Advances in Bioscience and Bioengineering
2023; 11(3): 42-47
http://www.sciencepublishinggroup.com/j/abb
doi: 10.11648/j.abb.20231103.12
ISSN: 2330-4154 (Print); ISSN: 2330-4162 (Online)

Promotion of Improved *Tef* (*Eragrostis Tef*) Technologies Through Cluster-Based Large-Scale Demonstration in Oromia and Amhara Regional States, Ethiopia

Truayinet Mekuriaw, Mohammed Ahmed, Yazachew Genet, Abune Gudeta, Wubishet Chiche, Habtamu Geremew

Ethiopian Institute of Agricultural Research (EIAR), Debre Zeit Agricultural Research Center, Debre Zeit, Ethiopia

Email address:
truyem@gmail.com (Truayinet Mekuriaw)

To cite this article:
Truayinet Mekuriaw, Mohammed Ahmed, Yazachew Genet, Abune Gudeta, Wubishet Chiche, Habtamu Geremew. Promotion of Improved *Tef* (*Eragrostis Tef*) Technologies Through Cluster-Based Large-Scale Demonstration in Oromia and Amhara Regional States, Ethiopia. *Advances in Bioscience and Bioengineering*. Vol. 11, No. 3, 2023, pp. 42-47. doi: 10.11648/j.abb.20231103.12

Received: July 20, 2023; **Accepted**: August 8, 2023; **Published**: September 8, 2023

Abstract: Technology awareness and adoption by farmers in Ethiopia are low. Therefore, the study was conducted to improve farmers' awareness, and enhance the adoption of full package *Tef* production technologies. The large-scale demonstration was implemented in two regional states using the Tef variety Dagim, Ebba and Boset for two years (2020-2021). The demonstration was implemented in three districts (Boset, Becho in Oromia region and Shebel Berenta in Amhara region) covering 9 kebeles and 100 hectares of land. A total of 212 households, including 29 women-headed households participated in the activity. Participated farmers contributed a land size of 0.25 to 1 hectares. The findings of the study showed that the improved variety of Tef showed better performance in grain yield where variety Specifically, Dagim variety gave 2370 kgha^{-1} and 2580 kgha^{-1} in Becho and Shebel Berenta districts respectively, whereas 2280 and 2480 kgha-^{1} were obtained from variety Ebba at the same location. In moisture deficit areas of Boset district, the average yield of Boset and Bora variety was 2260 kgha^{-1} and 2350 kgha^{-1} respectively, compared to the farmer's practice of 222 kgha^{-1} in highland area and 211 in lowland areas. The technology gap (TG) for the demonstrated varieties ranged from 540 to 725 kgha^{-1}, indicating that the technologies have not been adopted. Similarly, the extension gap ranged from 150to 275 kgha^{-1}, highlighting the need to strengthen the extension approaches to bridge the gap. The results demonstrate that the varieties are the best fitted, and the large scale demonstration approach significantly increased yield s compared to the farmers' local cultivars and traditional practices. Thus, to ensure a sustainable production of improved Tef technologies, both the extension and the seed system should be considered to deliver the seed supply for the entire Tef producers.

Keywords: Demonstration, Extension Gap, Large-Scale, Technology Gap

1. Background

Tef (*Eragrostis Tef*) is among the most important cereal crops for Ethiopia's agricultural economy, both in terms of production, consumption and as cash crop value. The crop is annually grown on over 2.93 million hectares of land, accounting for about 1/4 of the total cereal acreage and about 1/5 of the gross cereal grain production [7]. In 2019/20, Tef accounted for about 24.11% of the nationwide grain-cultivated area followed by maize at 17.68% and sorghum at 13.22%, and nearly half of the smallholder farmers grew it between 2014 and 2018 [7]. In terms of production, *Tef* is the second highest cereal grain production, accounted for 17.12% (5.6million ton) next to maize made up 32.79% (10.75 million ton) and followed by wheat at 17.71% (5.8m ton).

Tef becomes increasingly popular in the globe due to its high nutritional quality and absence of gluten [3]. It exhibits relative resistant to many biotic and abiotic stresses and can be grown under different agro ecological conditions, ranging from lowland to highland areas [10].

Despite the crucial importance of *Tef* in the national food security, nutrition and income generation for smallholder farmers of Ethiopia, both its total production and productivity remains relatively low, with a national average grain yield of

1.9 tons per hectares [7]. This yield is far below the genetic potential of 6 tha^{-1} [14] and the lowest among other cereal crops [9]. *Tef* research program at Debre Zeit Agricultural Research Center in collaboration with other research centers has released more than 54 improved tef varieties and a number of recommendations for different agro ecology of Ethiopia [12]. At the same manner, the agricultural extension research team has demonstrated and disseminated the technologies. However, the rate of adoption of the varieties has been low due to the lack of awareness, lack of improved seeds, poor seed system and others [9]. Therefore, this calls for creating high demand and broaden access to demonstrated high yielding, and demand driven quality *Tef* varieties that can make producers improve production and productivity and thereby improve their livelihood. Therefore, this activity was conducted to evaluate the improved *Tef* varieties yield performance and improve the awareness of farmers on improved *Tef* technologies using clustered based large-scale demonstration in targeted districts of the Oromia, and Amhara regional states during the 2021-22 main cropping seasons.

2. Materials and Methods

2.1. Description of the Study Area

Boset district is one of the districts in the Oromia Regional states of Ethiopia. Parts of east Shewa provinces located in the Great Rift Valley (GRV), Boset district, is bordered on the south by the Sire and Dodota, on the west by Adama district, on the east by Merti, on the north by the Amhara region, and on the northeast by Fentale; southeast by Jeju. The total land coverage is 124 160 hectares—the altitude range from 1200-1800 meters above sea level. Most part of Boset (about 89%) belongs to the tropical (Gammojji/Kolla) Agro-climatic zone, and the remaining smaller section (about 11%) is sub-tropical (Badda Daree/woina Dega). The major soils of Boset, Andosols, though have low water retention capacity, are quite productive, especially during periods of sufficient rains [1].

Shebel Berenta District is located in East Gojam Zone, situated in the North Central Highlands of Ethiopia in the Amhara region. It extends from 10° 15′ N to 10° 30′ N latitude and from 38° 15′ E to 38° 27′ [15]. It is bordered on the South-West by Dejen district; on the North-West by Enemay district; on the north by Enarj Enawga district, and on the South and South-East by Abay River Gorge, which separates it from the Oromia region. The district covers a total land area of 89,714 ha. Its altitude ranges from 1800 to 2150 masl. It has 2 agro-ecological zones with (28%) Woyina-Dega and (72%) Kolla. Shebel Berenta district has 26 Kebeles, of which 2 are urban and 24 rural Kebeles. Agriculture is the mainstay of the district livelihood activities for rural residents characterized by subsistence crop production, mainly dependent on rainfall, which is erratic in nature; the dominantly traditional farming system results in low input-output crop yields [13, 11].

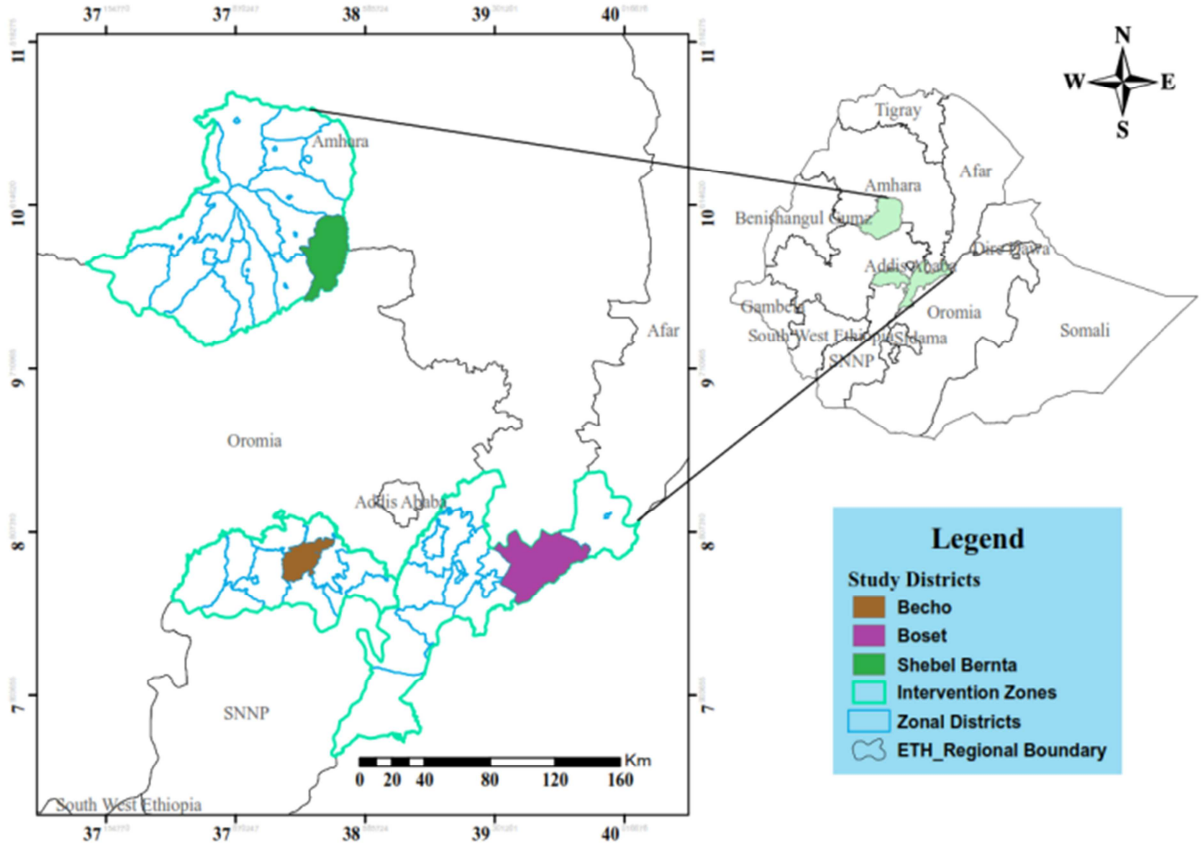

Figure 1. *Map of the study area.*

Becho district is located in the Southwest Shewa zone of Oromia region. The district is subdivided into 21 Kebeles (smallest administrative units in Ethiopia). From these, 19 Kebeles are rural and the other two are urban. The capital of the district, Tulu Bolo, is located at about 80 km southwest of Addis Ababa, the capital city of Ethiopia. The estimated population of the district in 2017 was 99, 090; among which 76.42% (75,724) were rural residents [5]. Geographically, the district is located between 8°34′59.99″ N and 38°14′60.00″ E, with an altitude ranging from 1,850 to 2,200 masl. Highlands, which roughly account 95% of the landmass, dominate the district. The remaining area is categorized under mid highland. The mean annual temperature of the district ranges from 16 to 25 °C and the mean annual rainfall is about 1,300 mm. The main rainy season extends from May to September. Mixed farming (crop and livestock production) is the dominant livelihood of the rural residents. Major crops produced in the district are *Tef*, wheat, and chickpea. *Tef* and wheat are grown from July to November whereas chickpea is grown from September to December [4, 8].

In the study area, improved varieties of Quncho, Kora and Boset *Tef* varieties were introduced by different stakeholders. However, the varieties were not widely adopted by *Tef* producer farmers due to their preferences for certain traits and the lack of strong extension services, except for the Quncho variety, which is well-known at the country level. As a result of this, farmers were not producing the newly released improved varieties. Over the last few years, demonstration of improved tef varieties on a small plots of land were conducted using a pre-extension demonstration approaches in the selected districts, leading farmers to prefer the Dagim, Ebba and Boset varieties due to their desirable characteristics such as high yield, quality for consumption, early maturity, straw palatability, and resistance to loading. Therefore, the variety Ebba and Dagim were promoted in the Shebele berenta districts of East Gojam Zone of Amhara region, and the Becho districts of South West Shewa Zones of Oromia region. Similarly, the variety Bora and Boset were demonstrated in the lowland growing areas of Boset district of East Shewa Zone of the Oromia region during 2021-22 main cropping season.

Table 1. *Description Tef varieties demonstrated.*

Varieties	Years of release	Altitude	Rainfall in mm	days of maturity	Seed color	On-station average yield (t/ha)	On farm average yield (t/ha)
Dagim	2016	1700-2400	700-1200	116-144	Very white	2.5-3.2	2.0-2.8
Eba	2019	1700-2500	700-1200	95-110	Very white	2..4-3..0	2.0-2.8
Boset	2012	750-1500	500-700	82-90	Very white	1.9-2.8	1.8-2.2
Bora	2019	750-1500	500-700	72-85	Very white	2.1-3.0	1.9-2.5

Source: (MoA, 2021)

2.2. Site and Farmer Selection

The activity was carried out in Boset and Becho districts of Oromia regional state and Shebel Berenta districs of Amhara regional state for two years (2021-2022). A total of 212 farmers were actively involved in the demonstration activity. The district agricultural office experts and Development Agents had also taken part in the implementation process. An interdisciplinary team composed of researchers (Agricultural Extensionist, Breeder, and Agronomist), district experts, and development agents was established to implement the activity successfully. Representative Nine Kebeles were purposively selected based on the potential area of Tef production and accessibility for field monitoring and follow-ups. Similarly, farmers' selection was conducted in collaboration with district experts and development agents. Farmers were selected based on their willingness and interest to participate, and the willingness to allot a minimum of 0.25 hectares of land for the intended purpose. Finally, the varieties were demonstrated with a participation of 212 farmers in 100 hectares of land. The seed rate used for this activity was 15kgha^{-1}. Soil fertilizer of NPS and UREA (100 kgha^{-1} and UREA and 100 kgha^{-1}) were applied. all recommended agronomic practices were implemented.

2.3. Data Collection and Analysis

Both qualitative and quantitative data were collected through supervision and follow up of the activity with the joint action of the stakeholders. A data record sheet was developed to collect the data. Thus, field observation, contacting the target farmer, and focus group discussion during the field visit were the data collection methods. Yield data and farmers' preference towards the variety were collected from the farmer's field. The number of farmers participated in training and field day, the number of locations addressed, the amount of seed distributed and the number of farmers benefited from the demonstration process were major types of data collected during the activity. Finally, the collected data were analyzed using descriptive statistics, and yield gap were analyzed using narrations.

Yield potential is the genetic potential, which is dependent on biological or plant factors under the ideal environmental conditions and crop management practices, having one definite yield level for the species or variety. One definite yield level is because there is only one ideal environment and set of crop management practices [2]. Potential yield is the yield of a variety × environment combination under the best crop management and will be different in environments differing in temperature and solar radiation regimes for a given variety [2]. Demonstration yield is the amount of grain yield of demonstrated improved *Tef* varieties obtained per

unit area with recommended production packages. At the same time farmers yield was computed as the grain yield of local variety with farmer's agronomic practices. Technology gap is the difference between potential yield and demonstration yield of improved *Tef* varieties per unit area. At the same time technology index is the difference between technology gap and potential yield and then multiplied by hundred. Technology gap, extension gap and technology index were calculated as per the following formula.

$$\text{Technology gap} = \text{Potential yield qt/ha} - \text{demonstration yield} \quad (1)$$

$$\text{Yield advantage \%} = \frac{\text{Yield of new variety} - \text{Yield of standard check}}{\text{Yield of standard check}} \times 100 \quad (2)$$

$$\text{Technology gap} = \text{Demonstration yield qt/ha- Farmers' practice yield} \quad (3)$$

$$\text{Technology index \%} = \frac{\text{Technology gap}}{\text{Potential yield}} \times 100 \quad (4)$$

3. Results and Discussions

3.1. Sex of the Household Heads

In this study age and sex of the household have been considered just to show the involvement of farmers in technology demonstration of improved *Tef* varieties. Based on this, gender disparities were observed for large scale demonstration of improved *Tef* varieties and hence the participation of women was not more than 14% from the total household headed farmers. This indicated that women should be more encouraged to involve and play a key role in technology dissemination and popularization (Table 2).

3.2. Demonstration Area Coverage

The large-scale demonstration was done in a total of 100 hectares of land. The minimum area allocated per farmers was 0.25 hectares whereas the maximum was 1 hectare. In general, for this study 20 ha from Becho and 40 ha both from Boset and Shebel Berenata districts were covered.

Table 2. *Summary of participants and area coverage for the large scale demonstration.*

District	Variety	No. of Clusters	Cluster size (ha)	Participants	
				M	F
Boset	Bora	1	10	3	3
	Boset	3	30	23	8
Shebel berenta	Eba	1	10	49	1
	Dagim	3	30	95	13
Becho	Eba	1	10	6	2
	Dagim	1	10	7	2
3	4	10	100	183	29

3.3. Training

Training delivered to farmers, experts, and development agents believed to be one of the prominent inputs to improve the adoption of high yielding varieties and its agronomic practices. In this regard, the Debre Zeit Agricultural Research Center organized training programs to farmers, experts, and development agents on *Tef* production, the concept of the cluster-based large-scale demonstration, the importance of improved varieties, and commitment and responsibilities of stakeholders. a total of 212 farmers (183 male and 29 women), and 17 experts and development agents (13 male and 4 women) attended the training.

3.4. Yield Performance and Yield Gap Analysis

3.4.1. Yield Performance

The performances of the technologies were assessed against some indicators such as minimum, maximum, average yield of clusters in each district. Thus, as depicted below (Table 3), the average yield of the variety Dagim was 2370kgha^{-1} and 2580 kgha^{-1} at Becho and Shebel Berenta, respectively. Whereas 2280kgha^{-1} and 2480 kgha^{-1} were obtained from variety Ebba at the same location. The average yield of the variety Boset and Bora was 2260 kgha^{-1} and 235 0 kgha^{-1} at Boset district, respectively. These imply an increment range of about 15.90-18% yield advantage for variety Dagim, 11.45-11.74% for variety Ebba, 16.11% for variety Bora and 11.85% for variety Boset over the current zonal average yield reported by the Central Statistics Agency [6]. This, in turn, implies the host farmers obtain an additional 340-410 kgha^{-1} yield from Dagim variety, 250 - 260 kgha^{-1} additional yield from Variety Eba, 340 kgha^{-1} from variety Bora and 250 kgha^{-1} yield from variety Boset due to the use of the technologies. Thus, the average yield obtained from the LSD districts, of all *Tef* varieties demonstrated is greater than the average yield recorded by the [6] zonal average yield. The higher productivity is mainly due to the application of the package approach (improved varieties along their recommended production and management practices). Therefore, the technologies demonstrated in the districts are promising in improving the production and productivities and ultimately contribute to the

food security of farmers in the respective area.

Table 3. *Yield yield advantage and yield gain from demonstrated varieties.*

Variety	Zone	District	Cluster yield kgha^{-1}	Zonal yield kgha-^{1}	Yield advantage gha^{-1}	Yield gain (%)
Boset	East Shewa	Boset	2360	2110	250	11.85
Bora	East Shewa	Boset	2450	2110	340	16.11
Dagim	East Gojam	Shebel berenta	2680	2270	410	18.06
	South west shewa	Becho	2470	2130	340	15.96
Eba	East Gojam	Shebel berenta	2530	2270	260	11.45
Eba	South west shewa	Becho	2380	2130	250	11.74

3.4.2. Technology Gap, Extension Gap and Technology Index

The yield gap was analyzed based on the actual implemented improved Tef technologies and the trend of farmers practices the tested districts. Based on those technology and extension yield gaps were made. The mean value of technology gap (TG) analysis and overall gaps against the recommended technology practices was computed. Hence, from the current study the overall technology gap was found 725kgha^{-1} for variety Dagim, 650 kgha^{-1} for variety Bora, 645 kgha^{-1} for variety Ebba and 540 kgha^{-1} for variety Boset. The yield difference may be observed due to the environmental differences. On the other hand, extension gap found 275 kgha^{-1} for variety Dagim, 240 kgha^{-1} for variety Bora, 255 kgha^{-1} for variety Ebba and 250 kgha^{-1} for variety Boset. The results indicated that it needs emphasis to strengthen the extension approach using various methods like offering training to farmers, skill and experience sharing, awareness enhancement via information dissemination channels and other pertinent methods. It is also believed that advanced improved *Tef* technology production package with acceptable grain quality will subsequently change the extension gap. Hence, the dissemination of newly released improved *Tef* technologies including production packages will have a significant contribution to replace old *Tef* varieties and then hasten the adoption rate. At the same time the technology index (TI) was computed using formula (4) and the result showed that variety Dagim recorded 22.66%, variety Bora recorded 21.67%, variety Ebba 21.5% and variety Boset 19.29%. This is an indication that *Tef* yields both at farmers' farms and at the demonstration sites still have huge potential to increase. If this gap is closed, *Tef* production and productivity will be enhanced (Table 4).

Table 4. *summary of Technology gap, Extension gap and technology index.*

Variety	Potential yield (maximum on stasion)	Cluster yield	Zonal yield	Technology gap	Extension gap	Technology index
Boset	28	22.6	21.1	5.4	1.5	19.29
Bora	30	23.5	21.1	6.5	2.4	21.67
Dagim	32	24.75	22	7.25	2.75	22.66
Eba	30	23.55	22	6.45	1.55	21.50

3.5. Field Day

Three field days were organized at Becho and Shebelberenta districts. A total of 256 farmers (197 male and 59 women), 45 experts from district agricultural offices and development agents, 10 researchers and 18 higher officials participated on field day. A total of 350 leaflets were distributed for the participants who describe the production, agronomic practices, and overall management of improved *Tef* varieties in different languages (English, Amharic and Afan Oromo). Finally, at the end of the visit during field day, group discussion was conducted to grasp farmer's feedback on the strength and weakness of improved *Tef* varieties demonstrated. According to farmers' observation the varieties captured their interest mainly because of yield advantage and its early maturity characteristics especially at moisture stress areas. Besides, they asked timely distribution of seeds by the participants field days.

Table 5. *Summary of participants on field day and experience sharing events.*

Participants	Field day Attendees			Districts
	Men	Women	Total	
Farmers	197	59	256	Becho, Shebel Berenta
Experts	35	10	45	
Higher officials	15	3	18	
Total	247	72	319	

4. Conclusion and Recommendations

A large-scale demonstration of *Tef* was undertaken with the active participation and collaboration of district experts, development agents, and farmers. The findings of the study showed that the improved variety of *Tef* showed better performance in grain yield compared with the farmer's

practice. This created greater awareness and motivated other farmers to adopt the improved package of practices of *Tef*. These demonstration trails also enhance the relationship and confidence between farmers, extension workers, and researchers. The host farmers of large-scale demonstration also played an important role as a source of information and quality seeds for wider dissemination of the improved variety of *Tef* for other nearby farmers. It is concluded that the large-scale demonstration is a successful tool in enhancing the production and productivity of *Tef* by improving the knowledge, attitude, and skill of farmers. Hence, the office of agriculture and rural development of the respective districts should further disseminate and scale-out *Tef* variety to several farmers in similar agro-ecologies. Seed producer cooperatives or organized farmers groups should also be formed to continuously and consistently multiply and supply the seed of these varieties so that there is sustainable seed supply.

Acknowledgements

The authors would like to acknowledge Integrated Tef project of Ethiopian Institute of Agricultural Research (EIAR) and development agents and experts in Boset and Becho districts of Oromia regional state and Shebel Berenta districs of Amhara regional state for their assistance during the implementation of the activity.

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