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Research Article

Adoption Status and Perception of Farmers on Improved *Tef* Technology Packages: Evidence from East Gojjam Zone, Ethiopia

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Tef is a major staple crop in Ethiopia and Eritrea. Many improved *Tef* varieties were released from the Ethiopian research institute in the past three decades. Information on the farmers' adoption status and perception on released improved *Tef* technology have paramount importance for launching new and modifying *Tef* technology packages. However, such information is meager in Ethiopia. Therefore, this study was conducted to assess farmers' status and perception of improved *Tef* technologies. A multistage random sampling technique was employed to select sample of 224 *Tef* grower farmers. The results were interpreted and discussed using descriptive and inferential statistics. The result indicated that farmers in the study area found at the medium level of adoption of *Tef* production technology (i.e., the average adoption index is 0.43). The findings also confirm that farmers perception towards the relative advantages of improved *Tef* varieties shows that high grain yield, good germination, early mature, and disease resistance capacity were perceived as the most crucial attributes of improved *Tef* varieties, whereas straw quality and tolerance to lodging were perceived as the least important attributes of the technology. Therefore, efforts and commitments to be expected from plant breeders and genetic specialists to reduce lodging of *Tef* through hybridizing semidwarf *Tef* varieties.

1. Introduction

The agricultural sector continues to play a dominant role in the development and growth of most African nations. Ethiopia is one of the most populous countries on the continent. In this regard, the agricultural sector is the mainstay of the economy and catalyst for the entire development of the country [1]. It accounts for about 34% of GDP [2] and 66.12% of employment [3].

Cereal crops are the main cultivated crop in Ethiopia. It contributes 81.39% and 87.97% in acreage and production for total crops, respectively, in the 2018/19 cropping season [4]. *Tef* (*Eragrostis Tef*) is a major cereal crop and extensively cultivated in most of the agroecological zones of Ethiopia and Eritrea [5]. In Ethiopia, a total of 3.07 million hectares of land were covered in *Tef* in the 2018/19 cropping season. From this, 54.03 million quintals production was produced. At the country level, *Tef* contributes 24.32% for the total cultivated cereal crops and 17.22% for the total production in the 2018/19 cropping season. In the Amhara region of Ethiopia, *Tef* contributes 25.4% in area coverage, 32% of the total production in the 2018/19 cropping season, and 2.5 million rural households of Ethiopia were engaged in *Tef* cultivation [4].

Tef is a major staple crop in Ethiopia and Eritrea. It is the most important crop in terms of production value and cultivation area with excellent storage properties, high-quality food, and the unique ability to thrive in extreme environmental conditions [1]. Besides being used to make the Ethiopian cultural food Injera (Injera is "pancake-like soft bread in Ethiopia"), its straw is used as a feed for livestock and binder of mud for house construction in rural and semiurban parts of Ethiopia [6]. Currently, *Tef* cultivation is spreading to other parts of the world (i.e., Australia, Canada, the Netherlands, South Africa, and the USA). Abroad, it is used for gluten (gluten is a protein found in wheat, barley, and other cereal crops. It is a major cause of lifelong gastrointestinal tract disease, which is called celiac disease. The only effective treatment for celiac disease is the total lifelong avoidance of gluten ingestion. *Tef* is one of the major gluten-free cereal crops [7]) free food, malting, and brewing [7].

Adoptions of improved technologies and production practices are important drivers of agricultural development in low-income countries like Ethiopia [8]. The Ethiopian Ministry of Agriculture has attempted to increase the production and productivity of *Tef* using conventional and modern breeding techniques and improved production technologies. So far, 42 improved *Tef* varieties and improved agronomic practices were released to the farming community [9].

The adoption of *Tef* production technology has paramount importance to increase *Tef* productivity, foster food security, and secure the well-being of smallholder farmers. Information on the farmers' adoption status and perception on released improved *Tef* technology have a paramount important prerequisite for launching new and modifying existing *Tef* technology packages. Such useful information is however meager in Ethiopia. Therefore, this study was undertaken to assess farmers' status and perception of improved *Tef* technologies in the West Gojjam zone, Ethiopia.

2. Materials and Methods

2.1. Description of the Study Area. Yilmana Densa district is located in the West Gojjam administrative zone about 42 Km far from the capital city of the Amhara region, Bahir Dar (Figure 1). According to Yilmana Densa Agriculture and Rural Development Office (YDARDO) report, Yilmana Densa district has 30 rural kebeles and 4 town kebeles. The main farming system in the study area is mixed farming including crop production and livestock. The majority of farmers practice a traditional way of crop production system such as plowing in oxen, harvesting in sickles, threshing in livestock and human power, sowing in broadcast, and poor land management. *Tef*, wheat, maize, potato, barley, field pea, and finger millet are the major crops grown in the district.

2.2. Sampling Technique and Sample Size. A multistage random sampling technique was employed to select sample households (in this study, a household is defined as all persons living in the same house and sharing their meals together) for this study. In the first stage, from the total of 19 potentials (out of 35 rural kebeles) *Tef* producer kebeles, three kebeles were selected using a simple random sampling technique. In the second stage, sample respondents were selected using a systematic random sampling technique from the selected kebeles. The sample size from each kebele was taken through population proportion (see Table 1). Availability of sample frames at the kebele agricultural office and homogeneous socioeconomic characteristics of the population were the main reasons for using this type of random sampling technique [10].

There are many rules-of-thumb used to determine the representative sample size to conduct analysis. In this study, Kothari's [11] sample size determination was employed to select a representative sample size. The main reasons to use this sample determination are: first, it is the latest sample determination method, and second, it considers two groups, failure (nonadopter) and success (adopter). There are two situations to consider p (population proportion of success).

First, if some approximation is known (from a previous study) that value can be used in the formula. Second, if no approximation is known, use 0.5. This value will give a sample size sufficiently large to guarantee an accurate prediction, given the confidence interval and the error of the estimate. The reason is that when each is 0.5, the product is at maximum [10]. Based on the following equation, 224 *Tef* grower farmers were selected using population proportion for each kebele:

$$n = \frac{z^2.p.q.N}{e^2(N-1) + z^2.p.q}, \quad (1)$$

where we have the following:

(1) n = estimated sample size
(2) e = the allowable error, where $e = 0.05$
(3) N = total *Tef* grower farmers ($N = 2584$)
(4) p = the estimated proportion of an adopter that is present in the population, which is 0.8 (from a previous study by Tamir [12])
(5) q = the population proportion of nonadopter in the population. $q = 1 - \mathrm{p}$, where $q = 1 - 0.8$; therefore, $q = 0.2$
(6) $Z\alpha/2$ = standard variate for given confidence level (as per normal curve area). It is 1.96 for a 95% confidence interval

2.3. Source and Type of Data Collection. In this inquiry, cross-sectional data were used for achieving the objective of the study. Data were collected from primary and secondary sources. Primary data were collected from the sample farmers using a structured interview schedule from 224 *Tef* grower sampled farmers. Primary data such as demographic, socioeconomic, institutional, farmer's perception, and plot-level data were collected using Kobo Toolbox (KoBo Toolbox is a free open-source tool for mobile data collection, available to all. It allows collecting data in the field using mobile devices such as mobile phones or tablets, as well as with computers) software. The data were collected using qualitative and quantitative approaches from sampled farmers. Information was gathered from the kebele administrative body, development agent, and district agricultural officers to capture supplementary information and to observe the validity of information from the household

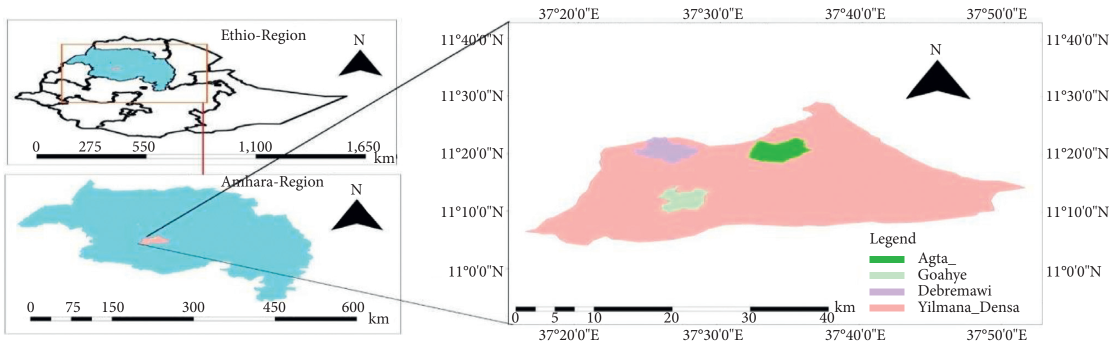

Figure 1: Location of the study area.

survey. Secondary data such as theories and models, empirical evidence, and supplementary data to primary data were collected from the journal article, previous studies, agricultural office manuals, proceedings, and NGO reports.

2.4. Methods of Data Analysis. After the data was collected, the data were arranged, coded, managed, and analyzed by using STATA version 15.1. The results were interpreted and discussed using descriptive and inferential statistics. Descriptive statistics such as mean, standard deviation, percentage, and frequency distribution were used to describe the socioeconomics, institutional, and demographic characteristics of the respondents. Furthermore, inferential statistics were used to compare the means (i.e., one-way ANOVA) between adoption categories.

2.4.1. Status of Adoption of Tef Technology Packages. To know the aggregate adoption level of *Tef* production technology, first, it was listed for the main components of the technology packages based on the *Tef* production manual, which was prepared by the Amhara National Regional State Bureau of Agriculture collaborated with ATA and EIAR in [13] for package study, giving equal weights for each package not acceptable because some components are easy to implement, while others are difficult to implement. In addition, all components do not have equal contributions to specific crop production.

Many scholars such as Mulugeta [14], Wuletaw and Daniel [15], Ogunya et al. [16], and Julius and Jimoh [17] had given weight to each package to obtain the intensity of adoption of a given technology. Therefore, this study has given different weights for each package of *Tef* production technology (see equation (2). Based on the weight, the *Tef* grower farmer's adoption level was calculated. Accordingly, the adoption index of the technology was calculated as follows:

$$AIi = \sum\left\{\left(\frac{ATi}{RTi} xISi\right)\right\}, \quad (2)$$

where ATi is the level or number of packages (plowing frequency, seed type, crop rotation, fertilizer rate, seed rate, sowing method, and weeding frequency) of the i^{th} farmer applied. RTi is the recommended level or number of packages farmers ought to apply, ISi is the proportion of score (weight) for each package. AIi is the adoption index of the i^{th} farmer.

Table 1: Sample size distribution.

No.	Kebele	Total *Tef* grower population	Sample
1	Agita	1,006	87
2	Goshiye	758	65
3	Debremawi	820	72
Total		2,584	224

Source: computed from kebele records, 2020.

As already explained above, researches conducted on agricultural technology adoption had been using weight to calculate adoption intensity. For instance, Mulugeta [14] used weight to calculate the intensity of the adoption of old coffee stumping technology packages. Wuletaw and Daniel [15] give a proportion score to calculate the adoption intensity of Malt-barley. Research conducted by Ogunya et al. [16] used weight for each package to calculate the adoption intensity and level of Nerica rice varieties in Ogun, Nigeria. Julius and Jimoh [17] give weight for each technology packages to calculate the intensity of adoption of cocoa production technology packages in Ekiti State, Nigeria. They calculated the weight from sample respondents. Hence, this study computed the proportion score (weights) of *Tef* production technology packages from district agricultural experts and model farmers.

2.4.2. Farmer's Perception towards Improved Tef Technology Packages. Farmers' perception towards improved *Tef* varieties and row planting was analyzed using five-point Likert scales as strongly agree (5), agree (4), undecided (3), disagree (2), and strongly disagree (1). The least favorable degree is given the least score (1), and the most favorable is given the highest score (5). The study used relative importance index (RII) analysis to rank the attributes of improved *Tef* varieties and row planting methods according to their advantages and disadvantages. The following formula was used to determine the relative index [18].

$$\mathbf{RII} = \frac{\sum \mathbf{W}}{\mathbf{AN}} = \frac{5\mathbf{n}5 + 4\mathbf{n}4 + 3\mathbf{n}3 + 2\mathbf{n}2 + 1\mathbf{n}1}{5\mathbf{N}}, \quad (3)$$

where RII is the relative importance index, *A* is the highest weight, *N* is the sample size, and *W* is the weight as assigned by each respondent on a scale of one to five with one implying the least and five being the highest. Scales for measuring farmers' perceptions were given from one to five. One implies the least, and five is the highest.

3. Results and Discussion

3.1. Demographic Characteristics. As shown in Table 2, from the total sample respondents, 85.27% were male-headed, while the remaining 14.73% were female-headed. Another notable result is that the mean age of the sample household heads was found to be 44.63 years with a standard deviation of 12.05. This shows that majority of the household heads were found at productive age.

The average family size of the household was 5.16 persons. The mean labor force based on the conversion factor of man-day equivalent was 2.76. This shows that over half of household members can work on the farm. In the case of the Yilmana Densa district, farmers starting their farming at the early age 18 s. Due to this, the majority of the household heads have solid *Tef* farming experience (24.50 years). Educated farmers are taught to adopt and peruse in using improved technology. The average education level of sample households was 1.35 with a standard deviation of 1.327. This implies farmers in the study area are not well educated.

3.2. Current Status of Farmers on the Adoption of Tef Technology Packages. The agronomic practice of improved *Tef* production technology package contains land preparation, crop rotation, improved seed, sowing method, planting date, seed rate, rate of fertilizer application, the timing of fertilizer application, weeding frequency, disease prevention, pest prevention, harvesting time, threshing method, and storage system. However, all the packages were not included in this study to calculate the adoption index because it is difficult to get reliable data for some packages (i.e., sowing date and harvesting). Furthermore, some packages are included in other packages. For instance, the recommendations of disease and pest prevention are integrated under management such as plowing frequently, deep plow, applying crop rotation, and use of improved seed. Therefore, those packages are included in crop rotation, improved seed, and plowing frequency. Eventually, this study included plowing frequency, crop rotation, rate of fertilizer application, seed type, seed rate, sowing method, and weeding frequency to know adoption status and intensity of *Tef* production technology in the study area.

The actual adoption categories were categorized into four groups such as nonadopter, low adopter, medium adopter, and high adopter based on the adoption index. The index score is 0.00, 0.01–0.33, 0.34–0.66, and 0.67–1.00, which represents none, low, medium, and high adopters, respectively. Similar studies, Endeshaw [19], Bosena and Susie [20], and Dawit and Gemechu [21], used similar techniques.

As shown in Table 3, from the total sample households, 21.43%, 3.13%, 69.64%, and 5.80% were categorized under none, low, medium, and higher adopter of *Tef* production technology packages, respectively. The result indicates that the average adoption index was 0.43 with a standard deviation of 0.24. This implies that farmers in the study area are categorized as medium adopters. There is a significant mean difference between adoption categories in the adoption index at less than 1% level of significance.

According to Table 4, from the total sample households, 78.57% of farmers were using improved *Tef* varieties. Evidence from the key informants in Goshiye kebele indicates that farmers in the sample kebele accessed improved seed from Avolla Goshiye community-based seed enterprise since 2014. Due to the fact, in the study area, majority of farmers are used improved *Tef* seed. Contrary to this, only 4.91% of the sample households applied the *Tef* row planting method in their *Tef* plots. Evidence from farmers' perception towards the row planting method indicates that farmers do not apply this package due to its low straw quality for the livestock feeding, more time consumption, and high labor consumption even they are accepted better yield, reduced seed cost and convenient for weeding attributes of the package. The result is consistent with the findings of Bart et al. [1].

The recommendation of seed and fertilizer rates for Nitosols and Vertisols are different. As shown in Table 4, 79.61% and 79.01% of the farmers applied improved *Tef* seed in their Nitosols and Vertisols, respectively. Another notable result is that 97.55% and 98.77% of the sample households applied urea and NPS/NPSB fertilizer for Nitosoils, respectively. Similarly, 93.87% and 93.25% of the farmers who have Vertisols applied urea and NPS/NPSB, respectively. This implies that farmers applied inorganic fertilizer almost in all their *Tef* plots. In addition, the adoption status of weeding and plowing frequency was found that the sample households were adopters (100%), whereas only 91.07% of the sample households were applied crop rotation in their *Tef* plots. This implies that the majority of farmers are applied crop rotation to reduce weed and improve soil fertility. According to Table 4, there is a significant mean adoption index difference between adopter categories in all the *Tef* packages at a 1% level of significance.

3.2.1. Adoption of Improved Tef Varieties. As illustrated in Table 5, the average area allocated in improved *Tef* seed was 0.31 ha with a standard deviation of 0.21, whereas the average area covered under local varieties was 0.16 ha with a standard deviation of 0.15. This implies that in the study area, the majority of sample households covered their *Tef* plot in improved seed rather than local seed.

Asgori, *Magna*, *Quncho*, *Dukem*, *Kena*, *Etsub*, *Dima*, *Kora*, *Dagm*, *Ngus*, *Tesfa*, *Flagot*, *Avolla*, and *Areka* 01 improved *Tef* varieties are recommended for the optimum rainfall areas. Relatively early maturing varieties such as *Tsedey*, *Gemechis*, *Simada*, *Hibr-1*, *Zobel*, *Workyu*, and *Boset* are recommended for terminal low moisture and stress areas. *Glmbichu* and *Dega Tef* are recommended for high land and high moisture areas [13] Yilmana Densa district is categorized under the optimum rainfall areas in the Amhara region [22].

Table 2: Demographic characteristics of the respondents.

Variables	Obs.	Mean/freq.	Std. dev./percent	Min	Max
Age (year)	224	44.63	12.05	18	73
Sex (male)	224	191	85.27	—	—
Family size (#)	224	5.16	1.34	2	10
Marital status (married)	224	[190]	[84.82]	—	—
Education (completed year)	224	1.35	2.63	0	10
Labor (man-day equivalent)	224	2.76	0.74	1	4.5
Tef farming experience (year)	224	24.50	11.59	1	52

Note. '#' denotes number; value in [ ] indicates frequency and percentage of the categorical variables.

Table 3: Aggregate farmer's adoption status in *Tef* technology packages.

Adoption category	Obs.	Percentage	Adoption index		Std. dev.	F
			Range	Mean		
Nonadopters	48	21.43	0.00	0	0	899.83^{***}
Low adopters	7	3.13	0.01–0.33	0.30	0.02	
Medium adopters	156	69.64	0.34–0.66	0.54	0.07	
High adopters	13	5.80	0.67–1.00	0.74	0.07	
Total	224	100	1.00	0.43	0.24	

Source: computed from own survey, 2020. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$, and ns $P > 0.1$.

Table 4: Adoption of *Tef* production technology packages in Yilmana Densa district.

Packages	Adoption category	Freq.	%	Mean adoption index	Std. dev.	F-test
Area allocation in improved seed	Nonadopters	48	21.43	0.00	0.0	$1,202^{***}$
	Low adopters	7	3.13	0.31	0.02	
	Medium adopters	53	23.66	0.53	0.08	
	High adopters	116	51.79	0.91	0.11	
	Total	224	100.00	0.60	0.37	
Row planting	Nonadopters	213	95.09	0.0	0.0	$84,580^{***}$
	Low adopters	1	0.45	0.13	0.06	
	Medium adopters	6	2.68	0.47	0.03	
	High adopters	4	1.79	1.00	0.0	
	Total	224	100.00	0.02	0.13	
Seed rate for Nitosols	Nonadopters	31	20.39	0.0	—	917.33^{***}
	Low adopters	3	1.97	0.29	0.03	
	Medium adopters	26	17.11	0.58	0.10	
	High adopters	92	60.53	0.77	0.07	
	Total	152	100.00	0.57	0.31	
Seed rate for Vertisols	Nonadopters	34	20.99	0.0	0.0	$1,534.76^{***}$
	Low adopters	1	0.62	0.29	-	
	Medium adopters	38	23.46	0.62	0.03	
	High adopters	89	54.94	0.77	0.07	
	Total	162	100.00	0.57	0.31	
Packages	Adoption category	Freq.	%	Mean adoption index	Std. dev.	F-test
Urea for Nitosols	Nonadopters	4	2.45	0.6	0.70	45.98^{***}
	Low adopters	2	1.23	0.33	0.0	
	Medium adopters	88	53.99	0.60	0.08	
	High adopters	69	42.33	0.81	0.07	
	Total	163	100.00	0.69	0.16	
Urea for Vertisols	Nonadopters	10	6.13	0.0	0.0	719.25^{***}
	Low adopters	0	0.00	-	-	
	Medium adopters	30	18.40	0.61	0.04	
	High adopters	123	75.46	0.80	0.07	
	Total	163	100.00	0.71	0.20	

Table 4: Continued.

Packages	Adoption category	Freq.	%	Mean adoption index	Std. dev.	*F*-test
NPS/NPSB For Nitosols	Nonadopters	2	1.23	0.66	0.94	50.23^{***}
	Low adopters	1	0.61	0.25	—	
	Medium adopters	75	46.01	0.64	0.05	
	High adopters	85	52.15	0.82	0.07	
	Total	163	100.00	0.73	0.14	
NPS/NPSB for Vertisols	Nonadopters	11	6.75	0.0	0.0	893.04^{***}
	Low adopters	0	0.00	—	—	
	Medium adopters	97	59.51	0.63	0.05	
	High adopters	55	33.74	0.79	0.06	
	Total	163	100.00	0.64	0.19	
Crop rotation	Nonadopters	20	8.93	0.0	0.0	$1,871.97^{***}$
	Low adopters	5	2.23	0.33	0.0	
	Medium adopters	69	30.80	0.56	0.08	
	High adopters	130	58.04	0.98	0.05	
	Total	224	100.00	0.75	0.31	
Weeding frequency	Nonadopters	0	0.00	—	—	484.63^{***}
	Low adopters	33	14.73	0.33	0.01	
	Medium adopters	154	68.75	0.58	0.08	
	High adopters	37	16.52	0.90	0.09	
	Total	224	100.00	0.59	0.18	
Plowing frequency	Nonadopters	0	0.00	—	—	87.76^{***}
	Low adopters	2	0.89	0.25	0.0	
	Medium adopters	3	1.34	0.62	0.0	
	High adopters	219	97.77	0.94	0.08	
	Total	224	100.00	0.93	0.11	

Source: own survey data, 2020. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$, and ns $P > 0.1$.

Table 5: Land allocation of improved and local *Tef* varieties.

Types of *Tef* variety	Obs.	Mean land (ha)	Std. dev.	Min	Max
Improved variety	224	0.31	0.21	0	0.7
Local variety	224	0.16	0.15	0	0.875

Source: own survey data, 2020.

As illustrated in Figure 2, the most cultivated improved *Tef* varieties in the study area were *Quncho* (70.98%) and *Etsub* (7.59%). The remaining 21.43% were covered in local *Tef* varieties (i.e., *Davo, Dimbito*, *Fesho*, and *Qey Tef*). This implies that adopter farmers are cultivating their *Tef* plots based on the recommendation of improved *Tef* varieties.

As shown in Table 6, low, medium, and high adopter farmers cover their *Tef* plots on average 0.14 ha, 0.27 ha, and 0.47 ha on improved seed, respectively. This shows that low, medium, and high adopters covered 36.84%, 54.00%, and 90.38% of their *Tef* lands with improved seed, respectively. The result implies that high adopters relatively covered their *Tef* plots widely in the improved seed. There is a significant mean difference between adopter categories with respect to adoption intensity of improved *Tef* variety at less than 1% level of significance.

3.2.2. Adoption of Seed Rate. Recommended seed rates for Nitosols and Vertisols are 25 kg ha^{-1} and 30 kg ha^{-1}, respectively [23]. As provided in Table 7, respondents on average applied 26.83 kg ha^{-1} and 32.89 kg ha^{-1} seed rates for Nitosols and Vertisols, respectively. Another notable result is that on average, low, medium, and high adopters applied 34.16 kg ha^{-1}, 37.04 kg ha^{-1}, and 32.73 kg ha^{-1} seed rate on their Nitosols *Tef* plots, respectively. Likewise, the low, medium, and high adopters applied on average 34.11 kg ha^{-1}, 48.42 kg ha^{-1}, and 38.82 kg ha^{-1} on their Vertisols *Tef* plots, respectively. Respondents in the study area applied 26.83 kg ha^{-1} and 32.89 kg ha^{-1} for Nitosols and Vertisols, respectively. It is worthwhile to note that farmers applied seed rates above the recommended rate. There is a significant mean difference between adopter categories with respect to seed rate in Nitosols and Vertisols at less than 1% level of significance (see Table 7).

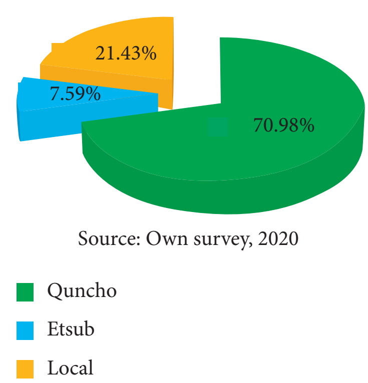

Figure 2: Types of *Tef* varieties grown in the study area.

3.2.3. Adoption of Fertilizer. In the study area, farmers use both organic and inorganic fertilizers in their plots.

Table 6: Land area covered by the improved *Tef* varieties.

Adoption category of improved variety	Freq.	%	Mean total *Tef* land area (ha)	Mean improved *Tef* land area (ha)	Std. dev.	*F*-test
Nonadopters	48	21.43	0.32	—	—	343.43***
Low adopters	11	4.91	0.38	0.14	0.04	
Medium adopters	49	21.88	0.50	0.27	0.07	
High adopters	116	51.79	0.52	0.47	0.11	
Total	224	100.00	0.47	0.31	0.20	

Source: own survey data, 2020. $^{***}p < 0.01$, $^{***}p < 0.05$, $^{***}p < 0.1$, and ns $P > 0.1$.

Table 7: Farmers' adoption status of improved *Tef* seed rate.

Soil type	Seed rate adoption category	Freq.	%	Mean kg ha^{-1}	Std. dev.	*F*-test
Nitosols	Nonadopters	31	20.39	0	0	790.17***
	Low adopters	3	1.97	34.16	3.81	
	Medium adopters	26	17.11	37.09	6.24	
	High adopters	92	60.53	32.73	2.908	
	Total	152	100	26.83	14.14	
Vertisols	Nonadopters	34	20.99	0	0	2,009.32***
	Low adopters	1	0.62	34.11	—	
	Medium adopters	38	23.46	48.42	2.41	
	High adopters	89	54.94	38.82	3.48	
	Total	162	100.00	32.89	17.68	

Source: own survey data, 2020. $^{***}p < 0.01$, $^{***}p < 0.05$, $^{***}p < 0.1$, and ns $P > 0.1$.

Farmers applied organic fertilizer for small plot crops, which are growing around their dwellings such as potato, maize, cabbage, and permanent crops (i.e., mango, coffee, and *Gesho*). However, they did not apply for *Tef* crops because it grows apart from their residence house and are covered in a large area. On the contrary, all respondents (100%) applied inorganic fertilizer in their *Tef* plots (see Table 8). This implies that the majority of farmers in the study area applied inorganic fertilizer than organic fertilizer in their *Tef* plots.

Nowadays, *Tef* production is unimaginable without inorganic fertilizer. As provided in Table 9, from the total respondents, 98.66% and 100% applied urea and NPS/NPSB fertilizer, respectively. On the other hand, fertilizer adopter farmers have applied 71.43 kg urea ha^{-1} and 104.16 kg NPS/NPSB ha^{-1} on average. This implies that *Tef* growers applied artificial fertilizer below the recommendation rate.

(1) Urea Fertilizer. In the study area, the recommendation rates of urea fertilizer for Nitosols and Vertisols *Tef* plots are 75 kg ha^{-1} and 125 kg ha^{-1}, respectively [13]. Sample households applied 51.87 kg ha^{-1}and 89.82 kg ha^{-1} urea for Nitosols and Vertisols, respectively. Low, medium, and high adopters applied 25 kg ha^{-1}, 45.31 kg ha^{-1}, and 62.23 kg ha^{-1} urea for Nitosols on average, respectively (see Table 10). Likewise, medium, and high adopters applied 77.27 kg ha^{-1} and 100.19 kg ha^{-1} urea for Vertisols, respectively. Respondents in the study area applied 51.87 kg ha^{-1} and 89.82 kg ha^{-1} urea on their Nitosols and Vertisols *Tef* plots on average, respectively. This implies that *Tef* grower farmers applied urea fertilizer below the recommendation rate. One-way ANOVA result shows that there is a significant mean difference between adopter categories in relation to the rate of urea fertilizer in both soil types at less than 1% level of significance.

Table 8: Adoption of fertilizer.

Types of fertilizer	Adopter		Nonadopter	
	Freq.	%	Freq.	%
Organic	0	0.00	224	100.00
Inorganic	224	100.00	0	0.00
Total	224	100.00	224	100.00

Source: own survey data, 2020.

(2) NPS/NPSB Fertilizer. The recommendation rate of NPS/NPSB fertilizer for *Tef* is 125 kg ha^{-1} and 150 kg ha^{-1} for Nitosols and Vertisols, respectively. Sample households applied on average 110.47 kg ha^{-1} and 97.19 kg ha^{-1} NPS/NPSB fertilizer for Nitosols and Vertisols, respectively (see Table 11). Low, medium, and high adopters applied 38.46 kg ha^{-1}, 96.55 kg ha^{-1}, and 124.73 kg ha^{-1} NPS/NPSB fertilizer for Nitosols, respectively. Similarly, medium and high adopters applied 95.57 kg ha^{-1} and 119.50 kg ha^{-1} NPS/NPSB fertilizer for Vertisols, respectively. This implies that farmers in the study area apply NPS/NPSB below the recommendation rate. One-way analysis of variance (ANOVA) result indicates that there is a significant mean difference between adopter categories with regard to the rate of NPS/NPSB fertilizer application at less than 1% level of significance.

3.2.4. Adoption of Plowing Frequency. Plowing is one of the crucial packages in *Tef* production. Its frequency varies from 2 to 4 times based on soil type and weed and pest infestation conditions. A mechanized plowing method is recommended for better plowing [13]. However, in the study area, mechanized plowing (i.e., tractor) is nonexistent at the farmer's level. As depicted in Table 12, sample

Table 9: Farmers' adoption status of inorganic fertilizer.

Inorganic fertilizer	Adoption category	Freq.	Mean kg ha^{-1}	Std. dev.	Min	Max
Urea	Nonadopter	3	0	—	0	0
	Adopter	221	71.43	20.67	20	120
	Total	224	70.47	22.12	0	120
NPS/NPSB	Nonadopters	0	0	—	0	0
	Adopters	224	104.16	19.16	50	150
	Total	224	104.16	19.16	50	150

Source: own survey, 2020.

Table 10: Farmers' adoption status of urea fertilizer.

Soil type	Urea fertilizer adoption category	Freq.	%	Mean kg ha^{-1}	Std. dev.	*F*-test
Nitosols	Nonadopters	2	1.23	0	0	138.13***
	Low adopters	2	1.23	25	0	
	Medium adopters	88	53.99	45.31	6.00	
	High adopters	71	43.56	62.23	7.42	
	Total	163	100.0	51.87	12.47	
Vertisols	Nonadopters	10	6.13	0	—	719.24***
	Low adopters	0	0	—	—	
	Medium adopters	30	18.40	77.27	5.76	
	High adopters	123	75.46	100.19	9.05	
	Total	163	100.0	89.82	26.01	

Source: own survey data, 2020. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$, and ns $P > 0.1$.

Table 11: Farmers' adoption status of NPS/NPSB fertilizer.

Soil type	NPS fertilizer adoption category	Freq.	%	Mean kg ha^{-1}	SD	*F*-test
Nitosols	Nonadopters	1	0.61	0	—	114.85***
	Low adopters	1	0.61	38.46	—	
	Medium adopters	75	46.01	96.55	8.44	
	High adopters	86	52.76	124.73	14.35	
	Total	163	100	110.47	21.11	
Vertisols	Nonadopters	11	6.75	0	0	893.04***
	Low adopters	0	0	-	-	
	Medium adopters	97	59.51	95.57	8.22	
	High adopters	55	33.74	119.50	9.89	
	Total	163	100.00	97.19	29.74	

Source: own survey data, 2020. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$, and ns $P > 0.1$.

Table 12: Farmers' adoption status of plowing frequency.

Plowing freq. adoption category	Obs	%	Plowing freq. plot^{-1}	SD	*F*-test
Nonadopters	0	0	—	—	24.87***
Low adopters	2	0.89	2.5	0	
Medium adopters	3	1.34	2.5	0	
High adopters	219	97.77	3.73	0.39	
Total	224	100.00	3.71	0.42	

Source: own survey data, 2020. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$, and ns $P > 0.1$.

households plowed their *Tef* plots using oxen 3.71 times plot^{-1} with a standard deviation of 0.42. This implies that farmers in the study area plow their *Tef* plots relatively based on the recommended frequency. Low, medium, and high adopters plowed their *Tef* plots on average 2.5 times plot^{-1}, 2.5 times plot^{-1}, and 3.73 times plot^{-1}, respectively. There is a significant mean difference across adopter categories in relation to plowing frequency at a 1% significant level.

3.2.5. Adoption of Weed Management. The management practice of weed remains one of the most tasks for *Tef* growers due to its poor competitive ability with weed. The manual weeding management method is recommended for *Tef* grower farmers [24]. According to Table 13, from the total respondents, 66.67% were used of manual-only weed control method, whereas the remaining 33.33% of the respondents used chemical and manual methods. This implies that in the study area, the majority of households manage

Table 13: Methods of weed management.

Weed management methods	Adopter		Nonadopter		Total			
	Freq.	%	Freq.	%	Freq.	%	Min	Max
Only manual	82	46.59	114	50.89	149	66.67	1	3
Only chemical	0	0.00	0	0.00	0	0.00	—	—
Both manual and chemical	94	53.41	110	49.11	75	33.33	1	2
Total	224	100	224	100	224	100.00		

Source: own survey (2020).

their *Tef* plots based on the recommendation method (manually).

(1) Frequency of Manual Weeding Management per Plot. The recommendation frequency of the manually weeding control method is two to three times [13]. As shown in Table 14, of the total respondents, 47.32% of households were managed their *Tef* plots with a frequency below two, whereas 52.68% managed two and above frequency using manual method. This implies that the majority of households practice manual weeding management based on the recommended frequency.

Table 14: Frequency of manual weeding management per plot.

Manual weeding management frequency plot^{-1}	Frequency	Percentage
Zero	0	0.00
Greater than zero and less than one	3	1.34
One and less than two	103	45.98
Two and above	118	52.68
Total	224	100.00

Source: own survey (2020).

(2) Farmers Adoption Status of Weeding Frequency. As shown in Table 15, adopter farmers managed manually their *Tef* plots 1.75 times plot^{-1} on average with a standard deviation of 0.49. Another notable result is that low, medium, and high adopters applied 1.12 times plot^{-1}, 1.76 times plot^{-1}, and 2.29 times plot^{-1} with manually weed control methods on average, respectively. This implies that farmers practice manual weed management methods based on the recommended frequency. One-way analysis of variance results indicated that there is a significant mean difference across adopter categories with regard to weeding frequency at a 1% level of significance.

3.2.6. Adoption of Crop Rotation. Crop rotation is another vital technology package in *Tef* production. The Ministry of Agriculture suggested farmers should not be planting *Tef* for two consecutive years on the same plot [22]. As shown in Table 16, sample households on average rotated their *Tef* plots 0.74 times plot^{-1} with a standard deviation of 0.32. Low, medium, and high adopters rotated their *Tef* plots 0.33 times plot^{-1}, 0.55 times plot^{-1}, and 0.97times plot^{-1}, respectively. On average, the respondents rotated their *Tef* plots 0.74 times. This implies that farmers in the study area practice monoculture production practice in consecutive cropping seasons. One-way analysis of variance results indicated that there is a significant mean difference across adopter categories with regard to crop rotation at a 1% level of significance.

3.2.7. Planting Method. Row planting by hand or machine at a row distance of 20 cm or transplanting at 10 to 15 cm between plants within a row is recommended to alleviate lodging and increase production and productivity of *Tef* [25]. Respondents in the study area were covered only 0.01 ha in a row planting method (see Table 17) from the average 0.47 ha *Tef* land (see Table 6). This implies that farmers in the study area seem to totally exclude the row planting method. This is because the row planting method is a backbreaker, labor-consuming, and lack of efficient row planter machine. The result is consistent with the findings of Joachim et al. [25]. One-way analysis of variance results indicated that there is a significant mean difference across adopter categories at a 1% level of significance.

3.2.8. Productivity of Tef in the Study Area. At the national level, the expected *Tef* production is 2,300 kg ha^{-1} [26]. Table 18 shows survey respondents' of *Tef* production ha^{-1} during the 2019/20 cropping season. According to the table, the average *Tef* production ha^{-1} in the study area was 954.90 kg ha^{-1}. It is worthwhile notable that *Tef* production is very low in the district. As can be seen, adopters are exceeding 96 kg ha^{-1} than nonadopter. Another notable result is that there is a significant production mean difference between adopters and nonadopters.

3.3. Farmers' Perception towards Improved Tef Technology Packages. This part of the study was including the two core technology packages such as the improved *Tef* varieties and row planting technology packages.

3.3.1. Farmers' Perception towards Improved Tef Varieties. To obtain farmers' preference of *Tef* varieties, first, the list of attributes are identified, which helps farmers characterize the different varieties of *Tef*. This was done by consulting *Tef* seed multiplication cooperatives (i.e., *Avolla Goshiye* farmers' seed enterprise), research center (i.e., *Adet* research center), and kebele plant science experts and validating the information with farmers. The identified attributes were better grain yield, tolerance to disease, lodging tolerance, good germination, early maturity, and high straw quality.

Table 15: Farmers' adoption status of weeding frequency.

Adoption category of weeding freq.	Obs	%	Weeding freq. $plot^{-1}$	SD	F-test
Nonadopters	0	0	—	—	89.38^{***}
Low adopters	33	14.73	1.12	0.32	
Medium adopters	154	68.75	1.76	0.34	
High adopters	37	16.52	2.29	0.48	
Total	224	100.0	1.75	0.49	

Source: own survey data, 2020. $^{***}p < 0.01$, $^{***}p < 0.05$, $^{***}p < 0.1$, and ns $P > 0.1$.

Table 16: Adoption of crop rotation.

Adoption category of rotation freq.	Obs	%	Crop rotation $plot^{-1}$	SD	F-test
Nonadopters	20	8.93	0	0	743.92^{***}
Low adopters	5	2.23	0.33	0	
Medium adopters	69	30.80	0.55	0.11	
High adopters	130	58.04	0.97	0.10	
Total	224	100.00	0.74	0.32	

Source: own survey data, 2020. $^{***}p < 0.01$, $^{***}p < 0.05$, $^{***}p < 0.1$, and ns $P > 0.1$.

Table 17: Farmers' adoption status of the *Tef* row planting method.

Adoption category of row planting	Obs	%	Mean land (ha)	SD	F-test
Nonadopters	213	95.09	0	0	$1,163.05^{***}$
Low adopters	1	0.45	0.09	—	
Medium adopters	6	2.68	0.17	0.05	
High adopters	4	1.79	0.42	0.11	
Total	224		0.01	0.06	

Source: own survey data, 2020. $^{***}p < 0.01$, $^{***}p < 0.05$, $^{***}p < 0.1$, and ns $P > 0.1$.

Table 18: Production of *Tef* per hectare.

Adopter category	Obs	%	Production ha^{-1} (kg)	SD	Min	Max	T-test
Nonadopters	48	21.43	879.29	137.66	600	1,200	-3.4^{***}
Adopters	176	78.57	975.52	182.23	521	1,450	
Total	224	100.00	954.90	177.82	521	1,450	

Source: own survey (2020).

(1) Improved versus Local Varieties. Table 19 shows the result of farmers' perception embodies in local and improved *Tef* varieties. As it can be seen, 89.73%, 87.05%, 59.38%, 45.54%, and 41.52% of the respondents perceived that improved seed is better in grain yield, germination, disease, early maturity, and tolerance to lodging than local *Tef* seed, respectively. However, 70.54% of the farmers perceived that the straw quality of local seed was better than the improved seed. This implies that attributes of improved *Tef* varieties are better than their counterpart local *Tef* varieties.

According to Figure 3, the respondents who agree with improved *Tef* variety have high yield, high disease resistance, early maturity, straw quality, and better germination were higher in adopter groups than nonadopter groups. When comparing adopter and nonadopter respondents with improved *Tef* varieties that have high lodging tolerance, the former one has a positive perception than the latter. The result shows that adopter groups in the study area perceived that improved *Tef* varieties are better than local varieties in different attributes. This implies that positive perceptions towards the technology has utmost importance to adopting the technology.

3.3.2. Farmers' Perception on Improved Tef Variety Attributes. Farmers' perception on the use of improved *Tef* technology is generally attached with the advantages of technology components. Farmers examine the advantages from the view of profitability and compatibility. Davis [27] suggested that the "degree to which a person believes that using a particular technology would enhance production" is a major factor that affects the acceptance of technology. Based on this farmers' perception on improved *Tef* varieties, they have been included in this study. Accordingly, ratings such as strongly agree (5), agree (4), undecided (3), disagree (2), and strongly disagree (1) were used to measure the respondents' perception of the technology. The value (5) indicates that how farmers perceived technology as highly positive, and values less than (3) show how farmers perceived the technology as negative or poor. According to

Table 19: Farmers' perception on improved versus local *Tef* seed.

	Better yield		Disease tolerance		Lodging tolerance		Good germination		High straw quality		Early maturity	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
Local	5	2.23	54	24.11	77	34.38	8	3.57	158	70.54	14	6.25
The same	18	8.04	37	16.52	54	24.11	21	9.38	60	26.79	108	48.21
Improved	201	89.73	133	59.38	93	41.52	195	87.05	6	2.68	102	45.54
Mean	2.87		2.35		2.07		2.83		1.32		2.39	
Std. dev.	0.39		0.84		0.87		0.45		0.52		0.60	

Source: computed from own survey, 2020.

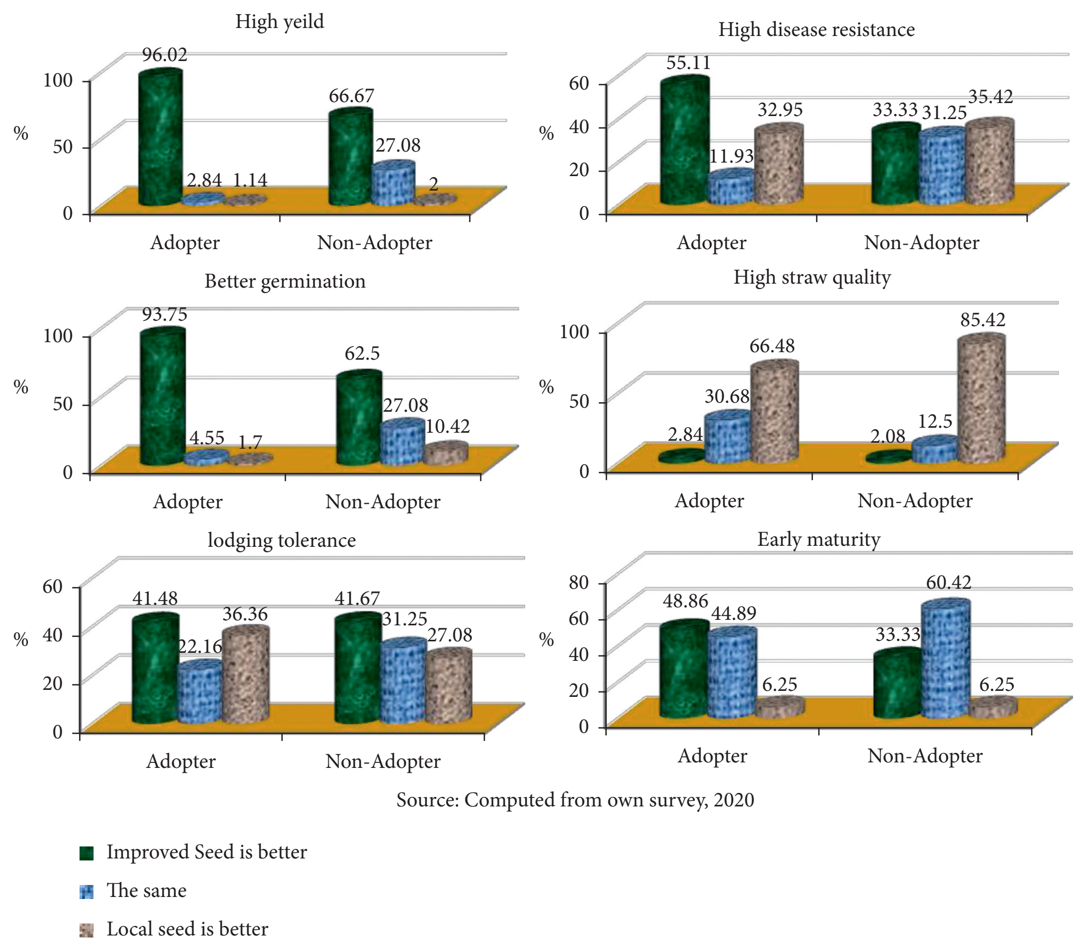

Figure 3: Farmers' perception towards improved versus local *Tef* varieties.

Table 20: Farmers' perception on improved *Tef* variety attributes.

Attributes of improved *Tef* varieties	Distribution of respondents based on the perception of improved *Tef* varieties (frequency)					Item mean	Std. dev.
	SA	A	ND	D	SD		
Grain yield is better	151	57	14	1	1	4.58	0.67
Early mature	5	97	108	14	0	3.41	0.64
Good germination	35	164	22	3	0	4.03	0.55
High disease resistance	2	110	37	54	21	3.08	1.06
High straw quality	11	13	53	64	83	2.12	1.12
High lodging tolerance	36	56	65	63	4	2.74	1.08
Sum of the mean						19.88	
Grand mean						3.31	

Source: own survey 2020. SA = strongly agree; A = agree; ND = no decision; SD = strongly disagree; *D* = disagree.

Table 21: Relative importance index of improved *Tef* varieties.

Items	Attributes	RII	Rank
1	High grain yield	0.917857	1st
2	Early mature	0.714286	3rd
3	Good germination	0.80625	2nd
4	Disease resistance	0.616071	4th
5	Better straw quality	0.425893	6th
6	High tolerance to lodging	0.549107	5th

Source: computed from own survey (2020).

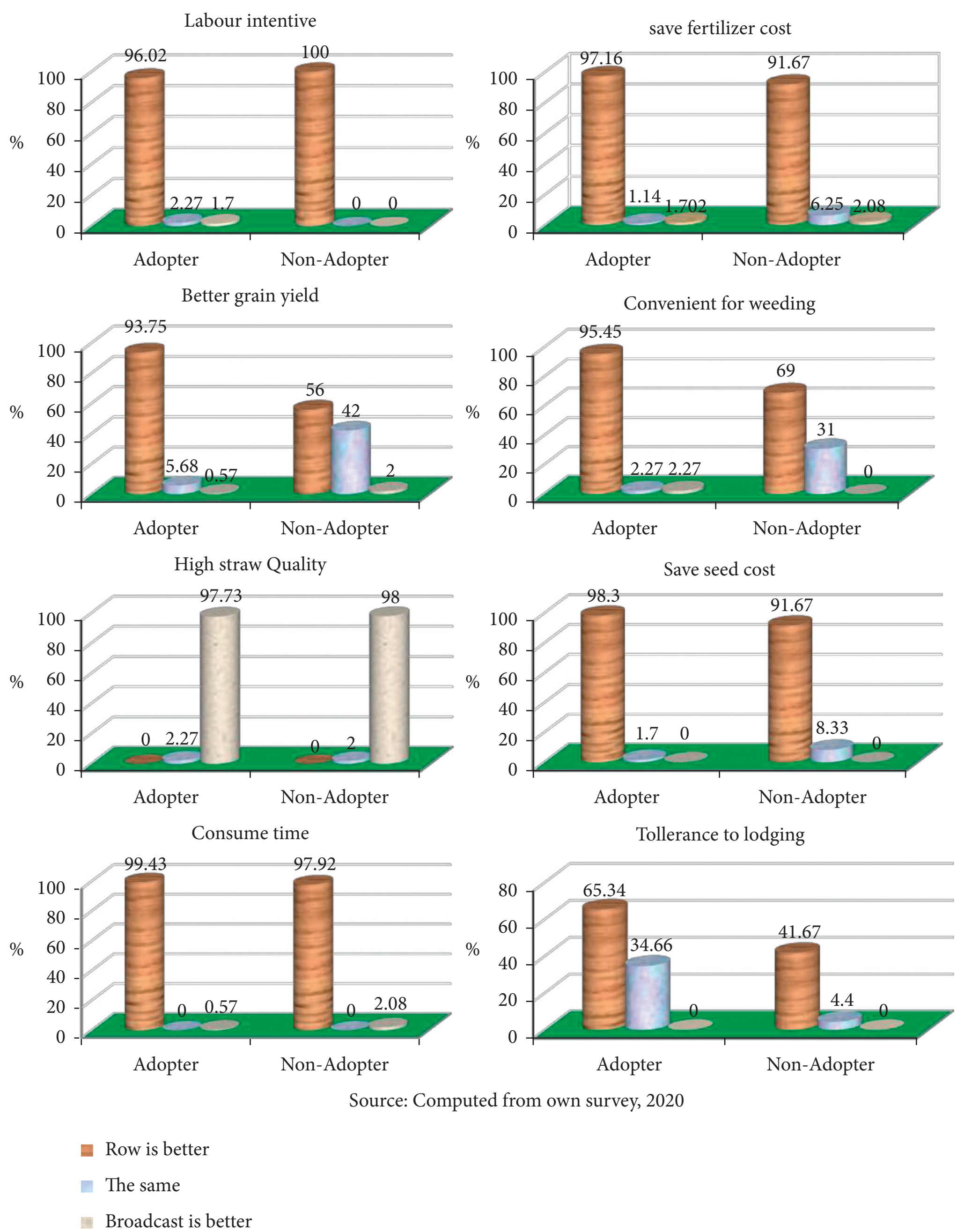

Figure 4: Farmer's perception towards *Tef* row versus broadcast planting method.

Table 22: Farmers' perception towards row planting method.

Attributes of row planting method	Distribution of respondents based on the perception of *Tef* row planting (frequency)					Item mean	SD
	SA	A	ND	D	SD		
Relative advantage							
High yield	158	37	27	27	0	4.56	0.73
Reduce seed cost	154	63	7	0	0	4.65	0.53
Reduce fertilizer cost	150	65	5	1	3	4.59	0.68
Tolerance to lodging	18	117	42	25	22	3.37	1.10
Convenient for weeding	125	84	15	0	0	4.49	0.62
Total mean						21.66	
Grand mean						4.33	
Relative disadvantage							
Consume high labor	190	32	2	0	0	4.82	0.50
Time consume	170	52	0	0	2	4.73	0.55
Low straw quality	160	56	4	3	1	4.65	0.63
Total mean						14.2	
Grand mean						4.73	

Source: own survey (2020). SA = strongly agree, A = agree, ND = no decision, SD = strongly disagree, and D = disagree.

Table 20, the grand mean (3.31) shows that the overall perception of the respondents based on the given attributes was positive. The result also shows that farmers' perceptions on straw quality (2.12) and lodging tolerance (2.74) capacity were negative. Negative perception for straw quality of improved *Tef* varieties could be because farmers need soft and weak straw for livestock feeding, but the quality of improved seed straw is strong. This result is consistent with Regasa et al. [28] and Dawit and Gemechu [21].

3.3.3. Relative Importance of the Attributes of Improved Tef Variety. As shown in Table 21, six Likert scale items were included to measure the relative importance of improved *Tef* varieties. Accordingly, the relative importance index was developed to determine which items were very highly important and of less importance. The result shows that high grain yield, good germination, early maturity, disease resistance, high tolerance to lodging, and better straw quality for livestock feeding ranks first to sixth, respectively. This implies that tolerance to lodging and straw qualities are less important attributes of improved *Tef* variety.

3.3.4. Farmers' Perception towards Row Planting Method. As illustrated in Figure 4, farmers in the study area perceived that the *Tef* row planting method is labor-intensive, consumes more time, and has low straw quality for livestock feeding than the broadcast method. Moreover, farmers perceived these attributes as demerits of the row planting method. However, they perceived that row planting has a high grain yield, is convenient for weeding, saves fertilizer cost, reduces seed rate, and has high tolerance to lodging than the broadcast planting method. Surprisingly, farmers perceived that row planting has paramount importance to boost *Tef* yield by reducing competition between *Tef* plants for water, light, and nutrients. Eventually, Figure 3, shows the comparison between adopter and nonadopter farmers with relation to perception towards row planting method.

Table 23: Relative importance and disadvantage index of row planting method.

Item	Attributes	RII	Rank
	Relative advantage		
1	Convenient for weeding	0.898214	4
2	Better yield	0.913393	3
3	Tolerance to lodging	0.675	5
4	Reduce seed cost	0.93125	1
5	Reduce fertilizer cost	0.919643	2
	Relative disadvantage		
1	Consume high labor	0.964286	1
2	Low straw quality	0.93125	3
3	Consume time	0.946429	2

Source: computed from own survey (2020).

To measure farmers' perception towards the row planting method, 5 and 3 Likert scale statements were included (see Table 22). The result shows that reduced seed cost, reduced fertilizer cost, high grain yield, convenience for weeding, and tolerance to lodging were perceived by the farmers as a relative advantage with item mean of 4.65, 4.59, 4.56, 4.49, and 3.37, respectively. On the other hand, high labor and time consumption and low straw qualities were perceived as a relative disadvantage with item mean of 4.82, 4.73, and 4.65, respectively. The grand mean (4.33) of relative advantage shows that the overall perception of the respondents with relative advantages of the row planting method is positive. On the other hand, the grand mean (4.73) of relative disadvantage shows that the overall perception of the respondents with a relative disadvantage of row planting was highly negative.

3.3.5. Relative Importance Index of Row Planting Method. As shown in Table 23, eight Likert scale items were included to measure farmers' perception towards relative importance and disadvantage of the *Tef* row planting method. From the advantage side of Tef row planting method, reduce seed cost, reduce fertilizer cost, high grain yield, convenient for weeding, and tolerance to lodging are ranked from first to fifth, respectively. On the other hand, from the disadvantage side, consume high labor, time-consuming, and low straw quality are ranked from first to third, respectively.

4. Conclusion and Recommendations

The findings verify that farmers in the study area were found at the medium level of adoption of *Tef* production technology (i.e., the average adoption index is 0.43). The findings also confirm that farmers perception towards the relative advantages shows that high grain yield, good germination, early mature, and disease resistance capacity were perceived by the farmers as the most crucial attributes of improved *Tef* varieties, whereas straw quality and tolerance to lodging were perceived as the least important of attributes of the technology. The findings also verify that even if farmers perceived that *Tef* row planting method has a high yield, reduces the quantity of seed and fertilizer costs, and has convenience for weeding, but time consumption, low straw quality, and high labor consumption nature of the technology are major bottlenecks to apply *Tef* row planting method.

The most crucial issues in the *Tef* row planting method are the high labor and time consumption nature of the technology. Due to this reason, farmers prefer the broadcast planting method even if they accepted high yield and convenience for field management attributes of the technology. Therefore, the Ministry of Agriculture of Ethiopia, particularly the *Amhara* Region Bureau of Agriculture, and Yilmana Densa District Office of Agriculture should avail easy, efficient, and least time; low labor consumer; and cost-effective row planter technology for the farmers. According to the finding of this inquiry, farmers perceived lodging tolerance attributes of improved *Tef* varieties as the least important. They also raised this attribute as a major bottleneck for their *Tef* production process. Therefore, the efforts and the commitments of plant breeders and genetic specialists to develop *Tef* varieties would help reduce lodging *Tef* through hybridizing semidwarf *Tef* varieties. The post-harvest practice of *Tef* technology can be future research priority.

Data Availability

The data used to support the findings of this study are available from the first author upon request using atrsawanteneh0918@gmail.com.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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