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Early Generation Seed production of tef [*Eragrostis tef* (Zucc.)Trotter] in Central Ethiopia, Challenges and opportunities

Bekele Gemechu*

Ethiopian Institute of Agricultural research Center, Debrezeit Agricultural Research Center, Ethiopia

**Corresponding author*

Abstract

Tef [*Eragrostis tef* (Zucc.) Trotter] is the major food crop in Ethiopia where it is annually cultivated on more than three million hectares of land and with the total of over 6.87millon holders but its average productivity of 1.88t/ha which is lower than its potential productivity which might be due to low genetic potential of local cultivars, low adoption of improved varieties, absence of improved seed from known sources and biotic and a biotic stresses. Tef research started before five decades and more than fifty varieties were released from the research system through hybridization and through pure-line and/or mass selection from farmers' varieties (germplasm). Even though numerous varieties have been released by the national agricultural research system, only few varieties have been widely adopted by the farming community based on their agro ecological suitability as adapted for optimum rainfall areas, for drought prone areas and suitable for optimum rainfall areas. Quality early generation seed production and supply is important for increasing production of the users. Based on this the research centers and public seed enterprises are involved in the production and supply of EGS. Debrezeit Agricultural research center is mandated as national coordinator for tef research program and EGS of most tef varieties were produced and supplied from this center. Breeder seed, Pre basic seed and basic seed are mainly considered as EGS and mainly supplied for certified seed producers who produces certified seed in large quantities and distributed to farmers for grain production. This day the demand for improved seed at different stages is increasing and the government focuses to meet the seed demand for further increase production. To encourage seed producers the government developed national seed policy, seed laws, regulations and seed standards under which seed producers and inspectors were guided in the course of seed production. In addition to the public institutions the involvement of private partners has to be promoted to address the increasing demand for improved seed.

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Early generation seed, tef, varieties, certified seed, seed class.

Introduction

Tef [*Eragrostis tef* (Zucc.) Trotter] is the most important commodity produced and consumed in Ethiopia. The flat pancakes injera provide livelihood for around 6.5 million small farmers in the country. Tef, *Eragrostis tef* (Zucc.) Trotter, is a member of the grass or Poaceae family and Chlorodoideae sub-family. Tef represents a unique biodiversity component in the agriculture and food security systems of millions of poor farmers in Ethiopia. In Ethiopia, tef is the most valuable source of human food (the grain) and livestock feed (the straw), cash and foreign currency earnings. It ranks first in terms of total area under cultivation where it accounts for about 28% of

the total acreage under cereal crops (2,928,206.26million ha) with the total of over 6.87millon holders and average productivity of 1.88t/ha (CSA, 2021). Tef is also known to be tolerant to extreme climatic and soil conditions; hence, it is a favorite crop in the semi-arid areas with moisture limitations (Tadele and Assefa, 2012).

In recent years, tef is receiving global attention for its nutritional and health-related benefits (Provost and Jobson, 2014) especially due to the absence of gluten, a cause for celiac disease in its grain (Spaenij-Dekking *et al.,* 2005).

Despite its versatility in adapting to adverse environmental conditions and being the staple food over 60 million people in Ethiopia, the seed yield of tef is low. The national average yield is 1.88 t ha-1, in contrast to 3.04 t ha-1for wheat and 4.18 t ha-1 for maize (CSA, 2021).

Ethiopia adopted the Organization for Economic Cooperation and Development (OECD) nomenclature for seed production and certification with some minor variations: breeder seed, pre-basic seed, basic seed and certified seed (Desalegne *et al.,* 2013; Bishaw *et al.,* 2008). Accordingly, breeder seed is the seed of first generation produced under the supervision of the plant breeder. Pre-basic seed is the progeny of the breeder seed and particularly used for crops with low multiplication factor. Basic seed is the progeny of pre- basic seed and usually provided to certified seed producers and suppliers. Certified seed is the progeny of basic seed and produced for sale to farmers. Certified seed (C1) can be further multiplied for one more generation (Certified 2), but in Ethiopia C3 and C4 are recognized which deviates from the OECD seed scheme.

Early generation seed (EGS) production constitute the maintenance breeding of improved variety and regular multiplication and supply of high quality breeder, pre-basic or basic seed (van Gastel *et al.,* 1996) for large-scale certified seed producers. EGS multiplication is a distinct step in seed production and should not be confused with large-scale certified seed production for end users (Tripp, 1997).

Atilaw *et al.,* (2017); Jaleta *et al.,* (2020); Bittle and Humpal, (2021) reported that EGS bottlenecks are both systemic and technical. The aim of this paper is to review the existing status of tef early generation seed production, challenges and opportunities and to further indicate ways forward for healthy functioning of the tef seed system.

Tef EGS production and supply by public institutions

Research institutions are involved in the supply of breeder and pre-basic seed of tef. Regional research institutes such as ARARI, OARI and SARI are involved in pre-basic seed, basic and certified seed production of tef. EIAR is mainly involved in the production of breeder and pre basic seed and sometimes basic seed production of most demanded varieties for community service and Pre extension Demonstration activities. Debre zeit research center is mandated for tef and the national tef breeding program is also based at Debre Zeit agricultural research center. Therefore Debre Zeit agricultural research center is responsible for tef EGS production and supply (Breeder seed, pre basic and basic) at the national level. Regional research institutes are also recently involved in the production and supply of EGS of tef, even though they are more focusing on hybrid maize and wheat. This days the demand for EGS is increasing as the public and private seed producers are increasing and NGOs and farmers are also demanding for EGS of improved varieties. The need for decentralizing EGS production to produce quality seed in more quantity is arising. Public seed enterprises are now a day's important actors in the seed industry of the country covering large amount of the demand for certified seed coming from the seed users. They are situated in different regions of the country.

A total of 50 varieties have been developed and released by the national agricultural research system of Ethiopia Until 2020, (Table 2) Out of these, 23 varieties were developed through hybridization, while the remaining varieties were developed through pure-line and/or mass selection from farmers' varieties (germplasm). Among the varieties developed through hybridization program, only "*Simada*" variety was obtained from an inter-specific cross of *E. tef* (DZ-01-2785) and *E. pilosa* (line 30-5), while the rest were developed from intra-specific cross of selected parental tef lines.

Even though numerous varieties have been released by the national agricultural research system, only few varieties have been widely adopted by the farming community. Hence, important varieties in the current seed system are the following. Varieties for optimum rainfall areas: Dukem, Quncho, Kora, Dagim, Tesfa, Nigus, Flagot, Ebba and Bishoftu

Varieties for terminal drought-prone areas: Tsedey, Simada, Boset, Bora and Boni

Varieties for cool highlands: Gimbichu, and Dega Tef,

Tef varieties like Qunch, Boset, Tseday and kora are dominantly demanded by the users based on their agro ecologies for the last abut 10 years and also Dagim is recently become dominant in the mid altitudes of the growing areas. The EGS production of tef is also following the demand for the seed users and the newly released varieties like Nigus, Ebba, Bora and others are also demonstrated and become demanded by the seed producers. But tef varieties like Dukem, and Enatit, were out of the seed system as the demand of the users shift to the new varieties and the EGS production of simada is also intermittent as it is rarely demanded in the law land areas. (Table 2).

According to Alemu 2011 and Thijssen *et al.,* (2008) the seed demand for improved varieties is supplied particularly by public organizations. Public seed enterprises, universities and Private seed producers also supply seed to the market. However, both public and private seed producers mainly concentrate on a few cereal crops, particularly hybrid maize and bread wheat. Moreover, Bishaw and Luwaars (2012) stated that, public and private seed producers supply only a small portion of the total quantity of seed demanded by farmers and they do not satisfy the diversified seed demand of farmers. However as Alemu 2011; Thijssen *et al.*,(2008) indicated that most smallholder farmers tackle the seed shortage through farmer-to-farmer seed exchange or using saved seed.

Seed quality control of EGS and stakeholder involvement

In EGS production there is internal and external quality control system working for quality assurance and certification mechanisms. The internal quality control system is becoming strong in research system and public seed producers working mainly on seed quality based on field and laboratory standards set on the seed law. The external seed quality control or inspections is one of the key stakeholder mainly engaged in inspecting the seed fields on field based on the field standard and inspecting the seed samples collected from the seed lot in their independent laboratory for seed physiological quality. Finally seed lots which meet the field as well the laboratory standards get certification and seed lots failed to meet the set standards were rejected by the external seed quality inspection or regulatory team.

EGS distribution of tef by EIAR

Mostly EGS distribution of major crops by EIAR is to the public and private seed producers for pre basic, basic and certified seed production. Different NGOS were also get the maximum share of EGS from EIAR followed by the seed enterprises mainly to support the cooperatives and community based seed producers. Universities involved in supporting the community were also the major clients of EIAR in delivering EGS to their community from EIAR. The Extension program and the agricultural offices were also largely utilize the EGS from EIAR for PED and demonstrations of new varieties on large scale demonstration and on FTC bases

Challenges and opportunities of EGS production supply of Tef

According to Singh *et al.,* (2013); Tadesse *et al.*,(2018) seed production is highly influenced by climate variability and related changes. In addition climate change influences the population dynamics of insects and also irregularity in rain fall distribution affects EGS production of tef in terms of quantity and quality.

Mechanization is also one of the critical challenges in tef production as tef is mostly produced on vertisol operations like sowing, weed management, harvesting and threshing are conducted manually. These operations have negative impact on seed quality as well as quantity since the operations are time, labour and budget demanding.

The challenges in EGS production and supply could also be lack of clear institutional arrangements and system setting, Limited information for the newly released varieties and, lack of market orientation/ information at the demand-supply interface, and limited material as well as human capacity for EGS production and weak or no law enforcement.

Table.1 Area, Production and Yield of tef in Major Growing Regions of Ethiopia in 2020/21

Crops	No. of small holder farmers	Area (ha)	Production (qt)	Yield (t/ha)
National	6,866,855.00	2,928,206.26	55,099,615.14	1.88
Oromia	2,861,364.00	1,393,455.62	26,904,670.12	1.93
Amhara	2,703,282.00	1,086,374.60	20,964,629.06	1.93
Tigay	633,525	188,391.88	3,117,538.77	1.66
SNNP	1,224,860.00	234,350.83	3,744,279.61	1.60
Benishagul Gumuz	53,786.00	22,021.32	334,445.20	1.60

Source: CSA, 2021

Table.2 Improved tef varieties developed and released until 2020 in Ethiopia

No.	Varieties	Releasing center	Year of release	Days to mature	Seed color	Yield(t/ha)	
						Research field	On-farm
1	DZ-01-99 (Asgori)	Debre Zeit	1970	80-130	Brown	2.2-2.8	1.7-2.2
2	DZ-01-196 (Magna)	Debre Zeit	1970	80-113	Very white	1.8-2.2	1.4-1.6
3	DZ-01-354 (Enatite)	Debre Zeit	1970	85-130	Pale white	2.2-3.0	1.7-2.2
4	DZ-01-787 (Wellenkomi)	Debre Zeit	1978	90-130	Pale white	2.2-3.0	1.7-2.2
5	DZ-Cr-44 (Menagesha)	Debre Zeit	1982	125-140	White	2.2-2.8	1.7-2.2
6	DZ-Cr-82 (Melko)	Debre Zeit	1982	112-119	White	2.2-3.0	1.8-2.2
7	DZ-Cr-255 (Gibe)	Debre Zeit	1993	114-126	White	2.0-3.0	1.6-2.2
8	DZ-01-974 (Dukam)	Debre Zeit	1995	76-138	White	2.4-3.4	2.0-2.5
9	DZ-Cr-358 (Ziquala)	Debre Zeit	1995	75-137	White	2.1-3.4	1.8-2.4
10	DZ-01-2053 (Holeta Key)	Holeta	1998	124-140	White	2.1-3.4	1.8-2.5
11	DZ-01-1278 (AmboToke)	Holeta	1999	125-140	White	2.1-3.4	1.9-2.6
12	DZ-01-1285 (Koye)	Debre Zeit	2002	104-118	White	2.1-3.4	1.8-2.5
13	PGRC/E205396 (Ajora)	Areka	2004	85-110	White	1.8-2.2	1.5-1.7
14	DZ-01-1868 (Yilmana)	Adet	2005	98-118	White	1.6-3.0	1.4-

							2.1
15	DZ-01-2423 (Dima)	Adet	2005	94-116	Brown	1.6-3.2	1.4-2.2
16	DZ-Cr-387 RIL355 (Quncho)	Debre Zeit	2006	80-113	Very white	2.2-2.8	2.0-2.2
17	DZ-01-1880 (Guduru)	Bako	2006	110-132	White	1.5-2.3	1.4-2.0
18	23-Tafi-Adi-72 (Kena)	Bako	2008	110-134	Very white	1.7-2.7	1.3-2.3
19	DZ-01-3186 (Etsub)	Adet	2008	92-127	White	1.9-2.7	1.6-2.2
20	DZ-Cr-438 RIL133B (Kora)	Debre Zeit	2014	110-117	Very white	2.3-2.8	2.0-2.3
21	Acc. 214746A (Werekiyu)	Sirinka	2014	90-100	White	2.0-2.7	1.8-2.2
22	DZ-Cr-438 RIL7 (Abola)	Adet	2015	112-115	Very white	2.1-2.7	1.8-2.3
23	DZ-Cr-438 RIL91A (Dagim)	Debre Zeit	2016	116-144	Very white	2.4-3.2	2.0-2.5
24	DZ-Cr-429 RIL125 (Negus)	Debre Zeit	2017	112-116	Very white	2.4-3.3	2.1-2.6
25	DZ-Cr-442 RIL77C (Felagot)	Debre Zeit	2017	108-112	Brown	2.2-2.8	1.9-2.4
26	DZ-Cr-457 RIL181 (Tesfa)	Debre Zeit	2017	112-120	White	2.3-3.0	2.1-2.7
27	DZ-Cr-419 (Heber-1)	Adet	2017	93-114	White	2.0-2.7	1.7-2.2
28	DZ-Cr-401 (Areka-1)	Areka	2017	112-119	White	1.8-2.2	1.4-1.7
29	Acc # 225931 (Abay)	Adet	2018	95-132	White	2.4-3.0	1.8-2.2
30	ACC.236952(Dursi)	Bako	2018	100-125	White	2.1-2.5	1.9-2.2
31	DZ-01-256 (Jitu)	Bako	2019	100-125	White	2.1-2.5	1.9-2.4
32	DZ-Cr-458 RIL18 (Ebba)	Debre Zeit	2019	95-110	Very white	2.3-3.0	2.0-2.6
33	DZ-Cr-429 RIl 29 (Washera)	Adet	2019	108-125	Very white	2.3-3.2	2.0-2.5
34	DZ-Cr-497 RIL133 (Bishoftu)	Debre Zeit	2020	94-110	Very white	2.4-3.2	2.0-2.8
35							
II. Varieties for low rain fall (terminal drought-prone) areas							
1	DZ-Cr-37 (Tsedey)	Debre Zeit	1984	82-90	White	1.8-2.8	1.4-1.9
2	DZ-01-2054 (Gola)	Sirinka	2001	77-90	White	2.0-2.4	1.6-

							2.0
3	DZ-01-1281 (Gerado)	Debre Zeit	2002	82-87	White	2.0-2.4	1.6-2.0
4	DZ-01-1681 (Key Tena)	Debre Zeit	2002	84-93	Brown	2.0-2.5	1.6-1.9
5	DZ-01-1821 (Zobel)	Sirinka	2005	78-85	White	2.0-2.5	1.5-2.1
6	DZ-01-146 (Genete)	Sirinka	2005	78-85	Pale white	1.8-2.4	1.6-2.1
7	DZ-Cr-136 (Amarach)	Debre Zeit	2006	63-87	White	1.8-2.5	1.4-2.2
8	Acc. 205953 (Mechare)	Sirinka	2007	79-90	Pale white	1.8-2.5	1.4-2.2
9	DZ-Cr-387 RIL127 (Gemechis)	Melkassa	2007	62-85	White	1.7-2.6	1.5-2.2
10	DZ-Cr-385 RIL295 (Simada)	Debre Zeit	2009	72-88	White	2.0-2.8	1.6-2.4
11	DZ-Cr-387 RIL273 (Lakech)	Sirinka	2009	74-85	Very white	2.2-2.7	1.7-2.4
12	DZ-Cr-409 (Boset)	Debre Zeit	2012	75-90	Very white	1.9-2.8	1.8-2.2
13	DZ-Cr-453 RIL120B (Bora)	Debre Zeit	2019	74-85	Very white	2.0-2.8	1.8-2.4
14	DZ Cr- 428 (Mena)	Sirinka	2019	80-86	Very white	2.2-2.8	2.0-2.5
III. Varieties for highland (water logged) areas							
1	DZ-01-899 (Gimbichu)	Debre Zeit	2005	118-137	White	1.5-2.2	1.4-2.0
2	DZ-01-2675 (DegaTef)	Debre Zeit	2005	112-123	White	1.5-2.4	1.4-2.2

NB; *DZ-Cr are varieties developed and released through crossing and DZ-01 as well as different accessions are those varieties from selection.*

Table.3 Breeder seed production trend of tef from 2018 to 2022

No	Varieties	Clean seed yield in qt			
		2018/19	**2019/20**	**2020/21**	**2021/22**
	DZ-Cr- 387 RIL355 (Quncho)	5.0	2.4	5.0	4.0
	DZ-Cr-438 (Kora)	3.0	2.5	6.0	3.0
	DZ-Cr-409 (Boset)	6.0	6.4	5.0	3.0
	DZ-Cr-438 RIL91 (Dagim)	5.0	4.4	5.0	4.0
	DZ-Cr-37 (Tsedey)	3.0	3.0	4.0	5.0
	DZ-Cr-429 (Nigus)	4.0	4.0	5.0	3.0
	DZ-Cr-457 (Tesfa)	2.0	2.3	2.0	3.0
	DZ-Cr-442 (Filagot)	3.0	5.5	4.0	3 .0
	DZ-Cr-385 (Simada)	3.0	3.7	4.0	3 .0
	DZ-Cr-453 RIL120B (Bora)		3.6	4.0	3 .0
	DZ-Cr-458 RIL18 (Ebba)		1.6	4.0	3 .0
	DZ-Cr-497RIL133 (Bishoftu)			4.0	5.0
	Gimbichu			2.0	0.5
	Dega Tef			1.0	3 .0
	Total yield (q)	**34.0**	**39.4**	**53.0**	**45.5**

Source DZARC production data

Table.4 EGS production trend at EIAR- Debrezeit agricultural research center from 2013 – 2021

Production year	No of varieties under production	Seed class	Area in ha	Seed yield in qt	Remark
2013	6	p/basic	46.70	504.2	
2014	8	p/basic	37.60	334.65	
2015	5	p/basic	37.00	434.54	
2016	6	p/basic	32.40	282.00	
2017	6	p/basic	28.90	289.51	
2018	9	p/basic	31.30	366.16	
2019	6	p/basic	48.39	326.32	
2020	10	p/basic	49.75	445.00	
2021	9	p/basic	51.62	552.00	

Source DZARC EGS data

T**able.5** Tef varieties under seed multiplication at public and private institutions from 2013 to 2021

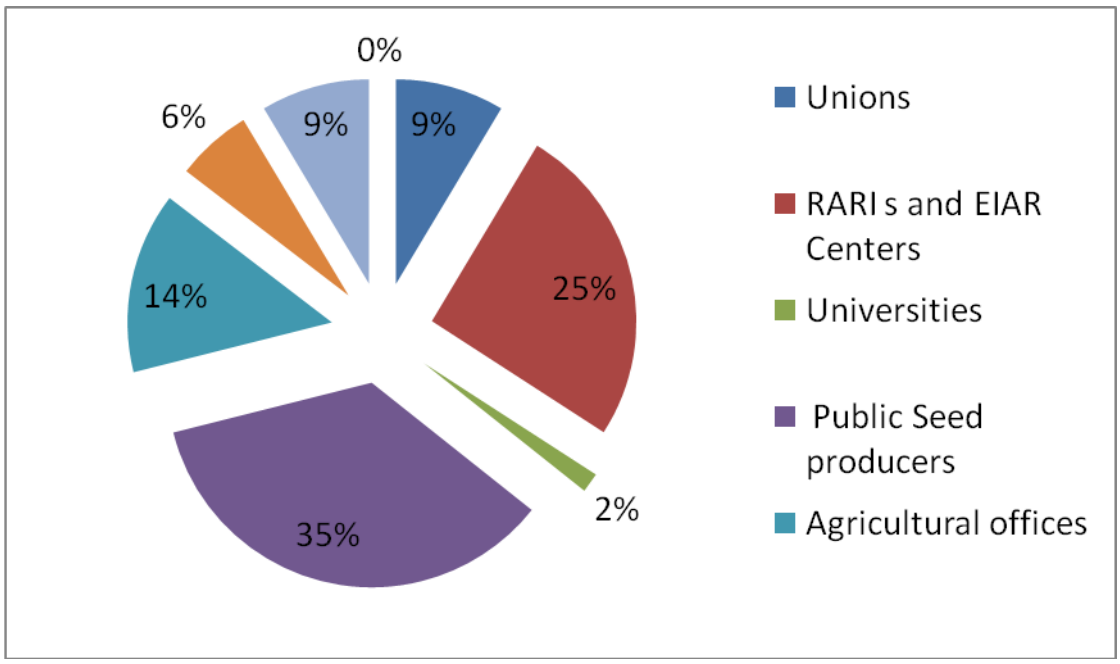
2013	2014	2015	2016	2017	2018	2019	2020	2021
Quncho	Quncho	Quncho	Quncho	Quncho	Quncho	Quncho	Quncho	Quncho
Tsedaye	Tsedaye	Tseday	Tseday	Tseday	Tseday	Tseday	Tseday	Tseday
Boset	Boset	Boset	Boset	Boset	Boset	Boset	Boset	Boset
Dukem	Dukem							
Simada	Simada	Simada	Simada		Simada			
Magna	Magna							
	Kora	Kora	Kora	Kora	Kora	Kora	Kora	Kora
	Enatit							
			Dagim	Dagim	Dagim	Dagim	Dagim	Dagim
					Nigus	Nigus	Nigus	Nigus
					Tesfa		Tesfa	
					Filagot		Filagot	Filagot
							Eba	EBA
							Bora	Bora

EGS production data

Table.6 Major stakeholders in the formal seed system and their roles.

Seed system components	Involved stakeholders	Regulatory stakeholders	Regulatory measures
Plant breeding Variety release	EIAR,RARIs, Universities	MOA	Distinctiveness, uniformity, stability
Breeder seed and Pre-basic seed production	EIAR, RARIs, Universities, EABC, RSES	MoA, regional BoA	Seed quality assurance
Basic seed production	EABC, RSEs, private seed companies, SPC	MoA, regional BoA	Seed quality assurance
Certified seed production	EABC, RSEs, private companies, SPCs, unions, farmers based seed production	MoA, regional BoA	Seed quality assurance

Fig.1 Tef seed distribution for stakeholders from 2017-2021



Opportunities

The production of tef is increasing from time to time with the total holder of more than six million and area coverage of about three million hectares of land currently in the country which is due to its increasing food vale in the country as well as outside the country. This day the demand for seed of improved varieties is increasing as majority of the farming communities use their own saved seed with low genetic potentials and physically and genetically contaminated. Further the demand for seed is also increasing due to the focus given for off season production in addition to the main season which is considered as a good opportunity for the EGS producers

The other opportunity area is there is an attention from the government in which a clear seed policy is already in place with different seed proclamations and regulations clearly developed. There is also a set standard for seed under which seed producers has to be followed to produce seed and the authorized institution is going to certify the produced seed basing the standard.

Tef ranks first in terms of total area under cultivation where it accounts for about 28% of the total acreage under cereal crops(2,928,206.26million ha) with the total of over 6.87millon holders and being the staple food over 60 million people in Ethiopia, Even though it covers large area, its productivity is very low(1.88t/ha) due to several factors in which low genetic potential of the cultivars, poor agronomic packages the farmers used and shortage of early generation seed were among the major challenges.

Currently tef is important in its nutritional value and health benefits in the country as well as its production in different countries becomes increasing. To increase the increasing production the availability of seed has to be crucial in terms of quality and quantity.

Therefore both public and private institutions engaged in early generation seed has to be encouraged to focus on the delivery of quality early generation seed to the users and the government has to strengthen the seed system of tef as it is an orphan crop of the country so that the research on technology generation and technology promotion as well as multiplication of early generation seed will be more promoted and large area will be addressed with seed of improved varieties to increase production and productivity.

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