July. It indicates poor seed germination and establishment and high disease and insect infestation occurrence in the area that lead to the row planting of tef treatment with minimum seed rates reducing total tef population in the plot then reducing total grain and biomass yields.

Focus group discussion with farmers

Farmers were selected and were arranged for group discussion to discuss issues on the different treatments especially between the hand broadcasting and row planting. The farmers for group discussion were composed of different ages and sex. Total participant of farmers for the group discussion were nine.

Table 6. Numbers of last year planting method of sample farmers

Last year planting method of sample farmers		
	Row method	Broadcast method
Sirinka	5	9
Kobo	2	8

Note: participants were nine at Sirinka and ten at Kobo including host farmers; all participants were male. *Source own survey result (focus group result), 2018*

At Sirinka, all participants used broadcast planting methods last year (table 6), but five farmers tried the row planting partially in small plots. And at Kobo, only 20% of participant farmers used a row planting method on an irrigation site but in a different practice from the normal row planting method. They usually make a line with oxen plough and then broadcast (spread the seed and fertilizer) over the plot then apply irrigation water in the furrow finally the seeds emerging on the ridge that can make a line. In the Meher season, they did not use row methods at Kobo (table 7).

Table 7. Merit and demerit of tef row planting stated by farmers

Merit of row planting	***Demerits of row planting***	***Remarks***
Easy for weeding	Difficult to keep straight line during row making	
Easy for spraying chemical	Requires more labor	Eg. One person can sow hectare of land per day in broadcasting and six persons required for only 625m^2 of land per day to sow in row method
Favorable for tef growth on its space	Time taken to plant on critical moisture	Moisture will be lost for emergence if once the critical planting time passes.
Reduced seed rates	Difficult to replant	
	Difficult to make row during rain on heavy black soil	

It was difficult to make rows in a straight line for tef row planting especially during rainfall and in heavy black soil condition and it took more labor and time on the study area. Finding in agreement with the reports of Mesfin et al. (2013), the major challenges that face farmers in row planting are its labor intensity, its time consumption and its extensive requirements of fertilizer compared to previous traditional practices of farming. And Getu (2014), due to adoption risk and vulnerability of teff production through row planting technology farmers in the study area prefer the application of broadcasting method of planting on account of its low labor cost, straw quality and application simplicity.

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Table 8. Merit and demerit of tef hand broadcasting stated by farmers

Merit of broadcasting	Demerits of broadcasting
Less labor required	Difficult for spraying chemical inside the plot
Easy for replant	Difficult for weeding inside the plot
Easy for planting on available moisture (in short period of time)	Can reduced yield and straw in time of insufficient moisture
Minimize the risk of total loss by insect using high seed rates High amount of tef straw for cattle feed and for sale	

There is a risk of tef crop failure by the occurrence of disease, insect and drought. For this replant the same crop totally or partially is usual practice in eastern Amhara; one advantage of tef is that both the grain and straw fetch a relatively higher price in the market in comparison to other resulting in a lower risk to the farmers. Therefore, due to its labor-intensive nature of row planting the poor and farmers having fragmented land holders cannot afford the replant cost and also loosing available moisture for the seeds to grow based on time taken for row planting is higher than that of hand broadcasting (table 8). The finding was in agreement with the report Getu (2014), row planting technology is not appropriate to the poor with fragmented landholding and small labor support because of risk of crop failure. And the farmers did not tend to plant tef using row planting method for next production year. This is confirmed the finding of (Vandercasteelen *et al*, 2014), which have assessed the farmer's perception in the Oromia region. The aforementioned authors stated the fact that farmers plan to plant the largest part (80 %) of their tef lands using broadcasting and only 19 % of the tef area of these farmers were allocated to row planting and 1 % to transplanting.

CONCLUSION

Even if the previous studies indicated that row planting of tef had a yield advantage over hand broadcasting; this study result indicated, the hand broadcasting with 25kg.ha^{-1}seed rate with proper field management showed a yield advantage and economically sound net benefit. This is due to higher pest prevalence in the study area and susceptibility nature of row planting for insects by its lower seed rates. Row planting methods were new for the farmers in low land areas of Eastern Amhara, then it was perceived as a more difficult technology option by farmers to be adopted for its labor intensiveness. In addition to tef grain yield, farmers also need large amounts of tef straw for their animal feed during dry season and higher economic importance for its price by planting higher seed rate of tef in broadcasting. It can be an insurance for the risk of total crop failure by pests and moisture stress.

Therefore under the lowland condition of Eastern Amhara, tef planting with hand broadcasting (25kg.ha^{-1} seed rate) method is advisable practice than row planting methods of (5 and 10kg.ha^{-1} seed rates) due to its advantage of high seed rate for insect resistance. In times of crop failure; the poor and farmers having fragmented land holders cannot afford the replant cost of tef by its labor-intensive nature of row planting. Due to this use of the hand broadcasting method of tef with proper field management can reduce the risk. Beside teff grain yield every tef producer should have considered tef straw as a source of animal feed and as a source of income by its high price for producers' livelihood. In order to gain optimum tef yield with feasible economic advantage from

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broadcast planting method, seed rate study should be a key area of future research**.**

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