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Comparative Technical Efficiency of Teff Production in Row Planting and Broadcasting Methods, Ethioopia

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Abstract Due to lack of clear awareness on different sowing methods, majority of Ethiopian smallholders are indifferent of sowing their teff in row or broadcasting method. This study therefore analyzes comparative technical efficiency of teff production under row planting and broadcasting methods and identifies its determinants in southwest Ethiopia, Gurage zone. The study was conducted using cross-sectional data from 276 households. One stage stochastic production frontier model was used for the analysis. The analysis' results depicted that labor, oxen power, quantity of seed and size of teff cultivated land significantly affects teff productivity under both methods. About 81.3% and 84.8% of the variation in teff output from the frontier was attributed to technical inefficiency in row planting and broadcasting methods, respectively. The mean technical efficiency was 80.4% under row planting and 43.8% under broadcasting; w confirmed that Gurage zone teff producers are more technically efficient under row planting than broadcasting method. Level of education, access to credit, use of improved variety seed, frequency of extension contact, and non-farm income affects technical efficiency positively whereas proximity of teff farm from homestead affects it negatively under both methods. Experience in teff row planting and farm experience affects technical efficiency positively under row planting and broadcasting methods, respectively. Hence, creating further educational opportunities for farmers, providing better credit service, ensuring frequent and more reliable extension contacts, encouraging the use of improved variety seeds, strengthening farmer's participation on non-farm activities and sowing teff on the nearer farm are vitally important to improve technical efficiency teff crop

Keywords: *broadcasting, stochastic production frontier, row planting, technical efficiency, teff*

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1. Introduction

1.1. Background of the Study

Teff is a small seeded cereal crop under grass family of Poaceae endemic to Ethiopia. It is believed to be originated, domesticated and diversified in this country [1]. It is hugely important to Ethiopians, both in terms of production and consumption which accounts for about 15% of all calories consumed in the country [2]. Approximately more than 6 million households are growing *teff*, and 2,337,850 hectare of land in Ethiopia had been cultivated with this crop. It is the second most important cash crop (after coffee), generating almost 464 million USD income per year for local farmers and takes 13.6% share of total crop production in the country [3]. As the crop has high protein and amino-acid content and it is gluten-free [1]; its national and international demand is increasing. its national and international demand is increasing. Since the last few years, it is being exported to different countries in different form and it is believed to be Ethiopian a super grain in the near future [4].

The average productivity of *teff* in Ethiopia is 1.4 tons/ha at smallholder farmer, level which is very low [5]. However, through research and applying improved agricultural technologies, *teff* yield can be raised to 5 tones/ha [6]. The most common *teff* sowing methods in Ethiopia is broadcasting (a simple throwing of seeds across the ground) or sowing seeds without any distinct arrangement with high seed rate and uneven distribution [7]. Experiments made by [8] proved that due to uneven and scattered distribution of seed 7.78 percent more lodging, high competition among plants, no or less tillering, thin stalk, light and short panicle length, decreased water use efficiency and fertilizer efficiency and difficulty of controlling weeds was observed under broadcasting method than row planting method.

Row planting (growing crops in a straight line with a linear pattern in one direction with a distinct arrangement) is another *teff* sowing method in Ethiopia [4]. Experiments on this method at research and demonstration center have improved *teff* yield per hectare by more than 70% and reduced the seed requirement by 22.5-47 kg/ha. Looking at this improvement, the government of Ethiopian has officially introduced the method to smallholder *teff* producers in 2012, as a national promotion campaign and all the farmers in the country start sowing their *teff* using both methods [9]. Beyond the introduction and dissemination of more efficient farming practices and technologies, evaluating the farm level effectiveness and improving its efficiency is crucial for enhancing crop productivity [10].

1.2. Problem Statement

It has been argued that the low productivity of *teff* is partly caused by the method of sowing. Even though the official introduction of *teff* row planting to Ethiopian smallholder producers was targeted to minimize the effect of sowing method on crop's productivity, due to the lack of information about its appropriate application, most of smallholder farmers were not effective in sowing their *teff* in row. Moreover, due to the absence of efforts to evaluate and compare the farm level effectiveness of *teff* production under both methods, majority of farmers were indifferent of using row planting or broadcasting method to sow their *teff* [9].

Experiments made by [8] has shown that row planting of *teff* increases grain yield by 15.7 %, straw yield by 327.8 kg/ha, plant height by 4.67cm and panicle length by 2.25cm and decreased the seed rate by 15 kg/ha over the broadcast method. However, most of Gurage zone teff producers is allocate very small plots of land for *teff* row planting mainly because they have no clear information about the farm level efficiency of each sowing method [11]. Reports from [11] indicated that the absence of evaluation program and related scientific investigations highly contributes for the existing information gap on the farmers that they are unable compare and use an efficient sowing method [11].

Most importantly, the question that "how much Gurage zone *teff* producers are technically efficient under broadcasting and row planting methods? and "what factors can significantly affect their efficiency" have not yet been answered [12]. This study therefore was aimed to measure and compare farm level efficiency of *teff* production using row planting (RP) and broadcasting (BC) methods and respective factors affecting their efficiency in order to enable farmers to apply more efficient sowing method for *teff* production.

1.3. Objectives

Generally, this study was aimed to measure technical efficiency (TE) of *teff* production under row planting and broadcasting methods in Gurage zone, Southern Ethiopia. Specifically this study was designed:

- To measure and compare technical efficiency of Gurage zone *teff* production in row planting and broadcasting methods.
- To identify the factors affecting technical efficiency under both methods.

2. Research Methods

Here, the methodologies used throughout the paper (study area, data type and methods of data collection, sampling techniques used, and data analysis methods) have been discussed in detail.

2.1. Description of the Study Area

Gurage Zone is one of the administrative zones found in Sothern Nations Nationalities and Peoples Regional state of Ethiopia. It is located in semi-mountainous region in southwest Ethiopia, about 125 kilometers southwest of Addis Ababa, Gurage is bordered on the southeast by Hadiya and Yem special woreda, on the west, north and east by the Oromia Region, and on the southeast by Silt'e zone. Its highest point is Mount Gurage. Welkite is the administrative center of the zone and Butajira is the largest city in the zone. The altitude of the zone ranges from 1000 to 3600 m.a.s.l with the mean annual temperature ranging from15^{o}C to 32^{o}C.. Agro-ecology of the zone is classified as lowland 3.1%, mid-highland 65.3%, and highland 31.6% with the mean annual temperature ranging from 15^{o}C to 32^{o}Cand an verage annual rain fall ranging from 700 mm to 1600 [11].

The Zone has about 1,279,646 total populations, of whom 622,078 are men and 657,568 women and total land coverage of 5,893.40 square kilometers with a population density of 217.13 per square kilometer. A total of 286,328 households were counted in this zone of whom 119,822 or 9.36% are urban inhabitants and the average rural land holding is 1.75 hectare per household [5]. Livelihood of more than 85 % of Gurage zone inhabitant is depending on agriculture. *Teff*, chat, niger seeds, cabbage, red paper and maize are major cash crops in the zone. Out of the total of 286,328 households, 33785 are *teff* producers and almost all of *teff* producers in the zone are participating in *teff* row planting. In the 2017/18 production year, bout 35,733 hectare of land in the zone was cultivated with *teff* of which only 9,022 hectare (25.25%) of *teff* cultivated land was sown using row planting method [11].

2.2. Data Type and Collection Methods

For this study, both primary and secondary data were used. The primary data were collected through interview of 276 sample respondents using semi-structured questionnaire whereas secondary data were obtained from the review of published documents in related field, books, governmental offices and other organizations' official reports. The data about the household demographic status and all other variables (input and inefficiency variables) used for the analysis was obtained directly from the total of 276 households where as the supplementary data like total number of *teff* row planters, total hectares of *teff* cultivated land, *teff* productivity and the current status on the expansion of *teff* row planting in the zone was obtained from official reports and other secondary sources.

2.3. Sampling Technique

Multi-stage sampling technique was used to select sample respondents. In the first stage, Gurage zone was selected purposely as it is one of major teff producing areas in the Southern Nations Nationalities and Peoples Regional state of Ethiopia with large number of *teff* row planters and very low *teff* productivity [12]. In the second stage, teff producing districts in the zone were identified purposely based on the status of *teff* production and four teff producing districts namely Abeshgie, Cheha, Enemorina Ener and Meskan were selected randomly. In the third stage, three teff producing peasant associations from each of the four districts were identified and the list of households sowing *teff* using both row planting and broadcasting methods was prepared. Finally, 23 households from each of the identified 12 kebeles (a total of 276 households) were selected randomly for an interview.

2.4. Sample Size Determination

As the target populations are those who produce *teff* using both row planting and broadcasting methods, the population in the sample frame of the study was homogenous. Therefore, the size of the sample for this study was determined by using [13] formula given as:

$$n = \frac{N}{1 + Ne^2}. \quad (1)$$

Where; n=the sample size, e=degree of precision and N=total no of households in the sample frame.

As the sample frame of this study was those households who sow their *teff* using row planting and broadcasting methods and they have almost identical agro ecological practices, the researcher has expected a minimum variability in the response of samples. Since almost all *teff* producers in the selected districts were sown their *teff* using both methods, each household have sown at least a plot of land in both methods, the sample frame of the study therefore being equal to the sum of *teff* producer households within selected four districts (33,785). The level of precision (e) has been determined based on the expected variability in the response of sample households. According to [24] for social science researches the probability of making an error in selecting sample can be committed up to 10% so the precession level up 10% is possible. The more the homogenous population, the less degree of variability is expected to happen; smaller sample size is required to represent the population; the higher the probability of committing an error term in selecting representative samples; (i.e. the larger the value of e should be taken). Having these literature ground and due to the fact that the higher the sample, the more accurate the response is, a precession level (e=6) was used to determine the sample size for this study.

Therefore; by taking e as 6% and N=33,785 the sample size for this study was estimated as:

$$n = \frac{33785}{1 + 33785(0.06)^2} = 275.51 \approx 276.$$

2.5. Methods of Data Analysis

To address the objectives of the study, both descriptive statistics and econometric models were employed. Descriptive statistics of mean, frequency and percentages were used. For the econometric analyses, one-stage SPF model was used.

2.5.1. Specification of Econometric Model

Data envelopment analysis (DEA) and stochastic production frontier (SPF) model are the most commonly used models to measure efficiency. One-stage SPF model was used for this study. It was preferred mainly because if the occurrence of inefficiency effect and random noise on the data is uncertain, using the model that consider both random noises and inefficiency effect gives more accurate result than the model that fails to do this [10]. The SPF takes into account both random noise and inefficiency effect in the composite error term and gives a percentage contribution of random noise and inefficiency effect for the variation from the frontier which DEA fails too [14]. Apart from this, the parameter estimates under SPF represent the production elasticity's, but the resultant weights associated with the input variables have no economic interpretation under the DEA [15]. Its simplicity features to implement and draw economic interpretations after analysis is also another reason that makes SPF more preferable than others efficiency models. Following [15] and [23], the SPF model can be specified as:

$$Y_{ii} = f(X_i; \beta_i) + \varepsilon_i \,(i = 1, 2, \ldots n). \quad (2)$$

Where: Y_{ii}=total output of the i^{th} farmer; X_i=a vector of actual input variables used by the i^{th} farmer; β_i=parameter coefficients of production variables to be estimated; ε_i=is total error term composed error term (V_i-U_i); V_i=systematic error term; U_i=technical inefficiency.

The SPF model requires a priori imposition of the functional form to be followed and the distributional assumption for the composite error term. Cobb-Douglus and Translog are most frequently used functional form of SPF model. Cobb-Douglus functional form has an advantage of handling multiple inputs in its generalized form [16]. Moreover, it is convenient in interpreting elasticity of production and it is very parsimonious with respect to degrees of freedom. They also argued that, it can adequately and easily handle various econometric estimation problems like correlation, heteroskedasticity, simultaneity and multicolinearity which are serious problem in translog functional form. Thus, Cobb-Douglus functional form with half-normal distributional assumption for the composite error term was employed in this study.

In small and homogenous samples, if errors are not normally distributed, estimated coefficients will not follow normal distribution, which complicates the inference [15]. Hence, half-normal distributional assumption was followed for the composite error term in this study. Following [3], the general log linear form of one-stage SPF can be specified as:

$$lnYi = ln\beta_0 + \sum \beta_i lnX_i + V_i - U_i; i = 1, 2, \ldots n. \quad (3)$$

Accordingly, the SPF model used for this study was specified as:

$$ln\ output = \begin{pmatrix} \beta_0 + \beta_1\ ln\ qseed + \beta_2\ ln\ fert + \beta_3\ ln\ land \\ +\beta_4\ ln\ lab + \beta_5\ ln\ oxen + V_i - U_i \end{pmatrix}. \quad (4)$$

Where; ln=natural logarithm, β_0=the constant term, β_1-β_5 coefficient of the input factors, ouput=total *teff* output for i^{th} farmer in kg, qseed= total quantity of *teff* seed in kg used by i^{th} farmer per hectare, fert=total amount of chemical fertilizer in kg used per hectare, land=size of land that i^{th} farmer allocated for *teff* row planting and *teff* broadcasting specifically, lab= total human labor used by i^{th} farmer/ha measured in man-days, oxen=total amount of oxen power used by i^{th} farmer/ha measured in pair of oxen days, V_i error term associated with random and statistical noises and U_i error term associated with technical inefficiency. Following [14], the inefficiency effect U_i for this study was defined as:

$$U_i = \begin{pmatrix} \delta_0 + \delta_1\ AGE + \delta_2\ SEX + \delta_3\ EDUC \\ +\delta_4\ MIRG + \delta_5\ CRDIT + \delta_6\ RPEXP \\ +\delta_7\ FAREXP + \delta_8\ FAMSZ + \delta_9\ TRN \\ +\delta_{10}\ EXTEN + \delta_{11}\ SOIL + \delta_{12}\ PROX \\ +\delta_{13}\ IMPVAR + \delta_{14}\ NFINC + \delta_{15}\ FARSZ \end{pmatrix}. \quad (5)$$

Where: U_i is the technical inefficiency, δ_0=the constant term for the inefficiency effect model, δ_1-δ_{15} =the coefficient of the inefficiency variables, AGE=age of the household head, SEX=gender of the household head, EDUC=educational level of the household head measured in the number of years of formal schooling, MIRG=marital status (1,2,3 and 4 if single, married, divorced and widowed, respectively), FARSZ=total hectares of land owned by i^{th} farmer, RPEXP=*teff* row planting experience of the household head, FAREXP=farm experience of the household head in years, PROX=proximity of *teff* farm from their homestead measured in minute on foot, CRDIT=use of credit (1 if used, 0 otherwise), FAMSZ=total number of the house hold member, TRN= number training that household head is participated per year, EXTEN=number of contact between extension agent and single farmer per year, SOIL=soil fertility status (1 if fertile, 0 otherwise), IMPVAR=use of improved variety seed (1 if used, 0 otherwise), NFINC=the amount of income that the households generate per year from non-farm activities. The final model used for the analysis had been specified as:

$$\begin{aligned} & Lnoutput \\ & = \beta_0 + \beta_1\ ln\ qseed + \beta_2\ ln\ fert \\ & +\beta_3\ ln\ land + \beta_4\ ln\ lab + \beta_5\ ln\ oxen \\ & +V_i \begin{pmatrix} \delta_0 + \delta_1 AGE + \delta_2\ SEX + \delta_3\ EDUC \\ +\delta_4\ MIRG + \delta_5\ CRDIT + \delta_6\ RPEXP \\ +\delta_7\ FAREXP + \delta_8\ FAMSZ + \delta_9\ TRN \\ +\delta_{10}\ EXTEN + \delta_{11}\ SOIL + \delta_{12}\ PROX \\ +\delta_{13}\ IMPVAR + \delta_{14}\ NFINC + \delta_{15}\ FARSZ \end{pmatrix}. \end{aligned} \quad (6)$$

In SPF hypothesis tests were made using general LR test. The value and significance of variance parameters gamma (γ) and sigma squared and LR test can be used for running all the tests required under this study. Following [12] LR test statistic can be calculated as:

$$\begin{aligned} LR &= -2ln\left[L(H0)/L(H1)\right] \\ &= -2\left[lnL(H0) - lnL(H1)\right]. \end{aligned} \quad (7)$$

Where, LR= the likelihood ratio, ln = the natural logarithms.
$L(H_0)$=the log likelihood value of the null-hypothesis
$L(H_1)$=log likelihood value of the alternative hypothesis
The variance parameter gamma can be calculated as:

$$\gamma = \frac{\sigma_u^2}{\sigma_S^2} \text{ where } \sigma_S^2 = \sigma_u^2 + \sigma_v^2. \quad (8)$$

Where, σ^2u is the variance parameter associated with technical inefficiency and σ^2v is the variance parameter associated with systematic error term. The farm–specific technical efficiency in terms of observed output (Y_i) to the corresponding frontier output (Y_i^*) can be defined as:

$$TEi = \frac{Yi}{yi^*} = \frac{f(Xi;\beta)\exp(\mathrm{Vi} - \mathrm{Ui})}{\mathrm{f}(\mathrm{Xi};\beta)\exp(\mathrm{Vi})} = \exp(-\mathrm{ui}). \quad (9)$$

Where; Y_i is the observed (actual) *teff* output and Y_i^* is the maximum possible *teff* output of i^{th} farmer, using the given level of inputs.

3. Result and Discussions

This section of the paper is devoted to present and discuss the basic outputs of the research. Here the details of the findings about the technical efficiency level, the factors affecting *teff* productivity and the efficiency of *teff* production under broadcasting and row planting methods have been discussed.

3.1. Descriptive Analysis

Descriptive analysis results indicated that, the average *teff* output in row planting (1488 kg/ha) was 920 kg/ha higher than in broadcasting (568 kg/ha). The result also indicated that, on average, row planting increases human labor and oxen power requirement by 5.8% and 7.9%/ha, respectively, than broadcasting. On the other hand, *teff* row planting minimizes the average chemical fertilizers and *teff* seed requirement by 27.3%/ha and 57.7%/ha, respectively, than broadcasting. The average size of teff row planted land was 1.02 ha and the average *teff* broadcasted land was 1.25 ha.

The average age of the sample household heads was 40.87 years and average family size of the households was 6.52 persons which is greater than the national average. On average, sample farmers spent 7.76 years in formal education and they have an average of 20.07 and 2.47 year experience in farming and *teff* row planting, respectively. Sample households had earned an average of 2205 ETB from non-farm activities per year. On average sample farmers were required 17.23 minutes to go from their home to *teff* farm. There was 171 times average contact between farmers and extension agents per year and farmers were trained on average two times per year.

The majority (71.37%) of the sample households were male headed. Only 47.10% of the sample farmers have an access to credit. More than 88.04% of the sample farmers were married and the remaining 11.96% were under other three categories (single, divorced and widowed). About 42.75% of the sample household heads perceived their *teff* cultivated soil as fertile.

3.2. Econometric Analysis

The maximum likelihood estimates of the parameters, of the SPF specified in equation (6), were obtained using the STATA 13 computer software linear models and related, frontier models. Since the data collected from a single household about the inputs used, output obtained, and determinant factors were separate for row planting and broadcasting methods, a separate econometric analysis was made to measure the level of technical efficiency and factors affecting the level of technical efficiency under the two sowing methods.

3.2.1. Hypothesis Tests

In this study three basic tests had been made. The tests were undertaken using the diagnostic statistics outputs of the SPF model as presented in Table 1.

Table 1. Summary of diagnostic statistics analysis

Diagnostic statistics	Row planting		Broadcasting	
	Coefficient	SE	Coefficient	SE
$\Sigma\mu$	0.2103	0.0271	0.246	0.018
Σv	0.1011	0.0146	0.104	0.011
$\lambda = \sigma\mu/\sigma v$	2.08	0.0369	2.36	0.021
$\sigma^2 = \sigma_\mu^2+\sigma_v^2$	0 .054***		0.071***	
$\gamma = \sigma_\mu^2/ \sigma^2$	81.29***		84.84***	81.29***

Note: *, **, and *** refers 10%, 5% and 1% level of significance.
Source: Own computation (2017).

The first hypothesis test was that sample *teff* producers are technically efficient (γ =0) under both methods. For this test the calculated value of γ was computed using equation (7) and is equal 81.3 under row planting and 84.8 under broadcasting which is significantly different from zero and greater than the critical chi-square value (3.84) at 5% significance level and 1 degree of freedom. The null hypothesis (γ =0) was rejected indicating that inefficiency effects are different from zero. Therefore, variations in *teff* output among sample farmers were subjected to both inefficiency effect and random noises; confirmed the appropriateness of using SPF model.

The second hypothesis tested was the null hypothesis that the quadratic and interaction parameters under translog functional form are all zero (H_0: $\beta_6=\beta_7=\ldots=\beta_{20}=0$) which enable us to choose between Cobb-Douglus and translog functional form. As it had been calculated using the equation (7), LR for this test was 14.52 under row planting and 16.32 under broadcasting which is less than the tabulated chi-square value (24.99) at 5% level of significance and 15 degree of freedom. Therefore, the null hypothesis was accepted and Cobb-Douglas production function was confirmed to be the appropriate over translog one.

The third hypothesis tested was that all coefficients of the inefficiency effect model are simultaneously equal to zero (i.e. H_0: $\delta_0=\delta_1=\delta_2 \ldots=\delta_{15}=0$). It was also tested by calculating the LR value using the Equation (7). The LR value for this test was 303.5 under row planting and 196.24 under broadcasting, which is higher than the critical chi-square value (24.99) at 5% level of significance and 15 degree of freedom which the number of restrictions to be zeros (the difference between total variable minus the variables in the production function). Therefore, the null hypothesis was rejected and confirmed that, the explanatory variables associated with inefficiency effects model are simultaneously different from zero and explains the variation in technical efficiency among sample farmers. Diagnostic statistics revealed that sigma squared (δ^2) was statistically significant at 1% (Table 1), confirmed the appropriateness of the half normal distributional assumption applied for the composite error term.

Table 2. Likelihood Ratio Test Statistics

Null hypothesis(H_0)	Calculated LR		DF	Critical X^2	Decision
	Row Planting	Broadcasting			
H_0: γ=0	81.29	84.84	1	3.84	Reject
H_0: $\beta_6\ldots\beta_{20}$=0	14.52	16.32	15	24.99	Accept
H_0: $\delta0=\delta1=\ldots\delta15=0$	303.46	196.24	15	24.99	Reject

Source: Own computation (2017).

3.2.2. Estimation of Production Function Parameters

Sizes of land allocated for *teff* production and quantity of *teff* seed used per hectare affects *teff* productivity negatively under both methods supporting the idea that high seed rate leads to lodging and high competition among plants for nutrients [7]. The finding is consistent with the finding of [17] and contrast with [18]. Accordingly, a percentage increase in the area allocated to *teff* and the quantity of *teff* seed decreases productivity by 0.259 and 0.053 percent, respectively, under row planting and by 0.37 and 0.544 percent, respectively, under broadcasting.

Table 3. ML Estimation Results of the Production Function

Variables	Row planting		Broadcasting	
	Coefficient	t-ratio	Coefficient	t-ratio
Constant	-3.90***	-13.03	-3.79***	-5.13
ln(land size)	-0.25***	-8.63	-0.37***	-3.30
ln(labor)	1.24**	2.28	0.38**	2.31
ln(oxen)	0.17***	9.42	0.12***	2.55
ln(fertilizer)	0.009	0.00	0.076	1.01
ln(quantity of seed)	-0.05 *	-1.47	-0.54*	-1.72

Note: *, **, and *** refers 10%, 5% and 1% level of significance.
Source: Own computation (2017).

As presented in Table 3 human labor and oxen power affect *teff* productivity positively which is consistent with the findings of [19,20]. This might be due to the reason that efficient utilization of labor and oxen power directly enhances the marginal productivity of other inputs [20]. Accordingly, a percentage increase in human labor and oxen power improves *teff* productivity by 1.241 and 0.179 percent respectively under row planting and by 0.38 and 0.12 percent respectively under broadcasting.

3.2.3. Technical Efficiency Score

The model output indicated that, there was a variation in technical efficiency among sample households. The mean technical efficiency was 0.804 and 0.438 under row planting and broadcasting respectively; confirmed that, the average technical efficiency of Gurage zone *teff* producers is higher in row planting than broadcasting.

Table 4. Descriptive Summary of Technical Efficiency Score

Statistical descriptions		Minimum	Maximum	Mean	SD
TE under	Row planting	0 .3010	0.999	0.804	0 .078
	Broadcasting	0.087	0.7985	0.438	0.082

Source: Own computation (2017).

As shown in the Figure 1, more than 60% of sample households have technical of between 0.80-0.999 under row planting and no farmer have technical score of more than 0.80 under broadcasting. In addition to this, more than 42.06% of sample households have technical of less than 0.40 under broadcasting and only 4.3% of the households have technical between 0.301 to 0.399 under row planting and no farmer have technical efficiency score of less than 0.30. All this again approved that, Gurage zone *teff* producers more better technically efficient under row planting than broadcasting.

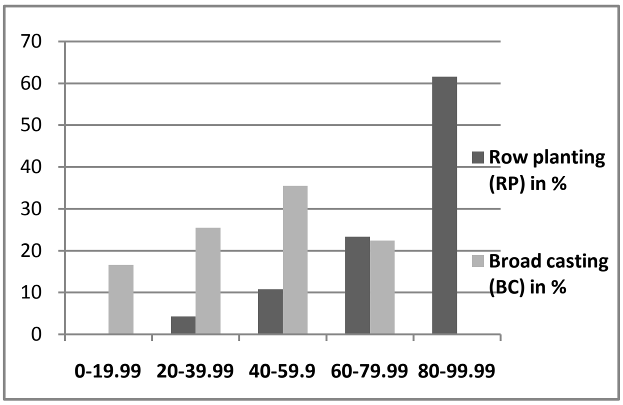

Figure 1. Graphical distribution of technical efficiency ranges (Source: Own computation 2017)

3.2.4. Determinants of Technical Efficiency

Among inefficiency variables, the level of education takes the lion-share on explaining the variation in technical efficiency among sample farmers. It significantly and positively affects technical efficiency which is consistent with the finding of [2,19] and [21] who argued that education enables farmers to diversify their source of information and improves their managing capacity. Access to credit and the use of improved variety seed also positively affects technical efficiency. This is due to the fact that, the use of improved seed is one of most efficient means to improve the productivity [6,20] access to credit can solve the farmers cash liquidity problem [18,20]. *Teff* row planting experience and farm experience affects technical efficiency of Gurage zone *teff* producers positively and significantly under row planting and broadcasting methods respectively. This can be supported by the finding of [17] and [21] who argued that, experienced farmers can better perform farm operations than non-experienced as they have better knowledge and skill about things to be done.

As shown in Table 5, the study result also confirmed that the presence of more contact between extension agents and farmers made farmers more technically efficient [22]. In this study frequency of extension contact and non-farm income affects technical efficiency positively and significantly in contrast with finding of [17,20]. The latter one is due to the fact that, non-farm income can be used as extra cash to buy agricultural inputs and for timely operation of farm activities which enhance productivity [18,22].

Proximity of *teff* farm from homestead affects technical efficiency negatively supporting the idea that sowing on the nearer farm enables farmers to use the traveling time for timely implementation of farm operations and improves productivity and technical efficiency [17,22].

Table 5. MLE of the Determinant of Technical Efficiency

Variables	Row planting		Broadcasting	
	Coefficient	t-ratio	Coefficient	t-ratio
Age	0.0034	0. 20	1.29	0.072
Sex	-0.162	-1.05	-2.11	1.001
Educational level	12.300***	4.77	8.45***	5.37
Marital status	0.850	1.15	2.35	0.889
Non-farm income	0.003*	1.58	2.50*	1.67
Credit access	9.088***	3.66	6.23***	3.71
Family size	0.598	0.98	1.76	0.05
Farm size	2.927	0.75	0.245	1.02
Row planting experience	2.074***	3.38	-	-
Farm experience	0.030	0.77	-1.22***	3.56
Proximity	-5.824***	-4.67	-5.03***	3.75
Frequency of extension contact	2.000**	2.34	1.83**	2.20
Frequency of training	0.049	0.25	0.87	1.21
Use of improved seed	6.128***	3.10	3.25	8.12
Fertility status of the soil	-0.558	-0.76	2.15	0.65

Note: *, **, and *** refers 10%, 5% and 1% level of significance.
Source: Own computation (2017).

4. Conclusions

Despite the improvements from *teff* row planting, due to the absence of clear information on the comparative farm level effectiveness of *teff* row planting and broadcasting, in Ethiopia still there are farmers who are indifferent of using broadcasting or row planting methods. The study' results confirmed that an increased use of labor and oxen power and reducing the quantity of *teff* seed and the size *teff* cultivated land up to its optimum point can significantly improve *teff* productivity under both methods. The average technical efficiency of sample households is 80.4% and 43.8% under row planting and broadcasting methods, respectively, indicating that Gurage zone *teff* producers are more technically efficient in row planting than in broadcasting method; therefore it is better for the farmers to sow their *teff* in row than simple broadcasting. The results also confirmed that, technical efficiency of sample farmers is significantly responsive to education level, access to credit, use of improved *teff* variety, frequency of extension contact, proximity of *teff* farm from home and non-farm income under both methods. Therefore, providing better education and credit access, encouraging farmers to use improved variety and enabling them to sow in the nearest farm, providing frequent extension contact and giving direction to generate non-farm income can improve their efficiency in *teff* production under both methods. Specifically, practicing more on *teff* row planting and farming activities can also be taken as a significant strategy to improve their technical efficiency under row planting and broadcasting method, respectively.

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List of Abbreviations

BC Broadcasting
ETB Ethiopian Currency (Birr)
ha Hectare
LR Likelihood ratio
MLE Maximum Likelihood Estimate
RP Row Planting
TE Technical Efficiency

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