

## Participatory on-farm evaluation and demonstration of improved teff (*Eragrostis teff* (Zucc.) Trotter) varieties in Western Amhara Region, Ethiopia

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### ABSTRACT

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*Teff, a staple food for most Ethiopians, is first in area coverage and second in total annual production next to maize. Its productivity is low compared to other cereals grown in the country partly because of less or ineffective promotion and dissemination of new teff varieties. Therefore, this activity was conducted in Libokemkem and Ebenat woredas of South Gondar Zone of the Amhara region, Ethiopia with the objectives of identifying teff variety selection criteria for use in future variety development, increasing farmers' awareness and their access to improved teff varieties, enabling farmers to assess the performance of improved teff varieties with their production package, and accelerating the dissemination of farmers preferred varieties in teff growing potential woredas of the region. The woredas were selected purposively, as they were intervention areas of the Norwegian Forestry Group/Forest Landscape Restoration Program, which is a stakeholder to ARARI and the need to acquaint farmers with recently released teff varieties. Twenty-five FREGs members and 6 interested and committed host farmers from each woreda were selected to undertake the trial on their farm plots. Two improved teff varieties: Hiber-1, and Etsub, and a local check (CR-37) were used in the trial. Farmers in the two woredas set their own evaluation and selection criteria and ranked them in order of importance using the pair-wise ranking method. Thus, based on the overall evaluation and selection criteria farmers in Libokemkem selected Hiber-1 while in Ebenat woreda they selected Etsub teff variety as their 1<sup>st</sup> choice. However, in the two woredas, Cr-37 was selected by farmers as their second choice next to Hiber-1, and Etsub which gave a mean grain yield of 1.73, and 1.6 t ha<sup>-1</sup>, in Libokemkem and Ebenat woreda, respectively. Hiber-1 variety gave a yield advantage of 15.3% in Libokemkem, while Etsub in Ebenat woreda gave a yield advantage of 14.3% over the local check. Therefore, since the two varieties were selected by farmers because of their quality, dry biomass yield, and yield advantage,*

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*it is worthwhile to scale up them in the woredas and other similar agro-ecologies of South Gondar Zone to ensure increased income, food, and nutrition security of the rural households.*

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## 1. INTRODUCTION

*Teff* is a cereal crop and the tiniest grain on the planet contributing to food security and crop diversification (Tadele and Hibistu, 2021). Ethiopia is the center of both the origin and diversification of *teff* and its domestication is anticipated to have happened somewhere in the range between 4000 and 1000 BC (National Research Council, 1996; Dereje et al., 2018). *Teff* is one of the major crops with the largest value in terms of production, consumption, or area of production value (Minten et al., 2016; Lee, 2018; Nandeshwar et al., 2020). It is a warm-season annual cereal crop and the only cultivated species in the genus *Eragrostis* which is relatively resistant to many biotic and abiotic stresses and adaptable to a range of growing conditions compared to other major crops (Assefa et al., 2015; Zhu, 2018).

*Teff* is profoundly nutritious and is a significant part of Ethiopia's cultural heritage and national identity. Being marked as one of the most recent superfoods of the 21<sup>st</sup> century, such as the old Andean grain quinoa, its worldwide acceptance is quickly rising (Collins, 2013). For dietary requirements, the country relies on *teff* for two-thirds of the daily protein intake and 11% of the per capita caloric intake (Crymes, 2015; Anadolu Agency, 2017). *Teff* grains are low on the glycaemic index, which makes them suitable for people with Type 2 diabetes. The grains are also gluten-free (Assefa et al., 2015) and attract individuals who suffer from gluten intolerance or celiac disease (O'Connor, 2016). Most notably, *teff* contains a higher quantity of minerals and amino acids than other cereals. It is also high in important fatty acids, fiber, and phytochemicals including polyphenols and phytates (Baye, 2014; Abraham, 2015; Hailu et al., 2017). Moreover, *teff* is one of the most important crops for farm income and food security and is the second-most important cash

crop (after coffee), generating almost 500 million USD per year for local farmers (Bachewe et al., 2019).

The most common utilization of *teff* in Ethiopia is the fermented flatbread called injera (Crymes, 2015; Zhu, 2018; Wato, 2020) which is a flatbread as a soft, thin pancake with a sour taste. Other utilizations of *teff* include local alcoholic beverages called *tela* and *katikala*, and porridge (Abraham, 2015). Additionally, *teff* plant residues could be used as fodder for livestock, and often incorporated as construction materials (Cheng, 2017; Lakew and Berhanu, 2019).

*Teff* is extensively cultivated in most of the agroecological zones of Ethiopia and Eritrea (Mihiretu and Abebaw, 2020). Ethiopia grows more than 90% of the *teff* in the world (Anadolu Agency, 2017). In the Amhara region, *teff* contributed 25.4% in area coverage and 32% of the total production in the 2018/19 cropping season. About 1.2 million hectares of land were covered by the *teff* crop and 2.16 million tons of yields were produced in the 2018/19 *Meher* season. From the total *teff* production of the country (5.4 million t ha<sup>-1</sup> from 3.1 million hectares), the Amhara region contributes 39% in area of production and 40% in production (CSA, 2019).

Although *teff* is the primary crop in area coverage and second in total annual production next to maize, the present production system cannot satisfy the needs of most Ethiopians because of the low productivity of the crop compared to other cereals grown in the country with a national average grain yield of 1.9 t ha<sup>-1</sup> (Abraham, 2015; Tesfahun, 2018; Lakew and Berhanu, 2019; CSA, 2022). This is attributed to poor crop management practices, reduced uses of improved varieties (low adoption of available technologies), lodging, low soil fertility, insects, and weeds (Berhe et al., 2011; EEA, 2015; Mihretie et al., 2022).

The improved *teff varieties* that were released by the research centers every year or every other year have not been demonstrated to smallholder farmers, pre-scaled up and scaled up by research and extension to the extent the sector's development requires. Put differently, in the past, there have been limitations in reaching out or acquainting farmers with new *teff* technologies/production packages (varieties, recommended agronomic and diseases and pest control practices) in all *teff* growing potential *woredas* of the region. This is attributed to the lack of human power, vehicles, road infrastructure, and inadequate numbers of seed producers. The limitations of research and extension systems contributed to farmers' low exposure to some of the released *teff varieties* (new and old), which in turn contributed to low production and productivity of farmers.

Due to the aforementioned shortcomings, research centers, and the extension system must promote innovative *teff* varieties along with the recommended production practices via participatory research and participatory extension techniques to increase farmers' understanding, adoption, and utilization of the varieties. This is very central to increasing the uptake of *teff* varieties to boost their production and productivity. Therefore, this research activity was conducted collaboratively by Adet Agricultural Research Centre (AARC) and the Norwegian Forestry Group/Forest Landscape Restoration Program (NFG/FLRP). It was conducted in Libokemkem and Ebenat *woredas* of South Gonder zone, Amhara region in 2020 with the objectives of identifying *teff* variety selection criteria for use in future variety development, increasing farmers' awareness and their access to improved *teff* varieties, enabling farmers to assess the performance of improved *teff* varieties with their production package, and accelerating the dissemination of farmers preferred varieties in the *woredas* and other *teff* growing potential areas of the

region.

## 2. MATERIALS AND METHODS

### 2.1. Descriptions of the study areas

Participatory on-farm evaluation of improved and local *teff* varieties with recommended agronomic practices such as row planting, fertilizer application, weeding, and crop protection practices such as disease and pest surveillance was conducted in Libokemkem and Ebenat *woredas*, South Gonder Zone, Ethiopia.

Libokemekem *woreda*, which is one of the 10 *woredas* of South Gondar Zone, is bordered by Ebenat *woreda* in the North, Fogera *woreda* in the south, Gondar Zuria *woreda* in the west, and Farta *woreda* in the east. It is located at 37°15'36" E to 38°06'36" E longitude and 11°54'36" N to 12°22'48" N latitude and has an altitude of 1975 meters above sea level. Addis Zemen is the administrative center of the *woreda*. It is situated 645 km from Addis Ababa and 82 km from the regional capital, Bahir Dar. The *woreda* has 29 rural and 6 urban *Kebeles* (Eshetie, 2019). The *woreda* is 95% midland, 4.1% highland, and 0.9% lowland agroecologies. The maximum average temperature of the *woreda* is 27.9 °C and the minimum is 11.1 °C. The cropping systems are mainly dependent on meher rains (75%) with supplementary irrigation (25%) production contribution of major crops. The *woreda* is characterized by rain-fed subsistence farming of crops (maize, millet, *teff*, and sorghum), animal husbandry, and irrigated paddy rice cultivation remain the principal agricultural activities despite poor soil fertility and highly variable rainfall in most areas (Yalew et al., 2012). In the year 2023 about 7,419 ton ha<sup>-1</sup> yield was obtained from a total area of 4,750 ha with an average productivity of 1.56 ton ha<sup>-1</sup> (Libokemkem Woreda Agriculture Office, 2023)

Ebenat *woreda*, on the other hand, is one of the *woredas* of South Gondar Zone of the Amhara region with a latitude and



longitude of 12°7'N 38°3'E / 12.117°N 38.050°E. It has an elevation range from 1800-2150 meters above sea level. Its capital Ebenat is 698 km from Addis Ababa, 122 km from Bahir Dar, and 109 km from the zonal capital Debre Tabor. The *woreda* is bordered by Belesa *woreda* to the north, Farta *woreda* to the south, Bugna and Dahena *woredas* to the east, and Laigaint, and Libokemkem *woredas* to the west. Topographically, 45% of the *woreda* is mountainous, 35% hilly, 15% plain and 5% is a valley. The *woreda* encompasses three distinctive agroecological zones namely lowland, mid-altitude, and highland. Moreover, the average annual rainfall of the *woreda* is between 500-1300 mm, the average minimum temperature is 23° and the maximum is 30°C. The total land area of

the *woreda* is estimated to be about 24,942,700 hectares of which 16,978,410 ha cultivable; 3,784,600 ha is grazing area; 1,122,440 ha is covered by forest; and the remaining hectares are covered by bushes, water bodies, housing and other infrastructures (Ebenat *woreda* Agriculture office, 2013). Even though many types of crops are grown in the *woreda*, the most commonly grown ones are wheat, *teff*, barley, maize, and peas. These crops are grown as staple and cash crops in the *woreda*. Domestic animals reared include cattle, sheep, goats, chickens, and donkeys (Agegnehu, 2015). In 2023 about 16,870.5 ton ha<sup>-1</sup> yield was obtained from the total area of 11,500 ha covered by *teff* with an average productivity of 1.46 ton ha<sup>-1</sup> (Ebenat *Woreda* Agriculture Office, 2023).

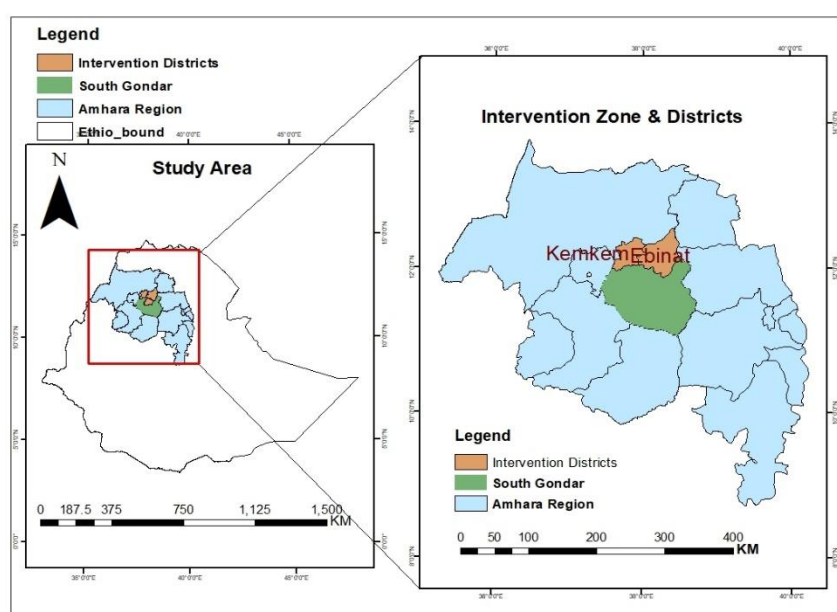


Figure 1: Map of Libokemkem and Ebenat *Woredas* (Extracted from google map)

### Selection of *woredas* and working with NFG/FLRP

The Norwegian Forestry Group/Forest Landscape Restoration Program (NFG/FLRP) as a stakeholder to ARARI works collaboratively with the institute and AARC on the demonstration and pre-scaling up of crop technologies to improve the income and livelihoods of farmers in its intervention areas as a trade-off for the natural resources conservation works

whose outcomes are very slow and are not rewarding within short periods.

The Norwegian Forestry Group/Forest Landscape Restoration Program (NFG/FLRP) is a Norwegian Government program having 6 work packages: restoration of degraded forestland scape with the participation of the local community; restoration of the degraded landscapes and protection of exclosures and development of sense ownership; granting of land ownership certificate to

enhance the willingness and the commitment of the forest land users to participate and be active actors in forest landscape restoration, to avoid conflictual situation related to land use and land ownership; restoration of the landscape at village level (green village) to make restoration interventions impact tangible and create “ model restored landscapes” that can be scaled up to larger areas through the adoption and promotion of the green village concept in some of the villages located in the degraded landscape (NFG/FLRP 2nd Phase Project Proposal Document, 2022).

As a 5th work package, NFG/FLRP deals with capacity building and training which are cross-cutting and complementary activities that are undertaken within the other work packages and designed carefully for the development and strengthening of skills and knowledge of the target community, stakeholders, and fulfilment of the required resources organizations and communities need to effectively develop, implement, and monitor program activities. Moreover, concerning the 6th work package, the program has developed the basics for a communication strategy for the goals of the program, build awareness among the target groups, and share information with the local stakeholders and partners through a continuous process of involvement, joint actions and information related to the working process, the applied approaches, the progress made, the encountered challenges and the way to settle them. The activity was accompanied by the recurrent practice of organizing informative and instructive meetings and working sessions at different levels and on different thematic about forest landscape restoration and other related subjects (NFG/FLRP 2nd Project Proposal Document, 2022).

To undertake the aforementioned activities, NFG/FLRP has created collaboration and partnership with the Bureau of Land; Amhara Cooperative Promotion Agency; REDD+ Coordination

Unit; Soil and Land Management; Ethiopian Forest Development; Land Administration and Use Bureau; Environment, Forest and Wildlife Protection and Development Authority; Bureau of Agriculture, and the Amhara Agricultural Research Institute. These institutes have been playing their roles in the realization of the objectives of the program (NFG/FLRP 2nd Project Proposal Document, 2022). ARARI, as a stakeholder to the NFG/FLRP is responsible for undertaking technology demonstration and pre-scaling up in some of the intervention woredas of the program: Quarit, Sekela, Farta, Libokemkem and Ebenat woredas. The latter two woredas were purposively selected for they are intervention woredas of the program and the resident farmers’ demand for new *teff* varieties communicated to the institute through the program. Consequently, the institute executed the research activity (PTE) in 2020 to address farmers’ technology needs and help farmers get additional income and food until they start to benefit from the fruits of natural resources conservation works, they undertook on their farm plots and/or communal lands.

### **Discussion with relevant stakeholders**

Before conducting the trial, researchers discussed with extension workers and representative farmers about the purpose of the participatory on-farm evaluation of improved *teff* varieties, the selection of trial sites, the nomination of farmers, and the establishment of Farmers Research and Extension Groups (FREGs). FREG is one of the research approaches, in which a group of farmers, extension workers, and a multidisciplinary research team jointly participate in agricultural technology generation, verification, and improvement so as to meet farmers’ needs and improve farmers’ production and management practices (Geneti et al., 2017). Given this, researchers discussed about the selection of host farmers from FREG members, the

date on which the PTE would be implemented, and the modalities of implementation.

### Signing of MOU

Following the discussion and the consensus between the researchers and the stakeholders, a memorandum of understanding (MOU) for the shared

responsibilities was signed by Adet Research Center and the *Woreda* and *Kebele* agricultural offices to accomplish the participatory on-farm evaluation of improved *teff* research undertaking (PTE of *teff*). The roles and responsibilities of different stakeholders enshrined in the MOU are indicated in Table 1.

**Table 1:** The roles and responsibilities of stakeholders in the PTE

Stakeholder	Roles and responsibilities	Joint responsibility	Separate responsibility
Adet	<ul style="list-style-type: none"> <li>Establish FREGs together with <i>Woreda</i> and <i>Kebele</i> Agricultural Offices</li> <li>Select trial sites, and host farmers together with Agricultural Offices</li> <li>Organize and provide training</li> <li>Deliver inputs (<i>teff</i> seeds and fertilizer)</li> <li>Assist in planting</li> <li>Conduct M &amp; E and Field days</li> </ul>	<ul style="list-style-type: none"> <li>X</li> <li>X</li> <li></li> <li></li> <li>X</li> <li>X</li> </ul>	<ul style="list-style-type: none"> <li></li> <li></li> <li>X</li> <li>X</li> <li></li> <li></li> </ul>
<i>Woreda</i> and <i>Kebele</i> Agriculture Offices	<ul style="list-style-type: none"> <li>Facilitate the formation of FREGs with AARC</li> <li>Assist in the selection of trial sites, and host farmers</li> <li>Mobilizing farmers for couples training</li> <li>Assist researchers in planting</li> <li>Mobilize farmers for technology evaluation</li> <li>Organize field visits, and mini-field days and encourage the attendance of resident farmers</li> <li>Organize field days with AARC and ensure the participation of farmers and extension workers</li> <li>Conduct joint M &amp; E with researchers and experts from NFG/FLR</li> <li>Sustain the production of the technology after the end of the trial</li> </ul>	<ul style="list-style-type: none"> <li>X</li> <li>X</li> <li></li> <li>X</li> <li>X</li> <li></li> <li>X</li> <li>X</li> <li>X</li> </ul>	<ul style="list-style-type: none"> <li></li> <li></li> <li>X</li> <li></li> <li></li> <li>X</li> <li></li> <li></li> <li></li> </ul>
Farmers	<ul style="list-style-type: none"> <li>Provide land (free of charge) and labor</li> <li>Planting and weed the trial</li> <li>Apply urea top dressing</li> <li>Guard the trial from livestock damage</li> <li>Make diversion canals when there are heavy rains</li> </ul>	<ul style="list-style-type: none"> <li></li> <li></li> <li></li> <li></li> <li></li> </ul>	<ul style="list-style-type: none"> <li>X</li> <li>X</li> <li>X</li> <li>X</li> <li>X</li> </ul>

Stakeholder	Roles and responsibilities	Joint responsibility	Separate responsibility
	<ul style="list-style-type: none"> <li>• Duty to participate in the planning of successive activities (agronomic and crop protection)</li> </ul>		X
	<ul style="list-style-type: none"> <li>• Contribute to the evaluation and selection of the <i>teff</i> technologies, and</li> </ul>		X
	<ul style="list-style-type: none"> <li>• Take part in the field visits and field days</li> </ul>		X
	<ul style="list-style-type: none"> <li>• Sustain the production of the technology after the end of the trial</li> </ul>		X

### **FREG establishment, trial sites, and host farmers' selection**

After the formation of FREG, the trial site, and host farmers' selection, couples training was given to FREG members, *kebele* administrators, and extension workers in the towns of Addis Zemene and Ebenat. Couples training was adopted as a training approach where both husbands and wives receive training together for collective household decisions and actions (Lemma et al., 2017). It was given to 37 farmers (22 male and 15 female) and 12 extension workers (9 male and 3 female) in Addis Zemen, while it was provided to 43 farmers (25 male and 18 female) and 11 extension workers (8 male and 3 female) in Ebenat. The training was given by a multidisciplinary team of researchers comprising breeders, pathologists, agronomists, and agricultural research extensionists. The training focused on *teff* planting, agronomic practices, integrated disease and pest control/management, post-harvest management, food processing, and seed dissemination mechanisms.

Couples' trainings were given considering gender equity. This is because agricultural experts of both researchers and extension workers primarily offer advice and training services to male members of the household with the understanding that these individuals will then pass the information on to their spouses or other female household members. In actuality, agricultural knowledge and information

are inefficiently transferred from husbands to wives and other female members of households. This necessitates the adoption of couples training that helps women exchange information more effectively both inside the household and with neighbors; it is imperative that couples training be implemented to promote information absorption, collective household decisions, training application, and family labor mobilization. On the other hand, for ease of communication among members; carrying out M & E, and technology evaluation; participation in field visits and field days, and taking minutes of discussions of FREG members, members were allowed to elect their chairperson and secretary. This was realized after the training of the farmers and extension workers.

### **Provision of couples training and delegation of committee**

Single plot observation (farmers' as a replication) was used and the size of the on-farm evaluation plot was 10 m by 10 m (100 m<sup>2</sup>) for each variety. The spacing between plots and rows was 1 m and 20 cm respectively. The seed rate was 10 kg ha<sup>-1</sup> and planting was done in rows by drilling. Fertilizer rates of 158 kg ha<sup>-1</sup> NPS and 66 kg ha<sup>-1</sup> on red soil while 158 kg ha<sup>-1</sup> NPS and 130 kg ha<sup>-1</sup> Urea were used on black soil. All NPS and 1/3 of Urea were applied at planting while 2/3 of the urea was used at tillering stage or first weeding. Hand weeding was done three times with the contribution of labor from the host

farmers. A total of two improved *teff* varieties namely *Etsub*, and *Hiber-1*, and a local check *Tsedey/ CR-37* (it is an old improved variety but considered a local variety for it is currently used by most farmers) were used in all research sites or locations.

#### **Planting and other agronomic practices**

Single plot observation (farmers' as a replication) was used and the size of the on-farm evaluation plot was 10 m by 10 m (100 m<sup>2</sup>) for each variety. The spacing between plots and rows was 1 m and 20 cm respectively. The seed rate was 10 kg ha<sup>-1</sup> and planting was done in rows by drilling. Fertilizer rates of 158 kg ha<sup>-1</sup> NPS and 66 kg ha<sup>-1</sup> on red soil while 158 kg ha<sup>-1</sup> NPS and 130 kg ha<sup>-1</sup> Urea were used on black soil. All NPS and 1/3 of Urea were applied at planting while 2/3 of the urea was used at tillering stage or first weeding. Hand weeding was done three times with the contribution of labor from the host farmers. A total of two improved *teff* varieties namely *Etsub*, and *Hiber-1*, and a local check *Tsedey/ CR-37* (it is an old improved variety but considered a local variety for it is currently used by most farmers) were used in all research sites or locations.

#### **Monitoring and evaluation (M & E)**

The team of researchers from Adet Agricultural Research Center and the Amhara Agricultural Research Institute, agricultural extension workers from the *woreda* and *kebele* agricultural development offices, focal persons from NFG/FLRP, and the host farmers jointly monitored and evaluated the trial plots. Successive joint M & Es (follow-up actions) were conducted by the joint monitoring and evaluation team at different growth stages of the crop, where technical advice to host farmers was provided based on emerging knowledge and skills. During the M & E, having a look at the evaluation trial and assessing the constraints encountered, the team was able to suggest corrective measures and confirm the implementation of agronomic

practices such as weeding, urea top-dressing, and disease and pest control, if any.

#### **Setting evaluation and selection criteria**

To evaluate and select *teff* varieties at their maturity stage using their own accumulated experiences, FREG members set their own criteria such as adaptability (earliness of maturity), plant height, panicle length, lodging resistance, and tillering capacity for comparison of *teff* varieties. Adaptability, which is defined as the ability of a crop (or variety) to respond positively to changes in agricultural conditions, is a genetically controlled trait that provides an ability to exploit environmental attributes, both natural and agronomic (Chloupek and Hrstkova, 2005).

Plant height, which affects lodging resistance, total biomass yield, as well as mechanical harvesting is defined as a vertical distance measured by the researcher (s) in cm from the base of the stem of the main tiller to the tip of the panicle at maturity (Tasew et al., 2024). Panicle length (cm), which is one of the yield determinant traits of cereals, is measured from the distance between the node where the initial panicle emerges and the tip of the main panicle when it reaches maturity (Fenta, 2018). As defined by Reda et al. (2018) lodging resistance is the resistance to permanent displacement of cereal stems from their vertical position which usually occurs after the ear or panicle has emerged. It is one of the most important factors connected with straw stiffness and plant height determining the productivity of cereals. Similarly, Krishnan et al. (2011) defined tillers as branches that develop from the leaf axils at each unelongated node of the main shoot or other tillers during vegetative growth, growing independently using their own adventitious roots.

The above-mentioned evaluation and selection criteria were ranked and prioritized in order of importance by using the pair-wise ranking method. The

varieties were evaluated considering each criterion by direct scoring methods (1= the best) and scores given to each variety concerning each criterion were finally added together and then ranked in ascending order in each *kebele* (the lowest sum gives the best score). The sum of the preference value (score x weight) of each variety across all criteria was used to determine the final acceptability rank among the varieties in each of the locations.

Moreover, days to physiological maturity (days) were calculated by the researcher (s) taking the number of days from the time the first seedlings emerged until 90% of the plants in the plot reached the stage of maturity. Physiological maturity is the occurrence of maximum seed dry weight and represents the end of dry weight accumulation and seed filling period. It has been widely adopted as an important growth stage and used by researchers and producers because it represents the end of active plant growth and the production of yield (Malarkodi and Srimathi, 2007). Total dry biomass ( $\text{t ha}^{-1}$ ) and grain yield are agronomic traits that were similarly measured by the researcher (s) weighing all *teff* biomass from six central rows of each plot area after sun drying for 2 or 3 days and weighing the threshed grains from six central rows of each plot and converting the result in tons per hectare after adjusting the grain moisture content to 12.5% respectively (Tasew et al., 2024). Total dry biomass yield can be put differently as the whole plant part which includes leaves, stems, and seeds harvested above the ground from the whole plot at maturity (Assefa, 2018). While seed coat color which is one of the agronomic traits was considered in the evaluation of the *teff* technologies. It is defined as the grain color which is considered as the dominant parameter in the trading and price setting on the local markets. It is usually used as an indicator of grain quality and thereby affects the consumers' preference and market price (Abewa et al., 2021).

### **Field visits, field days and mini-field days**

To acquaint farmers with *teff* technologies, solicit ideas from farmers and stakeholders, and utilize them for the upcoming technology promotion and popularization endeavors, field visits, mini field days, and field days were held in the two woredas. Field visits were arranged for FREG members and other resident farmers collaboratively by Kebele Agricultural Offices and committees to enhance the awareness of farmers about the *teff* technologies and bolster knowledge and experience sharing among them. Field visits are important extension methods for creating wider awareness and facilitating farmer-to-farmer information/experience sharing. Field visits were held 3 times (at emergence, in the middle, and at the maturity stages of the crop) in a production season to create an opportunity for the host and other FREG members to learn from each other.

Furthermore, to collect ideas and opinions of farmers and stakeholders on the performances of the *teff* varieties, and to discuss the seed system and dissemination, the linkage and synergy among the stakeholders, and wider scaling up of the recommended production package, field days were organized by Adet Agricultural Research Center in cooperation with Woreda Agriculture Offices. Field days are important extension methods for creating wider awareness and facilitating farmer-to-farmer information sharing (Geneti et al., 2017). In addition, after the main field days, mini-field days were also organized by the Kebele Agricultural Development Offices to facilitate wider knowledge and technology sharing among *kebele* inhabitants. They were organized to create opportunities for those farmers who were not able to attend field visits and the main field day for their own reason (s).

### **Data collection and analysis**

Data on agronomic traits such as days to

90% physiological maturity, adaptability, panicle length, lodging resistance, tillering capacity, plant height, grain yield, dry biomass yield, and seed coat color were taken at different stages of the crop to determine which *teff* variety has desirable trait (s) and is the highest yielder. Quantitative yield data were collected after harvesting and threshing of the crops, and a participatory approach was adopted to capture farmers' preferences for the improved *teff* varieties tested in PTE. Moreover, qualitative data (feedback or perception) from farmers and extension workers were gathered during M & E, field visits, mini field days, and field days. Furthermore, to ascertain the matchness between farmers' preference rank and the actual rank of grain yield Spearman's rank correlation analysis was employed.

The agronomic traits collected were compared with farmers' evaluation results. The quantitative data were analyzed using simple descriptive statistics such as mean, maximum, and minimum while cost-benefit analysis was used to analyze data such as costs of labor, fertilizer, and seed as well as benefits from grain and straw yields. The qualitative data were described or narrated qualitatively; farmers' preferences were analyzed using the pairwise ranking method based on their own evaluation and selection criteria. Farmers ranked these criteria in order of importance. Hence, based on each criterion, the varieties were selected by direct scoring methods (1= the best, 4 = the poorest) and the scores given to each variety were added together and then ranked in ascending order (the lowest sum gives the best score). The sum of the preference value (score x weight) of each of the varieties in all criteria were used to determine the final acceptability rank of the varieties in each location. In addition, spearman's correlation analysis was used to analyse how the farmers' preference rank coincided with the actual rank of grain yield.

Spearman's rank correlation coefficient  $r_s$

is defined as follows

$$r_s = 1 - \frac{6 \sum d^2}{n(n^2 - 1)}$$

Where N - denotes the number of individuals or phenomena ranked (number of varieties in this case); d - denotes the difference in the ranks assigned to the same individual or phenomenon (actual yield rank minus farmers preference rank). On the other hand, gender-disaggregated data were taken on couples training, organized field visits, mini field days, and field days so as to rectify the flaws and propose the development of a strategy for the upcoming pre-scaling-up endeavours. In addition to this, issues that were raised and discussed during the field days about the roles of the stakeholders in the upcoming technology pre-scaling up were recorded.

### 3. RESULTS AND DISCUSSION

#### 3.1. Agronomic traits

The calculated results of days to maturity revealed that the earliest days to physiological maturity (95 - 98 days) were recorded from the local check (Tsedey/Cr-37) in the two woredas while the latest days to physiological maturity (110 - 114.5 days) were recorded from Etsub *teff* variety in Ebenat and Libokemkem woredas. Generally, in Libokemkem and Ebenat woredas Tsedey/Cr-37 matured earlier than both Hiber-1 and Etsub varieties. However, farmers in Libokemkem and Ebenat woredas selected Hiber-1 and Etsub, respectively having a look at their panicle length, lodging resistance, tillering capacity/tiller numbers, and plant height which are yield determinant factors. Moreover, the difference in 90% physiological maturity between the local check and the other two improved varieties is not very considerable (Tables 2 and 3).

From Tables 2 and 3, it can be seen that *Etsub* is taller than that of *Hibre-1* and Cr-37 *teff* varieties with an average height of 105.9 and 110.4 cm in Libokemkem and

Ebenat *woredas*, respectively. Farmers who observed the varieties visually without measuring them with meter tape have selected *Etsub* to be the tallest *teff* variety in the two locations and this corroborates the results of the plant height analysis of the researchers. Since row planting was used as one package of the PTE, the *teff* plants are assumed to have grown tall because of less nutrient competition compared to broadcasting where there is competition among individual plants.

The panicle lengths measured by the researchers indicated that *Hiber-1* and *Etsub* recorded the longest panicle lengths 42.1 cm and 38.6 cm in Libokemkem and Ebenat *woredas*, respectively. Conversely, the shortest panicle lengths recorded from *Tsedey*/Cr-37 on the control plot in Libokemkem were 32.7 cm, and in Ebenat *woreda* they were 34.2 cm. By having a look at the panicles of the varieties FREG members have confirmed that *Hiber-1* and *Etsub* are the varieties with the longest panicle lengths; this is in agreement with the data taken by researchers in the research domains (Tables 2 and 3). As it can be understood from Tables 2 and 3, the highest lodging resistance indexes 95% and 90% were recorded from *Hiber-1* variety in Libokemkem and Ebenat *woredas*, respectively. On the contrary, the lowest lodging indexes (70 and 75%) were recorded from the local check or the control plot in Libokemkem and Ebenat

*woredas*. The result matched with the farmers' evaluation that *Hiber-1* has the highest lodging resistance.

On the other hand, the highest dry biomass yield (tone ha<sup>-1</sup>) was recorded from *Hiber-1* (8.5 ton ha<sup>-1</sup>) in Libokemkem while in Ebenat the highest grain and straw yields (6.4 ton ha<sup>-1</sup>) were obtained from *Etsub* variety. With respect to grain yield, *Hiber-1* gave the highest grain yield of 1.73 tone ha<sup>-1</sup> in Libokemkem while 1.6 ton ha<sup>-1</sup> was obtained from *Etsub* in Ebenat *woreda* outshining the local check/*Tsedey*/Cr-37. Concerning tillering capacity, the highest tillers 13 and 12 were obtained from *Etsub* in Libokemkem and Ebenat *woredas* respectively, while the lowest tiller numbers 7 in Libokemkem and 8 in Ebenat *woredas* were obtained from *Tsedey teff* (Tables 2 and 3).

Seed coat colour was evaluated after threshing, consequently, the two introduced new varieties were found to be white. Thus, the white colour observed after the threshing of the varieties exactly matched the farmers' prior anticipation with which they were very happy at last. Moreover, the varieties that were also visually assessed and evaluated by farmers (according to tradition) were found to be shiny (soft/malleable/*wozam*), hence they can be a good source of income for the resident farmers if they are scaled up at a wider scale.

**Table 2:** Agronomic traits and yield performance of *teff* varieties in Libokemkem *woreda*

Traits							
Variety	90% days to physiological maturity	Plant height (cm)	No. of tillers per plant	Panicle length (cm)	Lodging resistance (%)	Dry biomass yield (ton ha <sup>-1</sup> )	Grain yield (t ha <sup>-1</sup> )
<i>Etsub</i>	114.5	105.9	13	35.2	85	5.2	1.37
<i>Hiber-1</i>	102	103.67	12	42.1	95	8.5	1.73
<i>Tsedey</i>	95	85.6	7	32.7	70	7.5	1.5

**Table 3:** Agronomic traits and yield performance of *teff* varieties in Ebenat

Traits							
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Variety	90% days to physiological maturity	Plant height (cm)	No. tillers/plant	Panicle length (cm)	Lodging resistance (%)	Dry biomass yield (t ha <sup>-1</sup> )	Grain yield (t ha <sup>-1</sup> )
<i>Etsub</i>	110.4	110.4	12	38.6	80	6.4	1.6
<i>Tsedey</i>	98	92.3	8	34.2	75	5.2	1.4
<i>Hiber-1</i>	105	105.2	10	38.1	90	5.5	1.26

Farmers of Libokemkem *woreda*, who were given the chance to evaluate the *teff* varieties based on their visual judgments or having a look at the varieties' phenotypic appearances, have selected *Hiber-1* to be the best of all other varieties (improved and local) considering many of the agronomic characteristics. By the same token, FREG members in Ebenat *woreda* who were allowed to compare the varieties based on their experiences have selected *Etsub* which outshines *Hiber-1* and *Tsedey* *teff* varieties in terms of agronomic traits. Therefore, considering all the agronomic parameters mentioned herein before, farmers have suggested *Hiber-1* in

Libokemkem *woreda* and *Etsub* in Ebenat *woreda* to be scaled up at a wider scale since they are *teff* varieties with the highest yield (Tables 2 and 3).

#### Preference Ranking

FREG members (farmers) evaluated and selected *teff* varieties with the help of researchers and extension workers. Thus, the pair-wise ranking revealed that adaptability surpasses other evaluation and selection criteria followed by panicle length. Likewise, farmers selected lodging resistance as 3<sup>rd</sup>, tillering capacity as 4<sup>th</sup>, and plant height as 5<sup>th</sup> important criteria for the selection of the three different *teff* varieties (Table 4).

**Table 4:** Pairwise ranking of the varieties in Libokemkem *Woreda*

Traits	Traits					Rank
	Tillering capacity	Panicle /length	Adaptability	Plant height	Lodging resistance	
Tillering capacity	X	Panicle length	Adaptability	Tillering capacity	Lodging resistance	4 <sup>th</sup>
Panicle length		X	Adaptability	Panicle length	Panicle length	2 <sup>nd</sup>
Adaptability			X	Adaptability/earliness	Adaptability/earliness	1 <sup>st</sup>
Plant height				X	Lodging resistance	5 <sup>th</sup>
Lodging resistance					X	3 <sup>rd</sup>

As can be seen from Table 5, farmers' variety preference was assessed using the pair-wise ranking method. As a result, FREG members have selected *Hiber-1*, 1<sup>st</sup> in its adaptability, panicle length, lodging resistance, tillering capacity, and plant

height. They have selected Cr-37 (*Tsedey*) 2<sup>nd</sup> next to *Hiber-1*. *Hiber-1* has exceeded Cr-37 and *Etsub* *teff* varieties in all evaluation and selection criteria and has stood first.

**Table 5:** Farmers ranking of *teff* varieties in Libokemkem *woreda*

The scores of varieties							
Varieties	Adaptability	Panicle length	Lodging resistance	Tillering capacity	Plant height	Total score	Rank
Cr-37	32	26	32	36	32	158	2
<i>Hiber-1</i>	15	20	15	14	19	83	1
<i>Esub</i>	38	38	36	34	32	178	3

Note: Higher scores mean lower in rank and vice versa.

Before harvesting, farmers have not doubted selecting *Hiber-1* first considering all the evaluation and selection criteria incorporated in Table 4. Their evaluation and selection had perfectly matched after harvesting in such a way that *Hiber-1* gave

a yield ( $1.73 \text{ t ha}^{-1}$ ) that exceeded the yield of *Esub* (improved variety) and Cr-37 (local check) as indicated in Figure 2. It has given a yield advantage of 15.3% over the local check.

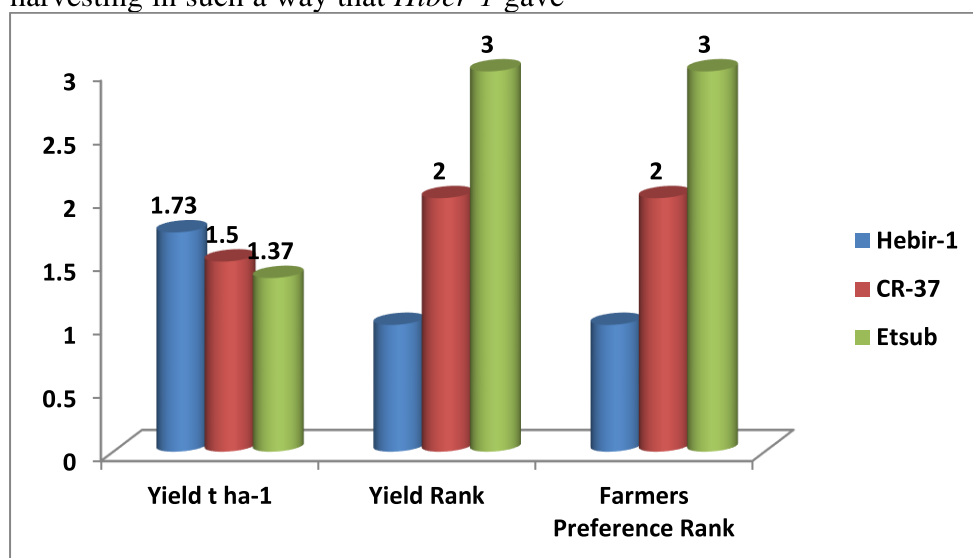


Figure 2: Mean grain yield ( $\text{t ha}^{-1}$ ), yield rank, and farmers' preference rank

Note: Higher scores mean lower rank and vice versa.

Similarly, in Ebenat *woreda* FREG members who have set evaluation and selection criteria as indicated in Table 6, selected adaptability 1<sup>st</sup> as it outshined other evaluation and selection criteria followed by tillering capacity. Likewise,

farmers selected panicle length as 3<sup>rd</sup>, lodging resistance as 4<sup>th</sup>, and plant height as 5<sup>th</sup> important criterion for the evaluation and selection of the three *teff* varieties.

**Table 6:** Pair-wise ranking of *teff* varieties in Ebenat *woreda*

Traits	Plant height	Panicle length	Lodging resistance	Adaptability	Tillering capacity	Rank
Plant height	X	Panicle length	Lodging resistance	Adaptability	Tillering capacity	5 <sup>th</sup>
Panicle length		X	Panicle length	Adaptability	Tillering capacity	3 <sup>rd</sup>
Lodging resistance			X	Adaptability	Tillering	4 <sup>th</sup>

					capacity	
Adaptability/ Earliness				X	Adaptability/earliness	1 <sup>st</sup>
Tillering capacity					X	2 <sup>nd</sup>

**Table 7:** Ranking of *teff* varieties in Ebenat *woreda*

Varieties	Score of traits						Rank
	Adaptability	Lodging resistance	Panicle length	Tillering capacity	Plant height	Total score	
<i>Hiber-1</i>	27	33	27	29	29	145	3
<i>Cr-37</i>	20	14	27	22	25	108	2
<i>Etsub</i>	21	19	14	17	18	89	1

Note: Higher scores mean lower rank and vice versa.

From Table 7, it can be understood that farmers in Ebenat *woreda* have selected *Etsub* 1<sup>st</sup> for its panicle length, tillering capacity, and plant height. They have selected the local check 2<sup>nd</sup> next to *Etsub* for its adaptability and lodging resistance. *Etsub* which is the newly introduced *teff* variety in the intervention *woreda* has outshined *Cr-37* and *Hiber-1* *teff* varieties by 3 evaluation and selection criteria and has stood first.



Figure 3: Evaluation and selection of *teff* technologies by farmers

From Figure 4, it can be read that the mean grain yield of *Etsub*, *Cr-37*, and *Hiber-1* is 1.6, 1.4, and 1.26 t ha<sup>-1</sup>, respectively. Before harvesting, farmers did not hesitate about selecting *Etsub* 1<sup>st</sup> considering all the evaluation and selection criteria incorporated in Table 6. Their selection perfectly coincided with the result after threshing in such a way that *Etsub* gave a yield that surpassed the yield of the other two (*Cr-37* and *Hiber-1*) improved *teff* technologies. It has given a yield advantage of 14.3% over the local check (*CR-37* variety) in Ebenat.

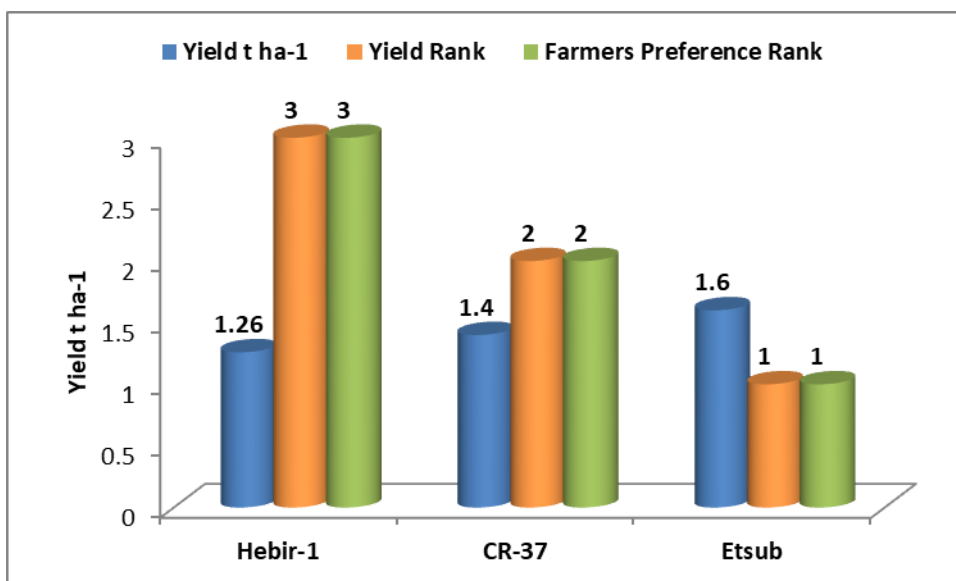


Figure 4: Mean grain yield (t ha<sup>-1</sup>), yield rank, and farmers' preference rank in Ebenat  
Note: Higher scores mean lower rank and vice versa.

#### Farmers' preference versus actual yield comparison

Spearman's rank correlation coefficient, "rs" was used to see the degree of coincidence between farmers' preference ranks and the actual grain yield rank of each treatment and then expressed in percentages (Ferdous et al., 2016), as shown below in Table 8.

**Table 8:** Farmers' preference value and actual yield comparison of teff varieties

No	Varieties	Libokemkem			Ebenat		
		Preferred values	Actual yield	D 2	Preferred values	Actual yield	D 2
1	<i>Etsub</i>	3	3	(1-1) <sup>2</sup>	1	1	(1-1) <sup>2</sup>
2	<i>Hiber-1</i>	1	1	(2-2) <sup>2</sup>	3	3	(2-2) <sup>2</sup>
3	<i>Tsedey</i>	2	2	(3-3) <sup>2</sup>	2	2	(3-3) <sup>2</sup>

Spearman's rank correlation coefficient for both locations, Rs = 1(100%)

$$\sum D^2 = (1-1)^2 + (2-2)^2 + (3-3)^2 + (4-4)^2 = 0; R_s = 1 - \frac{6 \sum D^2}{N(N^2 - 1)} = 1 - \frac{6 \times 0}{3(3^2 - 1)} = 1 - 0 = 1$$

The correlation coefficient, "rs" result, i.e., 100%, showed the degree of coincidence (matchness) between farmers' preference rank and the actual yield obtained in both locations.

#### Cost benefit analysis

The benefits of the varieties were very high with a Marginal Net Benefit (MNB) of 3.57 for *Hiber-1*. Similarly, the MNB for Cr-37 variety was 2.90 while for Etsub the MNB was 2.60. Therefore, as the actual yields have exactly coincided with farmers' preferences, it is worthwhile to continue with their production, especially with *Hiber-1*, and make sure that farm households have access to food and nourishment (Table 9).

**Table 9:** Cost-benefit analysis of *teff* varieties in Libokemkem woreda

	<i>Etsub</i>	<i>Cr-37</i>	<i>Hiber-1</i>
Mean GY (t ha <sup>-1</sup> )	1.37	1.50	1.73
Adj. yield (t ha <sup>-1</sup> ) by 10%	1.23	1.35	1.55
Straw yield (Cart)	8	7	10
Gross Field Benefit (ETB ha <sup>-1</sup> )	49320	54000	62000
Straw yield benefit (ETB)	8000	7000	10000
Total Field benefit (ETB)	57320	61000	72000
Labor cost (ETB ha <sup>-1</sup> )	6000	6000	6000
Seed cost (ETB ha <sup>-1</sup> )	750	750	750
Fertilizer cost	9000	9000	9000
TC (ETB ha <sup>-1</sup> )	15750	15750	15750
NB (ETB/ha)	41570	45250	56250
MNB (ETB ha <sup>-1</sup> )	2.60	2.90	3.57

Note: Average price of fertilizer in ETB/Kg = 30; Cost of improved seed in ETB/Kg = 50; Selling price of improved seed in ETB/Kg = 33.75; Cost of labor in mandays = 150

As shown in Table 10 here below, the benefits of the varieties in Ebenat woreda were very high with a marginal net benefit (MNB) of 4.12 for *Etsub*, 3.79 for *Cr-37*, and 3.00 for *Hiber-1*. Therefore, it is advisable to continue with the production of *Etsub* with precedence and with *CR-37 teff* variety as an option to ensure the income, food, and nutrition security of the community.

**Table 10:** Cost-benefit analysis of *teff* varieties in Ebenat woreda

	<i>Etsub</i>	<i>Cr-37</i>	<i>Hiber-1</i>
Mean GY (t ha <sup>-1</sup> )	1.6	1.4	1.26
Adj. yield (t ha <sup>-1</sup> )	1.44	1.26	1.13
Straw yield (Cart)	10	7	9
Gross Field Benefit (ETB ha <sup>-1</sup> )	54000	52920	41600
Straw yield benefit (ETB ha <sup>-1</sup> )	10000	7000	9000
Total Field benefit (ETB ha <sup>-1</sup> )	64000	59920	50600
Labor cost (ETB ha <sup>-1</sup> )	6000	6000	6000
Seed cost (ETB ha <sup>-1</sup> )	500	500	500
Fertilizer cost ETB	6000	6000	6000
TC (ETB ha <sup>-1</sup> )	12500	12500	12500
NB (ETB ha <sup>-1</sup> )	51500	47420	38100
MNB (ETB ha <sup>-1</sup> )	4.12	3.79	3.0

Note: Average cost of fertilizer in ETB/Kg = 30; cost of improved seed in ETB/Kg = 50 and selling price of improved seed in ETB/Kg = 33.75

*Etsub* was found to be the tallest of *Hibre-1* and *Cr-37 teff* varieties in Libokemkem and Ebenat woredas. Its tallness is in agreement with farmers' visual observation which corroborates the results of the plant height analysis of the researchers. All three varieties have grown tall because of row planting which contributed to less nutrient competition compared to the local practice

(broadcasting) where there is competition among individual plants. This is in agreement with Wato (2019) who reported that *teff* plant height increased with increasing row spacing due to less nutrient competition.

The highest dry biomass yield (t ha<sup>-1</sup>) was obtained from *Hiber-1* in Libokemkem while in Ebenat the highest grain and straw yields were recorded from *Etsub teff*

variety. In both *woredas* the improved varieties outshined the local check *Tsedey*/Cr-37 in terms of dry biomass yield. Likewise, the highest tillers 13 and 12 were obtained from *Etsub* in Libokemkem and Ebenat *woredas*, respectively, while the lowest tiller numbers 7 in Libokemkem and 8 in Ebenat *woredas* were obtained from the local check (Tables 2 and 3). This is attributed to the genetic difference as reported by Garba et al. (2013), where varietal characteristics are of major significance in the tillering ability of crops. In the PTE the improved and the local varieties had the same access to space, nutrients, water, and light and the difference in the tillering capacity was not caused by different environments/management.

The white seed coat color of the varieties which was observed after threshing harmonized with the farmers' prior speculation and happiness. The white color of the varieties corroborates the reports of Dagnaw (2018) and Hassen et al. (2018) which confirm that white *teff* is the most expensive, provides the highest price, and is consumed by the wealthiest individuals whereas brown *teff* is sold at a lower price to low-income communities. The varieties that were also visually assessed and evaluated by farmers (according to tradition) were found to be soft/malleable/*wozam*), hence they can be a good source of income and a better food choice for the resident farmers. *Hiber-1* and *Etsub* varieties could either be consumed especially during holidays or could be sold at a higher price than other crops and be a source of income, feed for livestock in the *woredas* if they are scaled up at a wider scale.

Among the varieties tested in Libokemkem *Woreda* in PTE, *Hiber-1*, and *Tsedey*/Cr-37 were found to be productive compared to *Etsub*, while in Ebenat *Woreda* *Etsub* and *Tsedey*/Cr-37 were productive compared to *Hiber-1*. Although the three *teff* varieties are white in color and are

productive, *Hiber-1* and *Tsedey* which were very adaptable and high-yielding varieties are recommended for wider production in Libokemkem *woreda* while *Etsub* and *Tsedey* are recommended for Ebenat *woreda*. In both *woredas*, the local check (Cr-37) has stood 2<sup>nd</sup> because it has adapted to the *woredas* well for it was released for drought-prone areas or areas that do not get adequate amounts of rain. Besides, the local check has fetched a better marginal net benefit (2.9 in Libokemkem and 3.79 in Ebenat) than *Etsub* and *Hiber-1* which stood 3<sup>rd</sup> in Libokemkem and Ebenat *woredas*, respectively.

The high straw yield from the two improved varieties which is linked to the high dry biomass yield is also a good source of feed for livestock in the two *woredas* where feed is scarce. Besides, the high straw yield could be used as a construction material as well as a source of income. This conforms with the study results of Gebrehiwot et al. (1989) who pointed out that *teff* straw is the basal diet of all classes of ruminants in Ethiopia, where it is considered a nutritious fodder comparable to good natural pasture and much preferred to the straw of other cereals, particularly during the dry season. Moreover, it complies with Bageru and Srivastava (2017) who reported that *teff* straw prices are higher than those of other cereal straws and it is traditionally used for feeding animals, and mud mix for houses.

In Libokemkem *woreda*, where three times field visits and twice mini field days were organized and conducted by the *Kebele* agricultural development office, over 120 (85 men and 35 women) and 86 farmers (66 male and 20 female) respectively participated, while a field day was organized once in collaboration with Adet Agricultural Research Center where over 59 farmers (42 male and 17 female), 17 *woreda* and *kebele* extension workers (11 male and 6 females) and 6 researchers (5 male and 1 female) participated. Likewise,

in Ebenat *woreda* field visits were held three times where 115 farmers (95 men and 20 women) participated and a mini field day was organized once by the *Kebele* agricultural development office where 40 participants participated of which 15 were females. Moreover, on the main field day organized collaboratively by Adet Agricultural Research Center and *woreda* Agricultural Office 50 farmers (40 men and 10 women), 15 *woreda* and *kebele* extension workers (10 men and 5 women), and 6 researchers (5 men and 1 woman) have participated. Other than the mini and the main field days, field visits have been conducted throughout the production season by *kebele* agricultural offices and the committees in the two *woredas*.

Despite the lower participation of women (bringing drastic change within a short while is inconceivable where patriarchy (Patriarchy is a social system in which positions of dominance and privilege are held by men Wikipedia The Free Encyclopedia) and cultural norms are prevalent) as shown here above, couples training where women farmers had the chance to be trained with their male counterparts has enabled them to have the understanding on *teff* production, to be inspired and play their part in the implementation of the trial, comparison of varieties based on agronomic traits, participation in preference (pairwise) ranking, evaluation and selection of varieties based on their merits and learning and gaining experiences from other FREG members through involvement in the field visits, field and mini-field days.

At the scene of the field days, FREG members and extension workers in Libokemkem confirmed unanimously that *Hiber-1* is the highest-yielding variety, while in Ebenat *woreda* *Etsub* was selected for it surpassed the other two *teff* varieties in terms of production and productivity. FREG members, in Libokemkem, pleased by the demonstrated *teff* varieties said:

*We have been using Tsedey for a long time and its yield has been declining year after year. Research has saved us from loss by bringing Hiber-1 to our area which is not only productive in grain yield but also in straw yield.*

Similarly, farmers in Ebenat pointed out: *“We are very happy to see Etsub variety, as its name implies it is indeed Etsub. Its grain and straw yields are better than the Tsedey variety. Moreover, its white color, softness, and malleability (woze) will help us get a better selling price.”*

Extension workers both in Libokemkem and Ebenat *woredas*, who have been very supportive in every stage of the trial from FREG establishment, trial site, and host farmers selection, execution of the PTE to field day organization confirmed:

*The two teff varieties Hiber-1 and Etsub have adopted the woredas, which are characterized as drought-prone woredas, and gave yields that surpassed Cr-37. Therefore, we are very happy to see the happiness of farmers and to work with research in the next up-scaling endeavors.*

In addition, farmers who participated in the field days but were not part of FREG expressed a desire for the variety. Regarding the upcoming pre-scaling-up activity, they pledged to participate fully if given the opportunity. In other words, they have expressed their readiness and willingness to collaborate with research and extension.

At the winding up discussions of the field days, farmers have asserted their interest in continuing with the production of the *teff* varieties so long as the respective government organs could provide them with certified seed and/or Quality Declared Seed (QDS). Quality declared seed (QDS) is an alternative system for seed quality assurance, developed for countries with limited resources. It is less demanding and less expensive than full seed certification systems yet promote a satisfactory level of seed quality (Mbatia, 2022). During the field day, ARARI, Adet Research Center,

NFG/FLRP, and agriculture offices of the *woredas* and the *kebeles* have promised to put their utmost effort into the next *teff* up-scaling activities. Moreover, the linkage among stakeholders (such as BoA and NFG/FLRP) was highly appreciated as it was a cause for the success of the trial. According to field day participants, the collaboration among the stakeholders has been found exemplary as it helped to bring human, material, and financial resources together, to share experiences, work with synergy, and make farmers aware of the varieties. Finally, the need for the production of seeds of the selected *teff* varieties, their wider scaling-ups, the importance of bringing other technologies to the *woredas*, and working with research centers were underscored to improve the income and livelihoods of farmers in the *woredas*.

#### 4. CONCLUSION AND RECOMMENDATION

This participatory technology evaluation research activity was conducted in Libokemkem and Ebenat *woredas* of South Gondar Zone of the Amhara region, Ethiopia with the objectives of identifying farmers' *teff* variety selection criteria for use in future variety development, increasing farmers' awareness and their access to improved *teff* varieties that suit them better, enabling them to assess the performance of improved *teff* varieties with their production package, and thereby accelerate the dissemination of farmers preferred varieties in the *woredas* and other *teff* growing potential areas of the region through different seed exchange mechanisms. Among the *teff* varieties evaluated in Libokemkem *woreda*, Hiber-1 (1.73 ton ha<sup>-1</sup>) and *Tsedey/Cr-37* (1.50 ton ha<sup>-1</sup>) were found to be more productive compared to *Etsub* (1.37 ton ha<sup>-1</sup>), while in Ebenat *woreda* *Etsub* (1.6 ton ha<sup>-1</sup>) and *Tsedey/Cr-37* (1.40 ton ha<sup>-1</sup>) were found to be productive compared to *Hiber-1* (1.26 ton ha<sup>-1</sup>). These results are exactly in

agreement with farmers' preference ranking. In addition, as the production costs and selling prices of all three varieties are equal, their economic benefits in terms of MNB differed with their respective productivity. Farmers' engagement in FREG and PTE activity from its inception to its conclusion has familiarized them with the *teff* varieties and has enabled them to assess the performances of improved *teff* varieties with their production package, and select variety(ies) that suit them better. Farmers' main *teff* variety evaluation criteria were found to be adaptability/earliness in maturity, tillering capacity, panicle length, lodging resistance, and plant height. Knowing these evaluation criteria of farmers is so crucial for the future variety development. Participating farmers and other key stakeholders in the whole process of PTE is very vital to accelerate the dissemination of farmers' preferred *teff* varieties in the farming communities as each of the stakeholders has its/his/her roles to play. Signing MOU with stakeholders on the roles and responsibilities of each actor has paramount importance for the successful implementation of PTE and for the intended wider upscaling of preferred *teff* technologies in South Gondar Zone, and in the Amhara region at large. The collaborative work has strengthened the linkage among the stakeholders in particular that of research-extension-farmers linkage in the intervention *woredas* of the NFG/FLRP. Moreover, participating women in the PTE has also provided them with the opportunity to evaluate *teff* varieties and share ideas with other FREG members and event participants. Of the total participants of FREG, couples training, field visits, mini-field days, and main field days, 26.5% of them were women. However, it is below what has been planned by ARARI (30%) over the past 15 years, and the target set by the Amhara Bureau of Agriculture to raise their participation in participatory



extension services (GTP II: 50% and 100% of the total extension service beneficiaries to be married women and female-headed households, respectively). For wider adoption and dissemination of the *teff* varieties in the *woredas* and elsewhere in the region, and for increasing the participation of women in agricultural technology evaluation the following recommendations are suggested.

- Before proceeding with the promotion and dissemination of the technologies on a wider scale through pre-scaling ups and scaling ups, seeds of the selected varieties have to be multiplied by the public and private seed producers.
- Biophysical researchers should consider farmers' *teff* varieties evaluation criteria when they strive to develop new *teff* varieties in the future so that they will be easily adopted by farmers.
- *As Hiber-1* and *Tsedey* in Libokemkem and *Etsub* and *Tsedey* in Ebenat *woredas* gave a better yield and economic advantage; the two varieties have to be scaled up at a wider scale in the two *woredas*, respectively.
- Emphasis should be given to increasing the participation of women in participatory agricultural research and development endeavors as they are often plant breeders in small-scale farmer production systems, responsible for domesticating species and selecting germplasms that have the best qualities for cooking, baking, and taste. They are concerned about quality, which is one of the factors for the adoption of varieties, as they are responsible for cooking and nurturing the household members.

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