
Participatory variety selection and promotion of improved tef varieties in vertisol areas of North Shewa Zone, EthiopiaShumet Chakle^{1*}, and Teklemariam Ayele¹^{1*}Debrebirhan Agricultural Research Center, P.O. Box 112, Debre Birhan, EthiopiaCorresponding author email: shumchakle@gmail.com

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ABSTRACT**Received:** February 19, 2023**Revised:** May 24, 2023**Accepted:** June 22, 2023**Available online:** June 28, 2023

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The production and productivity of tef in vertisol areas of North Shewa Zone is constrained by wider use of local cultivars which are low yielder and susceptible to lodging. The objective of the study was to select and promote high yielder and farmers preferred improved varieties. Ten improved varieties with the standard (Dega tef) and local (Bunign) checks were evaluated as mother trial at Deneba station in 2017 using RCB design in three replications. The top four selected varieties were evaluated as baby trial together with the checks on three farmers field during 2018 in simple plot design. Phonological and agronomic data were collected both from mother and baby trials. Farmers invited to evaluate varieties both in mother and baby trials. Panicle length, panicle uniformity, lodging tolerance, tillering capacity, seed boldness, disease tolerance and adaptability criteria used by farmers for mother trial selection, while panicle length, stalk strength, plant height, tillering capacity and panicle uniformity used for baby trial. After the selection process, starting from 2019 to 2021 scaling up activities also conducted at Siyadebr kebel. The analysis of variance showed highly significant ($p < 0.01$) differences for days to heading, days to maturity and shoot biomass yield ranging from 63 to 72; 134 to 139 and 5347 to 7932 kg ha⁻¹ respectively, and significant ($p < 0.05$) difference for grain yield with lowest and highest scores of 1824 and 2409 kg ha⁻¹. Variety Dima followed by variety Zobel were ranked by farmers as first and second, respectively both in mother and baby trials. Among the tested varieties Dima gave highest yield (2409 kg ha⁻¹), and showed best lodging tolerant trait. As a result, variety Dima has been recommended.

1. INTRODUCTION

Tef is economically important crop that belongs to Poaceae grass family which is the only cultivated type from 350 species of genus *Eragrostis*, and is an allotetraploid ($2n = 4x = 40$) C4 plant (Assefa et al 2015). Ethiopia is both the origin and center of diversity for tef (Vavilove 1951). Tef is Ethiopian origin crop and also believed that it will live as long as Ethiopians are present on this earth (Assefa et al, 2013). Even though tef adapts to diverse agro ecological zones including conditions marginal to the production of other crops, however the maximum production occurs between 1700 and 2400m above sea level (Tefera and Ketema 2001). Due to its tolerance to extreme weather conditions and lower susceptibility to disease problems, it becomes much attractive crop than other cereals (Hailu et al, 2017). Tef occupies 29.6% and 32.9% of the total acreage and 19.3% and 23.4 % of the gross grain production of all cereals in Ethiopia and in Amhara region, respectively (CSA 2020). Tef is a very nutritious cereal grain compared to most other cereals that contain relatively high minerals such as iron, and calcium (Akansha et al 2018; Syprose et al 2021). Its gluten-free nature and nutritious value showed an increased consumption rate over the last 15 years (Hailu et al 2017). Tef is staple food for 60-75% of Ethiopia's population and believed as a traditional medicine mainly for people with diabetic problem in diverse areas of the country (Gizaw et al 2018). As compared to the other cereals, tef has best injera making quality and fetches higher market price for its grain and straw. As a result, farmers give top priority for tef production. Although a number of improved tef varieties have been released, and improved agronomic

practices have been recommended through the research system (Misgan 2018; Mebratu and Kenea 2020), however their adoption and utilization are still poor (Tariku et al 2018).

Due to poor adoption and utilization of improved varieties and recommended agronomic packages (Mansingh and Bayissa 2018), the average productivity of tef is relatively low, 1.85 t ha^{-1} (CSA 2020) which creates wider gap between the ever-increasing demand for tef and its supply. Lodging, drought, heat, frost, low soil fertility, soil erosion, water logging, poor crop management practices, insect pests, and weeds are also another major contributing factors for having low yields in tef (Abate et al 2007). As a result, the productivity of tef has not yet been raised to satisfactory level as compared to its potential. Participatory Variety Selection (PVS) implemented with improved agronomic practices and followed by pre-scaling up of farmers' preferred varieties has been reported in different crops as the best method to increase farmers' varietal adoption and to enhance crop productivity (Olarinde et al 2017). Participatory variety selection is the research process by which farmers are regularly involved in choosing preferred varieties that they set the most appropriate traits in selection among stable varieties that are being field tested (Mitiku et al 2021). Utilization of farmers' indigenous selection criteria knowledge has tremendous contribution for cultivar development and improved management (Gizaw et al 2018). In the target area there is large coverage of tef production in which most of the land is covered with local cultivar. Moreover, the productivity of this local cultivar is

poor due to its low genetic potential and susceptibility to lodging. Therefore, this trial was conducted with the objective of evaluating, selecting and promoting improved tef varieties with the active participation of farmers that meet farmers' traits of interest in Vertisol areas of North Shewa.

2. MATERIALS AND METHODS

2.1. Description of the Study Area

The trial was conducted in North Shewa zone at Siyadebrena Wayu woreda. The area is located at 03904'36" E longitudes, 0947'08.8" N latitudes and its altitude is 2607 meters above sea level (Figure 1). The mean annual rainfall, mean maximum and minimum temperature of the location is 1447 mm, 23 °C and 5.5 °C respectively. The soil type of the area is mainly heavy Vertisol.

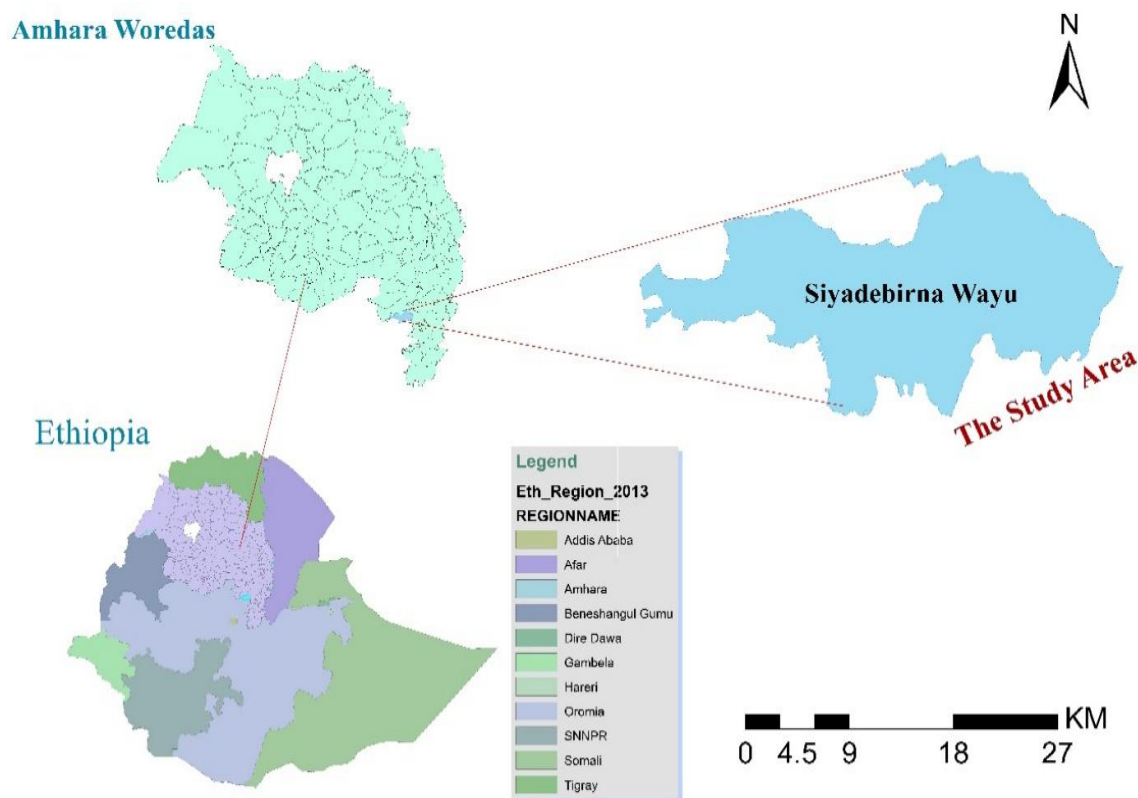


Figure 1: Location map of the study woreda.

Plant Materials, Design and Trial Management

Participatory variety selection (PVS) was conducted during 2017 and 2018 main cropping seasons using mother – baby approach. Ten improved tef varieties along with the standard check (Dega tef) and local check (Bunign) were included in the study (Table 1). The mother trial was laid out in a Randomized Complete Block Design (RCBD) with three replications while the baby trial was conducted farmer as a replication. The plot size of the mother and baby trial was 2m x 2m and 5m x 5m, respectively. Fertilizer at a rate of 60 kg ha⁻¹ N and 60 kg ha⁻¹ P₂O₅ was applied. The recommended seed rate 20 kg ha⁻¹ was broadcasted. All P₂O₅ and half of N was applied at planting while the remaining N was applied at tillering. Weeding management practices were implemented timely.

Table 1: List and passport data of improved tef varieties evaluated in participatory variety selection

SNo.	Variety	Year of release	Altitude (m a.s.l.)	Rainfall (mm)	Yield (qt ha ⁻¹)	Center of release*	Days to mature
1	Kora	2014	1700-2400	700-1200	25-28	DZARC	110-117
2	Lakech	2009	1450-1850	660-1025	22.4	SARC	90
3	Kena	2008	1850-2400	1000-1200	15-27	BakoARC	110-134
4	Etsub	2008	1800-2600	1230	19-27	AdetARC	92-127
5	Quncho	2006	1800-2500	800-1200	25-27	DZARC	86-151
6	Genete	2005	1450-1850	660-1025	21.7	SARC	78-85
7	Zobel	2005	1450-1850	660-1025	20.7	SARC	78-85
8	Gimbichu	2005	2000-2500	1000-1200	18	DZARC	118-137
9	Dega tef(st.ck)	2005	1880-2500	997-1200	18-28	DZARC	112-123
10	Yilmana	2005	2000-2600	>600	23.2	AdetARC	108
11	Dima	2005	2000-2600	>600	24.6	AdetARC	105
12	Bunign	-	-	-	-	Local check	

Source: Ministry of Agriculture, crop variety register

*DZARC = Debre Zeit Agricultural Research Center; SARC = Sirinka Agricultural Research Center; BakoARC= Bako Agricultural Research Center; AdetARC= Adet Agricultural Research Center.

Data Collection and Measurements

Data were collected on plant and plot basis. Days to heading, days to maturity, plant height (cm), panicle length (cm), biomass yield (kg ha⁻¹) and grain yield (kg ha⁻¹) were collected from the mother and baby trials. Days to heading was taken as the number of days counted starting from date of sowing when 50% of plants headed in a plot. Days to physiological maturity was taken by counting the number of days from the date of sowing up to the date when 90% of the plant stands in a plot changed to yellow color based on visual observation. Plant height (cm) taken as the average height of five randomly sampled plants which measured from the ground level to the tip of the panicle at maturity. panicle length (cm) taken at physiological maturity from five randomly selected plants measured from the base to the tip of the panicle. Biomass yield (kg) was taken at harvest as the total weight of the above-ground sun dried biomass per plot. Grain yield (kg) is weight of

grain measured in kg and expressed as kg per plot and converted to kg per hectare.

Farmers Preferences and Pre-scaling up

Farmers put their selection attributes and made comparison freely. After the basic evaluation of experiment, pre scaling up of the selected variety (Dima) was undertaken and implemented in 2019 and 2021 at Siyadebr kebele. During pre-scaling up phase, host farmer selection and farm land clustering was done by Woreda and Kebele agricultural experts and researchers. Training on how to produce quality tef seed and post-harvest handling was given for host farmers. Variety Dima was delivered with seed repayment base for host farmers. The same rate of fertilizer and seed was used as that of the experimental phase. Frequent monitoring and evaluation were done on the pre-scaled up farms by team of researchers, kebele agricultural experts and farmers. Field day was organized

when the crop reached maturity stage and different stakeholders were invited

and taken perceptions about variety Dima.

Social and Biological data analysis

Farmers' preference data were analyzed using pair-wise and preference ranking matrix techniques (Tim 1997). The pair-wise ranking method was used to analyze the position of each variety, and a weighted ranking matrix table was constructed. Members were asked to compare and contrast each variety with the other to assign values based on identified attributes and the same procedure was repeated for all varieties. By counting the number of times, each variety was chosen by each farmer and group; the aggregation was made to put scores for each variety. These aggregated scores are multiplied by a weight and the result obtained from multiplication is summed up to represent the rank and position of the varieties (Tim 1997). According to Tim (1997), farmers' preference data was analyzed using the formula:
$$WFP = \sum_{k=1}^n \frac{(RV \cdot NF)}{TNPF}$$
 where RV= Rank value, NF = Number of farmers and TNPF= Total number of participant farmers.

For biological data, analysis of variance was computed using R 4.0.3 statistical software (Chun 1964), and treatment mean separation was done using least significance difference (LSD) at 5% level of significance. Analysis of variance model was: $Y_{ij} = \mu + t_i + r_j + e_{ij}$; where μ = over all mean; t_i = the i^{th} treatment effect; r_j = the j^{th} replication effect; e_{ij} = the error term

3. RESULTS AND DISCUSSIONS

3.1. Analysis of Variance for Mother and Baby Trials

The analysis of variance for the mother trial showed highly significant difference ($p < 0.01$) among tested tef varieties for days to heading, days to maturity, shoot biomass, harvest index, and significant difference ($p < 0.05$) for grain yield (Table 2). This result is in agreement with the findings of Mamo *et al* (2018), which stated that days to maturity, shoot biomass and grain yield showed significant variation among the tested varieties while non-significant variation obtained from plant height and panicle length.

Among the tested varieties, Dima gave the highest grain yield (2409 kg ha⁻¹) followed by Dega tef (2287 kg ha⁻¹). Variety Dima showed 24 % and 5% yield advantage over local and standard checks, respectively. On the other hand, varieties Kora (1824 kg ha⁻¹), Lakech (1830 kg ha⁻¹), Kena (1848 kg ha⁻¹), Zobel (1853 kg ha⁻¹) and local

check (1938 kg ha⁻¹) gave low yield (Table 2). Similar findings have also reported by Yismaw and biadgie (2018), which stated that variety Zobel and local check gave low yield. This low grain yield attributed by the environment, genotype and interaction effects. The performance of measured characters of tef varieties including grain yield was influenced by genotype, environment and their interaction effects (Tariku *et al* 2018).

In terms of biomass yield, Zobel gave the highest, 7923 kg ha⁻¹ and the local check gave the lowest, 5347 kg ha⁻¹. The local check matured early (in 134 days), but it was short stature, susceptible to lodging and low yielder. The local check (Bunign) has fine stem characteristics which easily displaced from its vertical position in grain filling time. Even if root lodging is major contributors to tef lodging, however certain studies associated lodging to stem characteristics (Tafes *et al* 2022). Even though Local

varieties matured in short period of time compared to improved varieties (Fentie et al 2012), however lodging is a prevalent occurrence that contributes to the presence of low grain yields (Tafes et al 2022). More specifically the local cultivar Bunign is early maturing variety (<85 days) which is widely used in areas that have a short growing period, but Lodging problem is one of the factors for erosion of the land race & introduction of improved varieties (Abate et al 2020).

The analysis of variance for the baby trial showed highly significant difference ($p<0.01$) among tested tef varieties for days to heading, plant height, grain yield, harvest index, and significant difference ($p<0.05$) for biomass yield. This result is in agreement with the finding of Mitiku

et al (2021) who reported high ($p\leq 0.01$) significant difference for 50% heading, 95% maturity, Plant height, grain yields. The highest grain yield (1518 kg ha^{-1}) was obtained from Dega tef followed by Dima (1448 kg ha^{-1}), and the lowest yield (1094 kg ha^{-1}) was obtained from Yilmana. The highest biomass yield (4423 kg ha^{-1}) was obtained from Dega tef while the lowest (3129 kg ha^{-1}) was obtained from the local check (Table 3). During 2018 Meher season, from November 6-16, unexpected rainfall (15.9 mm) occurred at maturity stage and caused serious yield loss in the baby trial which made huge yield gap as compared with mother trial (source: Ethiopian national metrology agency).

Table 2: Mean performance of 12 tef varieties for grain yield and yield-related traits evaluated in mother trial at Deneba on station in 2017

Varieties	DTH	DTM	PH (cm)	PL (cm)	SBM kg ha^{-1}	GY kg ha^{-1}	HI (%)
Kora	68.7 ^{de}	136.3 ^{cde}	71	23	5986 ^{ef}	1824 ^c	30 ^{b-d}
Lakech	70.7 ^{a-d}	136.7 ^{bcd}	64	22.5	5945 ^{ef}	1830 ^c	31 ^{b-d}
Kena	69 ^{de}	137.7 ^{abc}	72	23.7	6780 ^{b-e}	1848 ^c	27 ^{c-e}
Etsub	70.3 ^{bcd}	137.3 ^{abc}	72	26.6	7521 ^{ab}	2090 ^{abc}	27 ^{c-e}
Quncho	72 ^{ab}	135 ^{de}	73	27	7154 ^{a-d}	1849 ^c	26 ^{de}
Genete	72.7 ^a	137.7 ^{abc}	71	27.4	7455 ^{abc}	1971 ^{bc}	26 ^{de}
Zobel	71.7 ^{abc}	137.7 ^{bcd}	74	27	7932 ^a	1853 ^c	23 ^e
Gimbichu	69.7 ^{cde}	138 ^{abc}	61	22	6411 ^{de}	2019 ^{bc}	31 ^{a-c}
Dega tef(st.ck)	69.7 ^{cde}	139.3 ^a	72	25.8	7075 ^{a-d}	2287 ^{ab}	32 ^{a-c}
Yilmana	70 ^{b-e}	138 ^{abc}	67	23.4	6658 ^{cde}	2146 ^{abc}	32 ^{a-c}
Dima	68 ^e	138.7 ^{ab}	62	22	6707 ^{b-e}	2409 ^a	36 ^{ab}
Bunign (local.ck)	63 ^f	134.3 ^e	65	22	5347 ^f	1938 ^{bc}	37 ^a
Mean	69.6	137	69	24.4	6748	2005	30
CV	1.7	1	9.7	11.8	7.5	10.5	10.2
LSD	2**	2**	11	4.9	857**	358*	5**

Where: CV = coefficient of variance, LSD = least significance difference, * significant at ($p<0.05$), ** highly significant at ($p<0.01$), DTH = days to heading, DTM = days to maturity, PH = plant height, PL = panicle length, SBM = shoot biomass, GYLD = grain yield, HI = harvest index

Table 3: Mean performance of tef varieties for grain yield and yield components evaluated as baby trial at Deneba farmers' field in 2018

Varieties	DTH	DTM	PH (cm)	PL (cm)	SBM kg ha ⁻¹	kg GY ha ⁻¹	kg HI (%)
Dima	75 ^a	130	54 ^b	22	3272 ^b	1448 ^a	42 ^{ab}
Yilmana	75.7 ^a	129	57 ^{ab}	22	3318 ^b	1094 ^c	33 ^{cd}
Dega	tef	73 ^b	63 ^a	23	4423 ^a	1518 ^a	
(st.ck)							35 ^{b-d}
Etsub		75.7 ^a	61 ^a	24	3520 ^b	1382 ^a	41 ^{a-c}
Zobel		76.3 ^a	63 ^a	24	4296 ^a	1212 ^{bc}	28 ^d
Bunign		69 ^c	45 ^c	18	3129 ^b	1367 ^{ab}	
(local.ck)							44 ^a
Mean		74	129	57	22	3660	1337
CV		1.2	1.1	6.9	10.2	11.2	6.4
LSD		1.6 ^{**}	2.65	7.2 ^{**}	4.1	743 [*]	155 ^{**}

Where: CV = coefficient of variance, LSD = least significance difference, * significant at (p<0.05), ** highly significant at (p<0.01), DTH = days to heading, DTM = days to maturity, PH = plant height, PL = panicle length, SBM = shoot biomass, GYLD = grain yield, HI = harvest index

Farmers' participation in variety evaluation and selection

At maturity stage, 24 (4 female) and 16 (3 female) farmers participated in variety evaluation and selection in mother and baby trials, respectively. The participant farmers have rich experience in tef production. Varietal selection was made based on the breeder orientation given to farmers. Selection criteria were established based on n farmers' indigenous knowledge. Farmers were permitted to set their own selection criteria and then both male and female participants discussed together for prioritizing their criteria and finally come up with commonly agreed preferred characters. Since the mother and baby trials conducted at different location and year within the same woreda, Farmers who participated in the mother trial evaluation and selection were not included in the baby trial evaluation and selection. That is why selection criteria slightly differed in mother and baby trials. In different locations, farmers set different selection criteria with having few same criteria in common which differed in rank from

location to location (Tariku et al 2018).

Panicle length, panicle uniformity, lodging tolerance, tillering capacity, seed boldness, disease tolerance, and adaptability were attributes set by farmers in mother trial evaluation and selection (Table 4), while panicle length, stalk strength, plant height, tillering capacity, and panicle uniformity were the attributes set by farmers in baby trial evaluation and selection (Table 6). The selection criteria of panicle length, lodging tolerance, tillering capacity, plant height, and adaptability also commonly used by Tariku et al (2018) and Mitiku et al (2021). Indeed, most of these traits are yield related traits in tef (Chanyalew et al 2009; Jifar et al 2015; Woldeyohannes et al 2022). In setting selection criteria farmers intentionally didn't give attention for seed color. In the area farmers commonly cultivate brown tef type due to its best tolerance to heavy vertisol stresses, which is a dominant soil type in the location. farmers often claim that the brown-seeded types perform better under less favorable conditions in marginal fields

than do the white-seeded types (Assefa et al 2002).

Based on pair-wise ranking method, farmers' varietal selection criteria were ranked and the top ones were used. The top three attributes in mother trial were disease tolerance, adaptability, and tillering capacity, while in baby trial the top attributes were stalk strength, tillering capacity, and panicle length. The weighted means of selection attributes, and varieties rank in mother and baby trials are summarized in Table 5 and Table 7, respectively using preference ranking matrix. To avoid mix-up confusion, firstly the whole farmers together selected the top five varieties out of the tested varieties. Then farmers were individually asked to make pair wise comparisons for the five selected varieties by using the above selection attributes. Accordingly, farmers selected Dima first followed by Zobel in mother trial (Table 5) while in baby trial farmers selected Zobel as first followed by Dima (Table 7).

Variety Dima gave high grain yield with lodging tolerance and large number of fertile tillers. Though, variety Zobel was one of farmers'

selected varieties, it showed poor grain yield performance both in mother and baby trials. Zobel was physically very attractive to farmers due to its appealing panicle length and plant height. However, it was poor in its biological yield which is possibly more in vegetative than grain yields. The farmers wanted to replace their local variety with Dima for its high grain yield, lodging tolerance and adaptability merits. Even though the local cultivar well adapted to the area, however it is highly susceptible to lodging due to its fine stem characteristics. For this major reason farmers wanted to replace it with Dima variety which showed better stem strength, tillering capacity, adaptability and panicle length. Though, cultivar Bunign is early maturing, but Lodging problem is one of the factors for erosion of the land race and introduction of improved varieties (Abate et al 2020). Similarly pervious study showed in various crops that small holder farmers used different important traits related to their desire to meet economic, social and agroecological conditions with local significance and gender effects (Mancini et al 2017).

Table 4: Pair wise ranking matrix of attributes in mother trial in 2017

Attributes	SB	PU	AY	DT	LT	PL	TR	Scores	Rank
SB		PU	AY	DT	LT	SL	TR	0	7
PU			AY	DT	PU	SL	TR	2	5
AY				DT	AY	AY	AY	5	2
DT					DT	DT	DT	6	1
LT						SL	TR	1	6
PL							TR	3	4
TR								4	3

Where: SB= seed boldness, PU= panicle uniformity, AY= adaptability, DT= disease tolerance, LT= lodging tolerance PL= panicle length, TR= tillering

Table 5: Varietal preference ranking matrix in mother trial in 2017

Varieties	Weighted means of farmers' varietal selection attributes							Mean	Rank
	SB	PU	AY	DT	LT	PL	TR		
Dima	1.5	2	1.6	1.5	1.6	3.2	1.9	1.9	1
Kena	1.6	2.1	2.5	2.8	3.1	2.4	3.1	2.51	3
Zobel	2.9	2.6	2.8	2.6	3	1.4	2.2	2.50	2
Etsub	4.1	3.6	3.6	3.9	3.7	3.5	3.4	3.7	4
Yilmana	4.3	4.5	4.4	4.2	3.5	4.5	4.4	4.3	5

Scoring Value = 1- excellent, 5= poor

Where: SB= seed boldness, PU= panicle uniformity, AY= adaptability, DT= disease tolerance, LT= lodging tolerance PL= panicle length, TR= tillering

Pre-scaling up of farmers' selected variety

Pre scaling up of farmers' preferred variety (Dima) was conducted in 2019 at Siyadebr kebele on five volunteer farmers' land covering 1.25 ha. Field day was organized at maturity stage, and 58 (8 female) farmers, 5 (2 female) agricultural experts, and 6 (2 female) researchers participated. Technology evaluation and distribution process requires participatory approach and confirms the participation of all stakeholders, especially the poorest members of society (Binswanger-Mkhize et al 2009). After visiting the performance of the variety, discussion was made among the field day participants, and each group of participants suggested their reflection as follows:

Farmers Reflection

During the field day farmers gave sound feedbacks regarding to their improved technology gaps and limitations. Farmers said that most of the farm land in the area is covered

with cereal crops mainly tef and wheat; however, there is lack of improved tef varieties in the area and still growing the local cultivar which is not productive. They suggested that the improved variety Dima was better as compared to the local cultivar in terms of panicle length, stalk strength, seed size (boldness), lodging tolerance, disease tolerance, and grain yield while the local cultivar is highly susceptible to lodging and low yielder. Since farmers ultimately decide whether or not to adopt a particular variety, it is imperative to include farmers' knowledge for the promotion of improved technologies (Tariku et al 2018). They showed keen interest to expand Dima variety in the coming cropping season in many hectares. Farmers are in a stronger position to analyze and recognize the technologies that best serve their current circumstances (Kassa et al 2021).

Table 6: Pair wise ranking matrix of attributes in baby trial in 2018

Attributes	PL	SS	PH	TL	PU	Scores	Rank
PL		SS	PL	TL	PL	2	3
SS			SS	SS	SS	4	1
PH				TL	PU	0	5
TL					TL	3	2
PU						1	4

Where: SS = stalk strength, PL= panicle length, TL = tillering, PU = panicle uniformity, PH= plant height

Table 7: Varietal preference ranking matrix in baby trial in 2018

Varieties	Weighted means of farmers' varietal selection attributes					Mean	Rank
	SS	TL	PL	PU	PH		
Dima	2.00	1.86	2.33	1.93	2.66	2.16	2
Dega tef	3.93	3.60	3.33	3.66	2.93	3.49	3
Etsub	4.46	4.46	4.33	3.73	4.06	4.20	5
Zobel	1.13	1.2	1.06	1.53	1.00	1.18	1
Local check	3.53	3.80	3.93	3.73	4.33	3.86	4

Scoring Value = 1- excellent, 5= poor

Where: SS = stalk strength, PL= panicle length, TL = tillering, PU = panicle uniformity, PH= plant height

Researchers and Agricultural Experts' Reflection

On the other hand, agricultural experts and researchers suggested that farmers should apply the recommended tef seed production package together with their indigenous knowledge to enhance the production and productivity of tef in the area. Rigorous efforts are required to motivate farmers to adopt improved production technologies and close the extension gap (Kassa et al 2021). They further suggested that for sustainable production and productivity, the linkage among different actors including research institutions, seed enterprises, unions, cooperatives, chemical supply agents, agricultural experts and farmers should be strengthened. Promotion improved technologies cannot be provided by a single organization (Amare et al 2023), and it needs multi stakeholders who shared common goal for enhancement of agricultural production (Kebede et al 2021). The sustainability of seed supply system should be assured

through multi stakeholder approach; by establishing and strengthening seed producers and marketing cooperatives, and farmers to farmers seed exchange systems. Agricultural experts and researchers also discussed how to provide farmers with quality seed of this variety and agreement was made between them to support farmers on seed dissemination and follow up. The second-round pre-scaling up of Dima variety was done at Siyadebr kebele in 2021 with the participation of 14 (1 female) interested farmers covering eight-hectare land by providing two quintals of pre basic seed. The pre-scaled up grain yield and biomass yield of variety Dima was 2353.3 kg ha⁻¹ and 9879.4 kg ha⁻¹, respectively, and grain yield and biomass yield of local check (Bunign) was 2068.67 kg ha⁻¹ and 7874.67 kg ha⁻¹, respectively (Table 8). Variety Dima showed 13.8% grain yield and 29.6% biomass yield advantages over local control (Table 9).

Table 8: Mean values of grain and biomass yield of the pre scaled up variety (Dima) vs local control (Bunign)

Varieties	Dima		Bunign (local control)		T-test
	Mean	Std.deviation	Mean	Std.deviation	
Biomass yield (kg ha⁻¹)	9879.4	1183.22	7874.67	1756.46	1.141 ^{ns}
Grain yield (kg ha⁻¹)	2353.33	421.87	2068.67	364.73	2.117 [*]

Note: * = significant at $p < 0.05$ and. ns = non-significant. The quantitative data were analyzed using simple descriptive statics by SPSS version 20 software (mean, percentage

and standard deviation) and also used inferential statistics (independent sample t-test).

Table 9. Yield advantage of Dima over the local check during the pre-scaling up phase

Varieties	Average grain yield kg ha ⁻¹	Yield advantage (%)	Average straw yield kgha ⁻¹	Yield advantage (%)
Dima	2353.33	13.76	7526.1	29.63
Bunign (Control)	2068.67	-	5806	-

Note: Yield advantage of the improved technology (%) = $[(Y_i - Y_j)/Y_j] * 100$; Where: Y_i : average yield of the improved technology, Y_j : average yield of local variety

4. CONCLUSIONS AND RECOMMENDATIONS

The analysis of variance indicated that Dima gave the highest yield (2409 kg ha⁻¹) followed by Dega tef (2287 kg ha⁻¹). Dima was ranked by farmers 1st in the mother trial and 2nd in the baby trial. Even though Dima is red-colored, it is highly preferred by farmers for its smart traits including lodging tolerance, tillering capacity, and adaptability as compared with other tested varieties. Based on the result of farmer's variety preference and biological data analysis variety Dima has been recommended for Siyadebrena Wayu district and other similar areas. Dima was pre-scaled up and different stakeholders were invited to evaluate and comment on the performance of the variety. The stakeholders were inspired by the best performance of the variety and they recommended that it should be expanded in large scale at Siyadebrena Wayu and other potential tef growing Vertisol areas.

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