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Cost-benefit Analysis of New Tef (*Eragrostis tef*) Varieties under Lead Farmers' Production Management in the Central Ethiopia

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አህፅሮት

ጤፍ ኢትዮጵያ ውስጥ በሰፊው የሚመረት የምግብ ሰብል ሲሆን በየዓመቱ ከሦስት ሚሊዮን ሄክታር የሚበልጥ መሬት ይሸፈናል። ይህ የመሬት ስፋት ለብርዕ እና አገዳ ሰብሎች በየዓመቱ ከሚውለው የመሬት ስፋት ውስጥ 30 በመቶ ይሆናል። በቆሎ እና ስንዴ ከመሳሰሉት የብርዕ እና አገዳ ሰብሎች ጋር ሲወዳደር ጤፍ ሕይወት ባላቸውና ሕይወት በሌላቸው ነገሮች የሚመጡ ተፅዕኖዎችን የበለጠ የመቋቋም አቅም አለው። የጤፍ ማሻሻያ ፕሮግራም ኢትዮጵያ ውስጥ በ1940ቹ ከተጀመረበት ጊዜ ጀምሮ 42 የሚሆኑ የተሻሻሉ የጤፍ ዝርያዎች በብሔራዊ የምርምር ሥርዓቱ ተለቀዋል። ሆኖም ግን ጤፍን ለማምረት የሚወጣው ወጪ እና የሚገኘው አጠቃላይ የምጣኔ ሀብት ጠቀሜታ በውል ተጠንቶ አያውቅም። ስለሆነም ጤፍን ለማምረት የሚከናወኑ ተግባራትን ከምጣኔ ሀብት ጠቀሜታ አንፃር ለመገምገም በመካከለኛው ኢትዮጵያ ባሉት አራት ዋና የጤፍ አምራች ወረዳዎች (አደአ፤ጊምቢቹ፤ሞረትና ጅሩ እና ምንጃር- ሸንኮራ) ውስጥ በሚገኙ 46 ግምባር ቀደም አርሶ አደሮችን ያካተተ የመስክ ጥናት ተካሂዷል። በቅርብ ጊዜ የተለቀቁ ኮራ እና ቦስት የሚባሉ የጤፍ ዝርያዎች በጥናቱ ተካተው ተሞክረዋል። ኮራ እና ቦሰትን ለማምረት የሚያስፈልገው የሥራ ማስኬጃ ወጪ እንደቅደም ተከተላቸው በአማካይ 19,308.70 እና 18,859.27 ብር በሄክታር ነበር። ኮራን በማምረት የተገኘው ምርት በሄክታር ከ1,200.00 እስከ 2,500.00 ኪ.ግ ሲሆን አማካይ ምርቱ ደግሞ 1,963.00 ኪ.ግ. ነበር። በተመሳሳይ መልኩ ቦሰትን ለማምረት የተገኘው ምርት በሄክታር ከ2,000.00 እስከ 2,800.00 ኪ.ግ ሲሆን አማካይ ምርቱ በሄክታር 2,540.00 ኪ.ግ. ነበር። ኮራ የተዘራው በተስማሚ እና በቂ ዝናብ በሚገኝበት ስነምህዳር ቢሆንም በ2008 ዓ. ም በነበርው ያለተስተካከለ ዝናብ ምክንያት ከቦሰት ያነሰ ምርት ሊሰጥ ችሏል። ኮራን በማምረት የተገኘው ትርፍ በሄክታር 22,676.43 ብር ሲሆን ቦስትን በማምርት የተገኘው ትርፍ ደግም በሄክትር 35,721.12 ብር ነበር። ጤፍ ለማምራት ከሚወጣው ጠቅላላ ወጪ ውስጥ ከፍተኛው ወጪ የዋለው ለሰው ጉልበት (58%) እና ለማዳበሪያ (22%) ነበር። ለሰው ጉልበት ከወጣው ወጪ ውስጥ ትልቁን ድርሻ የወሰደው የአጨዳ ሥራ (43%) ሲሆን የአረም ሥራ (35%) በሁለተኛነት ይከተላል። ለአጨዳ እና ለአረም ሥራዎች ወጪ መጨመር በሄክታር የሚወጣው ወጪ እንደጨምር ከፍተኛ አሰተዋፅኦ ከማድረጋቸውም በላይ ትርፋማነትንም እንደሚቀንሱ ጥናቱ አረጋግጧል። ስለሆነም ለአጨዳ እና ለአረም ሥራዎች የሚወጣውን የሰው ጉልበት ወጪ ለመቀነስ የሚረዱ ቴክኖሎጂዎችን ማመንጨት ወይም መፈለግ ያስፈልጋል።

Abstract

*Tef [**Eragrostis tef (**Zucc.) Trotter] is the most important food crop in Ethiopia. It is annually cultivated on over three million hectares of land, which is equivalent to 30% of the total area allocated to cereals in the country. Compared to other cereal crops, such as wheat and maize, tef has higher tolerance to unfavorable environmental conditions, which include both biotic and abiotic stresses. Since the inception of Tef Improvement Program in Ethiopia in the late 1950s, the National Research System has released 42 improved varieties. However, cost of production and economic benefit derived from tef farming was not clearly understood. Thus, a study was carried out in the field plots of 46 lead farmers in four districts (namely, Ada'a, Gimbichu, Moretna-Jirru, and Minjar-Shenkora) where tef is the major cereal crop in order to assess the economics aspects of the tef faming venture. Two recently released tef varieties Kora and Boset were used for the study. On average, the total variable cost of production was 19,308.70 birr ha^{-1} for Kora and 18,859.27 birr ha^{-1} for Boset. Although the average grain yield was 1,963.00 kg ha^{-1} for Kora and 2,540.00 kg ha^{-1} for Boset, it ranged from 1,200 to 2,500 kg ha^{-1} for Kora and from 2,000 to 2,800 kg ha^{-1} for Boset. Kora was sown at appropriate agro-ecologies that receive better rainfall but Boset gave higher yield as a result of climate change and erratic rainfall in 2016. The average profit was 22,676.43 birr ha^{-1} for Kora and 35,721.12 birr ha^{-1} for Boset. The two highest production costs were labor (58%) and fertilizer (22%). From the total labor costs used in tef production, the lion's share went to harvesting (43%) and weeding (35%). The study revealed that harvesting and weeding are the most critical factors to escalate cost of production, and thereby to decrease its profitability. Thus, technologies should be sought to minimize cost of labor for harvesting and for weeding in tef production.*

Introduction

Tef [*Eragrostis tef* (Zucc.) Trotter] is among the major cereal crops in the Horn of Africa particularly in Ethiopia where it is number one in terms of acreage allocated to its cultivation. It is grown by about 6.5 million smallholder farmers on over three million hectares of land, which is equivalent to 30% of the total area allocated to cereals (CSA, 2015). The wide-scale cultivation of tef is related to its tolerance to diverse environmental constraints, which include both excess and scarce soil moisture. In addition to being nutritious, tef grains are free of gluten (Spaenij-Dekking *et al*., 2005), a causal agent for celiac disease; and hence tef is becoming globally popular as a life-style crop (Provost and Jobson 2014).

Despite these agronomical and nutritional benefits of tef, both the total production and productivity of tef is relatively low. The main reasons for inferior yield of tef are suboptimal genetic gain, low access to seeds of improved varieties, poor agronomic practices and lodging (Kebebew *et al*., 2017; Mizan *et al*., 2016). Although 42 improved tef varieties have been released by the National Research System in Ethiopia (MoANR, 2017), their adoption by farmers is low (Kebebew *et al*., 2017).

The central issue of applying the latest agricultural technology and/or innovation lies not only on the improvement of farm performances but also on the impact of technology on social and economic conditions of rural households, and on the promotion of land and labor productivity in agricultural sector. When improved tef technology is developed, it is necessary to perform cost-benefit analysis, to assess that the new technology is economical, socially accepted, technically feasible, as well as environmental friendly. Such efforts require a coherent multidisciplinary team of researchers (Coudel *et al*., 2013; Ogwal-Kasimiro *et al*., 2012). Several studies have been made in the past to investigate cost of production and economic benefits derived from tef farming. **(**Kidane and Abera, 2017; Abate and Asfaw, 2013; Abate *et al*., 2005).

Before the introduction of new technology to farmers, the social researcher and the extension agent need to devise a program that facilitates or enhances the adoption of the technology by the farmer. This requires the estimation of yield, cost of production and economic benefit derived from tef farming that was not clearly understood; the verification of the economic benefits of the varieties to reduce the economic risks farmers fear; and the training of lead farmers in the dissemination of the new technology in order to convince fellow farmers in the vicinity.

This study analyzes the cost-benefit of two new tef varieties on 46 lead farmers from four districts in the central highlands of Ethiopia.

Materials and Methods

Study area

Four woredas in the central highlands of Ethiopia, where tef is the major crop, were selected for the study. These are Ada'a and Gimbichu districts from East Shewa Zone in the *Oromia* Regional State, and *Moretna-Jirru* and *Minjar-Shenkora* from North *Shewa* in the *Amhara* Regional State. The four districts have long experiences in tef farming. Tef and wheat are the major crops, which occupy 75 percent of the total cropped area. Virtually, all farmlands are cultivated and farmers use improved technologies to compensate land scarcity. The locations of the four districts are shown in Figure 1.

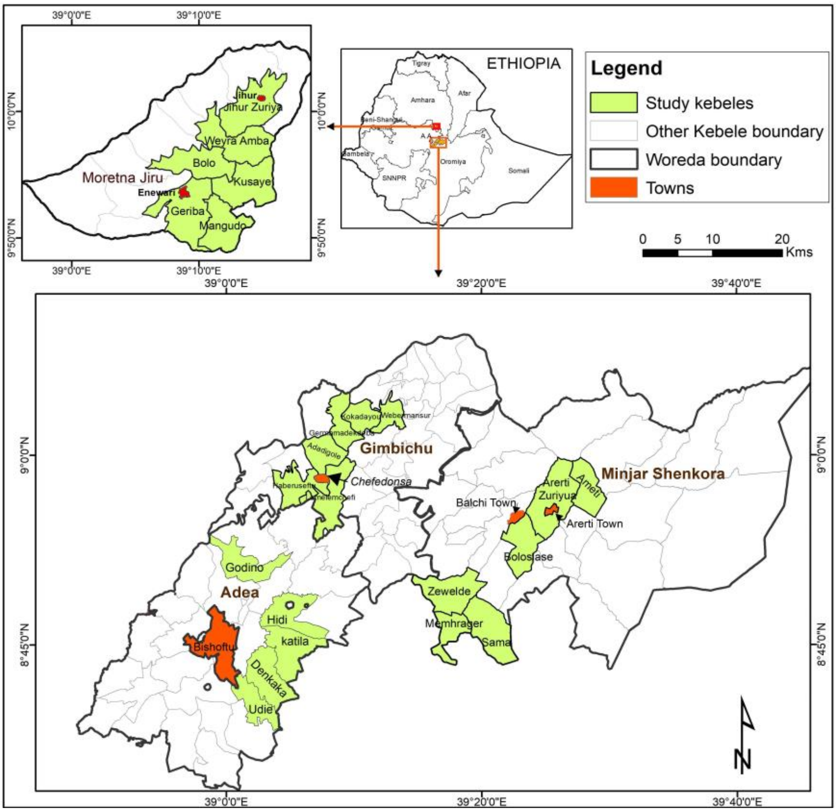

Figure 1. The location of the study area

Design and sampling

Forty-six farmers were randomly selected from among 70 lead farmers. Lead farmers refer to smallholder farmers who are ready to test new farming technologies including improved seeds in their fields. Based on farmers' preferences and seed availability, *Kora* variety was grown by 26 lead farmers, while both *Kora* and *Boset* varieties were grown by 20 lead farmers to avoid risks occurred because of climate change and erratic rainfall. *Kora* is a late-maturing variety (100-120 days) which is recommended for relatively high-rainfall areas while *Boset* is an early maturing variety (80-90 days) recommended for relatively low rainfall areas. In the 20 lead farmers' fields, where both varieties were grown, the two tef varieties were planted side-by-side on the same field and at the same sowing date each on about 0.25 ha. The seed rate of both varieties was 16-20 kg ha^{-1}, while farmers individually decided on all other agronomic practices, which include frequency of ploughing, time of sowing, time of hand weeding, and type, time and rate of fertilizer application. Moreover, except the seed required for demonstration, the lead farmers used their own inputs and they were responsible for managing the demonstration trials, while the researcher and the extension agent were responsible for developing the format for input used for the trails and facilitating training on record keeeping. The researcher also assisted the lead farmers to ensure that the demonstrations/trials were within their capabilities by keeping field trials as simple as possible, i.e., only one to two treatments and reflected on what the farmers are currently practicing.

Data collection and analysis

Relevant physical and cost data were collected from the primary sources. Primary data on grain yield, labor and oxen use, and application rates of inputs such as seed and fertilizer were based on the field trials. The data were coded and entered into the SPSS computer software package for analysis. Data were initially analyzed using descriptive statistics such as means, frequency, percentages and standard deviations. Merged trial analysis was applied because the lead farmers involved in the field trials have similar production sets, farming practices, and farm tools, as well as low amounts of purchased inputs other than labor, share the same support structures and are exposed to the same technical guidance on how to manage the field trials (Assefa and Heidhus, 1996; Coelli *et a*l., 1998; Abate *et al*., 2009; Norton and Alwang, 1993).

Gross margin was calculated as the difference between gross revenue and variable costs. Gross revenue is the product of the total grain produced and the price per unit of product. Profit was estimated for 10 lead farmers and refers to the difference between total revenue and total costs that include both variable and fixed costs. Performance indicator is the ratio between the total output and the total input in terms of market value; the benefit cost ratio.

Farmers were classified into groups using hierarchical clustering, and the inputs coefficients of the field trials were then determined by applying a multiple regression model. All costs and revenues were quantified based on 0.25 ha land of each farmer which were later extrapolated to the hectare basis.

Multiple regression model

Multiple regression model was applied to predict the value of five variables. The multiple regression was implicitly specified as follows:

$$Y = f(X_1, X_2, X_3, X_4, X_5)$$

Where Y = Yield of tef, kg/ha, X_1 = seed, kg/ha, X_2 = Urea, kg/ha, X_3 = DAP, kg/ha, X_4 = Labour, man-hour/ha, and X_5 = traction, oxen-hour/ha (Agwu *et al*., 2008; Gujarati, 1995).

Results and Discussion

Socio-economic characteristics of the lead farmers

The farm size, the level of education, the age and the farming experiences of the lead farmers were highly variable (Table 1). It is hypothesized that the above-mentioned parameters can be positively or negatively related to farm productivity and efficiency. For instance, higher-level education, for example, secondary school of the lead farmers is assumed to enhance tef productivity through the application of pertinent information that improves farm productivity and efficiency.

The result of the analysis showed that the proportion of respondents in each age class was nearly equal (Table 1). With regard to education, most of the respondents had completed primary education. This shows that over 90% of the respondents are able to read and write; hence, they can easily adopt tef production technology. The proportion of respondents who had between 5-10 years of farming experiences was greater than those who had either 1-5 or more than 10 years of experience. The study further showed that the majority (48%) of the respondents owned 1-2 hectares of land although those possessing over two hectares are also about 40%.

Table 1. Socio-economic characteristics of lead farmers (N = 46)

Socio-economic characteristics	Ada'a'a	Gimbichu	Minjar-Shenkora	Moretna Jirru	Respondent	
	(No of respondents)				(number)	(%)
Age group						
21-30	0	1	6	6	13	28.3
31-40	2	2	4	4	12	26.1
41-50	2	2	5	2	11	23.9
Above 50	2	2	3	3	10	21.7
Educational level						
Non-formal education	0	1	1	2	4	8.7
Primary school	4	4	13	10	31	67.4
Secondary school	2	2	4	3	11	23.9
Farming experience						
1-5 years	2	1	5	6	14	30.4
5-10 years	2	5	9	3	19	41.3
> 10 years	2	1	4	6	13	28.3
Farm size						
< 1 ha	0	2	2	2	6	13.0
1-2 ha	3	2	10	7	22	47.8
> 2 ha	3	3	6	6	18	39.1

Grain yield

The researchers made frequent observations and monitoring throughout the cropping calendar. These frequent observations and monitoring by the researchers have convinced the farmers to strictly follow and manage their tef trials, although the lead farmers planted the new tef varieties on properly ploughed land. Based on the recommended farming practices of the respective locations, planting and weeding were done at the appropriate times during the season. As depicted on Table 2, the average grain yield of Kora and Boset varieties were 1,963 and 2,540 kg ha^{-1}, respectively, although it ranged from 1,200 to 2,500 kg ha^{-1} for Kora and from 2,000 to 2,800 kg ha^{-1} for Boset. This large yield gap among the farms led us to group the farms into four clusters (Table 2). On average, Boset variety gave higher grain yield than Kora variety mainly due to the early maturing period of the former which enabled it to escape from frost that occurred anomalously during the trial season at the heading or flowering time. Whereas the cessation of the rainfall and frost occurrence during the flowering period of the late maturing Kora variety lowered its productivity although under normal cropping season, Kora produces more grain yield than *Boset*. Based on the trial record sheet and field observation, *Kora* was substantially affected by frost and erratic rainfall in the fields of six farmers in Gimbichu.

Table 2. Grouping of lead farmers based on the tef grain yield obtained from the two varieties

Farm group	Group interval ($kg\ ha^{-1}$)	Kora (n = 46)		Boset (n = 20)	
		N	%	N	%
I	1000 – 1500	6	13.0	0	0
II	1501 – 2000	18	39.1	0	0
III	2001 – 2500	22	47.8	11	55
IV	2501 – 2800	0	0	9	45
	Total	46	100	20	100

Input types and variable costs

Farmers were advised to keep record of accomplishment of farm inputs they utilized on their plots. The major inputs considered for analysis were amount of seed, type and amount of fertilizer, oxen hours for seedbed preparation, and a variety of costs related to labor. Labor costs include those for ploughing, planting, weeding, harvesting and threshing. Person-hours spent on transporting the harvested crop from the farm to homestead, stacking, and post-threshing processes, which include cleaning and winnowing the seeds, were not included in the study. Accordingly, growing tef from ploughing the field to harvesting and threshing required on the average 910.5 person-hours labor ha^{-1} and 460.2 oxen-hours ha^{-1} (Table 3). The three major practices where oxen power is required were for threshing (323.65 oxen-hours ha^{-1}), land preparation (98.96 oxen-hours ha^{-1}) and planting (37.57 oxen-hours ha^{-1}). This substantial amount of labor and oxen time also reflects on increased costs from this sector. The study also revealed that the lead farmers did not apply the recommended doses of fertilizers for tef. The mean amount of DAP and urea fertilizers applied by these farmers were 213 kg ha^{-1} and 135 kg ha^{-1}, respectively. Since DAP constitutes 46% P_2O_5 and 16% N and urea constitutes 46% N, the equivalent amounts applied by farmers were 98 kg P_2O_5 ha^{-1} and 96 kg ha^{-1} N. While the whole amount of DAP was applied during tef sowing, urea was applied in two splits: the first half during planting whiles the second half a month later at the time of peak tillering. Urea and DAP are still the dominant fertilizer types used in Ethiopia. Blending fertilizers have potential for future use as they contain vital micronutrients in addition to the major macronutrients. However, the distribution of blending fertilizers is limited in the country; hence, they were not used in the current study.

Where there is scarcity of land to cultivate, no one could raise debate on the noble concept of increasing yield per unit area but yield is not an end in itself unless it is accompanied by reasonable gross margin and profit to remain competitive and stay in farm business. Consequently, lead farmers must manage variable and fixed costs. To that end, lead farmers were trained and provided a standard format to record input quantities used for the field trials they hosted. Based on the trial record sheet kept by the farmers and researchers' close observation, the total variable costs were determined using the respective input prices. On average, the total variable costs were estimated at 19,309.00 birr ha^{-1}. Out of this, the highest costs were 11,162.40 birr ha^{-1} for labor and 4,291.30 birr ha^{-1} for fertilizer, which respectively represent 58% and 22% of the total cost.

One means of generating increased agricultural production is to increase the use of improved inputs. To this end, investigating the cost structure has an important role to play in increasing agricultural productivity since the potential for expanding the land resource is limited in the areas where these field trials were conducted. Hence, while labor and fertilizer were relatively high-cost inputs, seed of improved tef variety was a low-cost input as it accounts for only 2-3% of the total cost. This extremely low share of seed to the total variable cost is due to lower seed rate of tef which ranged from 15 to 20 kg ha^{-1}.
Labor was the most important limiting factor of production in small-scale farming. A higher-yielding variety required more labor, but it produces more output per unit of labor (Coelli *et al*., 1998; Moseley, 2000; Abate *et al*., 2005). If the technology is neutral with respect to its effect on labor use, the demand for labor grows proportionately. When labor used in the tef trials was grouped into different components of operation, the lion's share went to harvesting (43%) and weeding (35%). In addition, untimely rainfall during harvesting caused high labor payment rates. Costs incurred in planting and threshing were the lowest. This indicates that in order to increase tef productivity, future research needs to focus on reducing the time for weeding and harvesting. This could be possible through the use of effective herbicides to substitute hand weeding and the use of mechanical harvester.

Gross margins or revenues

Gross margin of a farm is the difference between gross revenue (price x yield) and variable costs. Answering the question 'Does High Yield Mean High Gross Margin and Profit?' is difficult and tough because input costs continue to rise and farmers do not keep track of several of their production costs, including land, seed, fertilizer, labor and oxen power costs.

Most often, the potentials of a technology for gross margin and profit offers farmers the incentive to accept new technologies to improve crop productivity. Higher gross margin and profits are the results of higher yield and improved product quality, whereas lower cost per unit of product could most likely be achieved through a combination of farm inputs, and better utilization of inputs. Profitable farmers will be better able to protect the environment, utilize resources, and produce abundant and safe foods. They will also adopt science, technology and innovation successfully (Norton and Alwang, 1993; Mellor, 1990). Any adjustments of technologies or activities being adopted rely on the economic advantage gained. Farmers who do not understand the technology are afraid of the economic risk that might be encountered.

To ascertain the economic viability of new technology-based tef production, the two improved varieties were demonstrated and their gross margins were determined. The parameters used to determine gross margin was the grain yield level obtained per hectare, which was classified into four groups. In all yield categories, the variable costs incurred were almost uniform. This entailed that farmers, who produced high yields with low unit cost, obtained progressively higher revenues per hectare when prices are similar.

Farmers, who achieved low yields in the two districts (Moretna-Jirru and Gimbichu), were asked to identify the main reasons for the obvious yield differences between the two varieties? Almost all the lead farmers stated that shortage of rainfall at grain filling stage and frost were the main reasons for low yield across the field trials. All lead farmers confirmed that Boset variety gave higher grain yield and higher revenue per hectare than Kora because it escaped both the drought and frost (Table 3). While Kora is grouped under lower yield groups ranging from 1,000 to 2,500 kg ha^{-1} (yield group I to III) Boset is grouped under higher yield groups ranging from 2,000 to 2,800 kg ha^{-1} (yield group III and IV). Thus, in anomalous seasons, varietal selection concerning drought and frost should never be overlooked. This in turn suggests the need for developing weather forecasting system and availing generated information to end users.

Table 3. Mean revenues, variable costs and gross margins of farmers cultivating *Kora* and *Boset* varieties

Yield group	Group interval (kg ha^{-1})	*Kora* variety (n=46)				*Boset* variety (n = 20)			
		N	Revenue (birr ha^{-1})	Cost (birr ha^{-1})	Gross margin (birr ha^{-1})	N	Revenue (birr ha^{-1})	Cost (birr ha^{-1})	Gross margin (birr ha^{-1})[1]
I	1000 - 1500	6	29,773.33	19,486.81	10,286.52	0	0	0	0
II	1501 - 2000	18	39,771.12	19,374.95	20,396.15	0	0	0	0
III	2001-2500	22	49,660.00	19,205.94	30,454.06	11	53,480.00	18,815.12	34,664.88
IV	2501-2800	0	0	0	0	9	58,813.33	18,913.31	39,900.03

Average cost and benefits analysis

Cost and benefit analysis is employed to ensure that improved tef production technologies are desirable and economically sound. Thus, the technique of input-output analysis indicates the cost and benefit relationship of tef production technology as a basis for its proper evaluation and selection. Comparatively, Boset variety would benefit a larger number of farm families, especially those in urgent need of higher income through sales to the consumers.

Profit

Arithmetically, profit is the difference between total gross value of yield at prevailing market prices and total costs (total variable and fixed costs). For variable costs such as seed, fertilizer, herbicides, actual quantity used and actual amount of labor and oxen hours spent for the entire cropping season were taken into account. Fixed costs are periodic costs that remain more or less unchanged irrespective of the output level. Among the fixed costs, the interest on fertilizer loan and cost for land renting are considered. Unlike variable costs, fixed costs are not simple to compute. To tackle the problem, 10 lead farmers were randomly selected to estimate the fixed costs. The fixed costs considered were land taxes, fixed cash costs (annually hired labor), interest on capital (loan) and farm tools. The total sum estimated was divided by crops cultivated in a household for finding out the fixed costs per hectare. Thus, following the interview with 10 sampled lead farmers, the fixed cost estimated was 1,948.68 birr ha^{-1}. This covered 10 percent of the total variable costs. Looking after the smallest details of the fixed costs and going to the other households was difficult and time consuming. We only focused on the ten lead farmers and extrapolated to 36 other farmers. This estimate falls within acceptable limits of other studies that confirmed that fixed costs contribute for 10-15% of variable costs in smallholder farmers who operate at low level of performance (Kohl, 2016; Moran, 2009; Mellor, 1990; Yang, 1980).

The average profit, which includes the fixed costs, was 22,676.43 birr ha^{-1} for Kora variety and 35,721.12 birr ha^{-1} for Boset variety (Table 4). Thus, based on the scale of profit farmers obtained, Boset variety was more preferred to Kora variety. Increased farm profit triggers farmers to accept new technology/innovation, reduce cost per unit product, maintain soil fertility and search for better marketing (Darst and Fixen, 2000).

Performance indicators of improved tef varieties

The central issue of technology dissemination is not the improvement in performance of actors but the improvement in farm input productivity (for example, seed, fertilizer, land and labor) and consequences of technology dissemination on the actors are important indicators (Roling, 2009).

Increase in tef crop output per unit of area and per worker is recognized as a necessary condition for economic development. The benefits of improved tef technology in small-scale farming are realized in terms of increase in farm output, higher income and improved standard of living (Hart, *et al*., 2005). Smallholder farmers are characterized by the difference in relative endowments of improved technologies, land and labor.

Table 4. Variable costs, gross benefits and net profits by farmers growing the two improved tef varieties

Costs and benefit	Improved variety	
	Kora (n = 46)	Boset (n = 20)
Costs (birr ha^{-1})		
Seed	450.00	450.00
Fertilizer	4,291.30	4,291.30
Labor	11,162.40	10,950.75
Oxen	3,405.00	3,167.22
Total variable costs	19,308.70	18,859.27
Fixed costs*	2,413.59	2,357.41
Total costs	21,722.29	21,216.68
Benefits (birr ha^{-1})		
Grain yield	43,196.56	55,880.00
Straw yield	1,202.16	1,057.80
Total revenue**	44,398.72	56,937.80
Gross margin	25,090.02	38,078.53
Profit (birr ha^{-1})	22,676.43	35,721.12
Benefit-cost ratio	1.04	1.68

** Fixed costs contribute for 12.5% of the total variable costs*
***Grain and straw priced at 22.0 and 1.2 birr kg^{-1}, respectively*

Performance indicators in tef production vary based on farm size, effective use of improved technologies and labor. Compared to other cereal crops, tef is labor intensive because of low productivity per unit of labor and per unit of land. This can be partly explained by the fact that smallholder farmers cannot afford to purchase improved technologies. Tef grain yield per hectare and return per unit of fertilizer, labor and number of oxen used were important performance indicators of cost for tef production.

In this experiment, the field trial results revealed that marked productivity differences existed between Kora and Boset varieties (Table 5). However, the average production cost for Kora variety was greater than Boset variety. Farmers acknowledged that threshing Kora variety took longer time, which might have entailed more labor and oxen costs. The results further revealed that as productivity per unit area increased, the production cost per unit product decreased. Low tef price benefits consumers and stimulate industrial growth but can lower agricultural producers' incomes and reduce employment of landless workers. To the extent that lower tef prices reflect lower production costs due to adoption of improved tef technologies, income reductions to producers could be mitigated.

Table 5. Performance indicators of improved tef varieties disseminated to lead farmers

Performance indicator	Kora (n = 46)	Boset (n = 20)	T-test
Average tef grain yield (kg ha^{-1})	1,963.48	2,540.00	9.54**
Average production cost (birr ha^{-1})	19,308.71	18,859.31	1.87^{NS}
Seed multiplication ratio	109.08	151.19	7.85**
Tef grain return per unit of DAP (kg)	9.22	12.33	8.62**
Tef grain return per unit of urea (kg)	14.57	22.09	5.39**
Labor productivity in tef (kg man-hour^{-1})	2.15	2.80	8.92**
Oxen productivity in tef (kg oxen-hour^{-1})	4.27	5.55	8.67**
Production cost (birr kg^{-1})	9.84	7.43	7.98**

*** = highly significant (p<0.01); NS = non-significant (p>0.05*)

Multiple regression model

In this multiple linear regression model, tef yield was expressed as a function of seed, fertilizers (DAP and urea), labor and oxen inputs. Except for urea, the estimated coefficients of all the input variables had positive signs as expected (Table 6). Increasing DAP by 10% would increase tef yield by 6.2%. Similarly, use of improved seed could increase tef output by 2.2%. From the estimated coefficient, it is evident that amounts of seed and DAP were by far the most important independent variables explaining positive significant effect on tef grain yield. This had indicated that improved tef varieties with increased efficiency in DAP utilization boost productivity, while urea might have encouraged lodging that attributed to the reduction in grain and straw yield. Furthermore, farmers applied excessive amount of urea, which is higher than the economic optimum anticipating more grain yield per unit area.

Hence, based on our study, the estimated grain yield (Y) of the improved tef variety would be Y = 13.5 + 0.22seed + 0.62DAP - 0.36urea + 0.09labor + 0.14oxen. This implies that, to maintain high level of tef yield, farmers should learn to adjust input use in changing conditions, where adding more urea per unit of area had negative impact on grain yield. R^2 (R-square) estimated at 0.52 had shown that there are still other relevant factors which account for this influence.

In multiple regression model, the small size of *n* and how high an R^2 are indicators to detect collinearity. A sign of multicollinearity is, first, detected when R^2 is very high and none of the regression coefficients is statistically significant on the basis of conventional t-test. Our results revealed none of the above. Second, when the sole purpose of using multiple regression analysis is for prediction or forecasting, then multicollinearity cannot be a serious problem.

Table 6. Multiple regression analysis of major variables influencing tef grain yield (n = 46)

Independent variable	Coefficient	SE	T	Sig
Constant	13.5	4.31	3.13	0.002
Seed (kg ha^{-1})	0.22	0.12	1.92	0.050*
DAP (kg ha^{-1})	0.62	0.16	3.87	0.000**
Urea (kg ha^{-1})	- 0.36	0.14	-2.57	0.002**
Labor (man-hours ha^{-1})	0.09	0.12	0.75	0.767
Oxen (oxen-hours ha^{-1})	0.14	0.13	1.108	0.274

Adjust $R^2 = 0.52$

*** and * significant at < 0.01 and 0.05, respectively*

Perception of farmers to the improved tef varieties

When farmers were asked about the new varieties, 89% of respondents chose Boset variety particularly when the rain between July and August were low. Due to its early maturity, this particular variety escapes from frost and terminal drought, which normally occurs during crop maturity. According to 85% of the farmers, Boset shatters if not harvested early. Thus, farmers do not wait until late, when the moisture contents of the grain and stem are lower. Field days and several informal visits were organized to show the performance of the two tef varieties at farms of 46 participating farmers. In these field visits, 70 farmers, extension agents and researchers participated where presentations were made by host farmers followed by discussions that mainly involve fellow farmers. In addition, due to their key locations, as most of them were on the roadside to the market, many farmers informally visited these fields with new tef varieties. The feedback received from participating farmers was positive and many requests for seeds of the two varieties used in the current study. During farmers' field days and several informal visits, large number of farmers had expressed their interest to grow both varieties, although they were skewed towards Boset.

Conclusions and Recommendations

On the basis of the field trials, the following conclusions were made Kora was sown at appropriate agro-ecologies that received better rainfall but Boset gave higher yield as a result of climate change and erratic rainfall in 2016. Boset variety was superior to Kora variety in terms of productivity and profitability, especially in areas with limited and erratic rainfall due to its early maturity.

In the multiple linear regression analysis, seed, DAP, urea, labor and oxen were considered of which DAP had a statistically significant and positive influence on tef yield ($p < 0.01$). Whereas, urea had a statistically significant but negative influence on tef yield ($p < 0.01$). This indicates that farmers should not apply excessive amount of urea over the economic optimum anticipating more grain yield per unit area.

Analysis of production cost structure revealed that the highest proportion of the production costs across the lead farmers for both Kora and Boset varieties went to cost of labor (58%) and fertilizer (22%).

As opposed to the traditionally used seed rate of 30 to 35 kg ha^{-1}, the current study indicated that reduced seed rate (15-20 kg ha^{-1}) for tef increased yield per unit area but farmers challenged the researchers to improve the feasibility of using reduced seed rate for both row planting and broadcasting.

Finally, given the input and output prices that prevail in the selected districts, the lead farmers obtained substantial benefits, indicating that small-scale tef farming is not only a financially viable venture, but it has been significantly contributing towards generating household cash income and ensuring food security in the changing climate.

Similarly, the following five recommendations have been forwarded

- Studying production costs make technology sustainable and profitable, and bridge the glaring gap between production costs and farm product selling prices;
- The optimum amount of urea required for tef production should be revised based on the inherent fertility of the soil, land use pattern and crop rotation system;
- Knowledge sharing among farmers across the study districts could speed up technology transfer;
- From focused observations, interviews and group discussions held with farmers, interventions are needed to minimize cost of labor for harvesting and weeding in tef production; and
- The future research need to focus on reducing the time for weeding and harvesting. This could be possible using effective herbicides to substitute hand weeding and the use of mechanical harvester.

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