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Early Generation Seed Production and Supply in Ethiopia: Status, Challenges and Opportunities

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Abstract

Early generation seed production may constitute maintenance breeding of improved variety and regular multiplication and supply of smaller quantities of breeder, pre-basic and basic seed. The main purpose of EGS Early generation seed production is to maintain the genetic potential and identity of a variety and regular provision of high quality breeder seed which is the basis for subsequent seed production. Ethiopia has adapted four seed classes for seed production: breeder seed, pre-basic seed, basic seed and certified seed. Variety maintenance, production, and distribution of the breeder, pre-basic, and basic seed are carried out by the public breeding institutions or private seed sector. EGS production is a distinct step in the seed production requiring particular knowledge, skills and facilities. This article summarizes the regulatory framework and institutional and technical arrangements in EGS production and the challenges and the opportunities to enhance EGS supply. To meet the current demand of EGS, it suggests the institutionalization of early generation seed production in Ethiopia.

Introduction

The development of the national seed system has been identified as one of the key components of the agricultural transformation agenda of the country. A new seed sector development strategy has been formulated by Agricultural Transformation Agency (ATA) where systemic bottlenecks have been identified and key interventions have been formulated. Among these availability and quality of early generation seed (EGS) has been identified as one of the major constraints of the national seed sector (MoANR/ATA, 2013).

Newly released crop varieties need to be multiplied and made available to farmers as quickly as possible for farmers to access and benefit from the genetic gain of the crop improvement programs. Seed production is a key component of a functional seed system and is expected to produce sufficient quantity seed of adequate quality within the national prescribed rules, regulations and standards. Formal seed production follows a limited generation system although the number of generations depends on the mode of reproduction of the crop, risk of contamination, multiplication factor and ultimately the quantity of certified seed required (van Gastel *et al.*, 2002).

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 recognised which deviates from the OECD seed scheme.

The aim of this article is, therefore, to review the status, challenges and opportunities for EGS production and supply with particular reference to the public national agricultural research system of Ethiopia.

Framework of early generation seed production

There are two critical stages in seed multiplication, where a small quantity of 'parental material' ('nucleus seed')of new variety received from breeders is systematically multiplied into large quantity certified seed for distribution to farmers (Bishaw and van Gastel, 2007):small-scale early generation seed multiplication and large-scale certified seed production. 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).

During seed production, several factors may reduce the genetic, physical and health quality of the seed due to a progressive increase in the quantity of contaminants. Generally, three types of contamination are recognized: (i) genetic contamination, due to cross pollination, (ii) mechanical contamination, due to physical admixture and (iii) pathological contamination, due to increased infection and transmission of seed-borne diseases. The main purpose of early generation seed multiplication is to ensure that the genetic purity and potential of newly released variety is maintained and regular supply of high quality pre-basic and basic seed is produced and supplied for the entire seed program.

Breeder seed is expected to be of the highest varietal purity and seed quality. All seed classes are related to breeder seed through one or more generations and subject to certification (except the breeder seed itself) and must meet the prescribed field and seed standards (ESA, 2012).

Variety maintenance and breeder seed production

Lavarack (1994) defines variety maintenance as 'the perpetuation of a small stock of parental material through repeated multiplication following a precise procedure'. Parental material, often called 'nucleus seed', is the initial seed obtained from bulking breeding lines to constitute the new variety by the breeder (Bishaw and van Gastel, 2007). It is the original stock of a new variety and can be used as a reference material for varietal maintenance, seed production or seed certification. It is used to produce breeder seed and later generations. It should be noted that breeder seed can be produced from the progenitors of breeder seed (parental material or nucleus seed) or breeder seed itself.

There are different approaches in variety maintenance to ensure varietal purity and identity based on pollination habit of crops. Different variety maintenance procedures have been described by various authors for both self-and partially cross-pollinated crops (Bishaw and van Gastel, 2007) and cross-pollinated crops (Maize Program, 1999).The number of ears or plants used for maintenance can be determined by the number of plants that can adequately represent a variety and the amount of seed required to meet future needs such as the number of generations to be multiplied, the multiplication factor and the quantity of certified seed required, which can be adjusted accordingly.

Self-pollinated crops (e.g. wheat)

For strictly self-pollinated crops such as wheat an ear-to-row (and row-to-plot) method is the common variety maintenance procedure (van Gastel *et al*., 2002). Ears typical of a variety are collected from 'parental material', threshed individually and planted in ear-rows. Each row is inspected separately for any off types during the entire crop growth period; and rows with off types would be discarded entirely. Individual ears will be collected for next cycle of maintenance whereas the remaining rows will be bulk-harvested as 'breeder seed'. In case ear rows have some level of variation, the seed harvested from each row will be advanced into a plot (row to plot) and inspected further where similar procedures are followed as for ear rows. The seed from uniform plots will be bulk-harvested and can be sued as 'breeder seed'. The bulk harvested seed will be multiplied into pre-basic seed. For crops like chickpea and lentil, plants instead of ears can be used for variety maintenance (Bishaw and van Gastel, 2007). Each plant will be handled separately and planted in rows and inspected where the same approach is followed as for ear rows explained earlier, both for variety maintenance and breeder seed production.

The number of ears used for maintenance can be determined by the number of generations, the multiplication ratio and the quantity of certified seed required. Oka (1975) has suggested that the population suitable for maintenance of seed production of a commercial crop of self-pollinated crops should be 300. However, for various seasons more ears or plants which are typical of the variety are selected, and used for variety maintenance and breeder seed production.

Partially cross pollinated crops (e.g. faba bean)

Faba bean is partially cross-pollinated crop with up to 33% out-crossing where the 'rest seed' method can be used (Bishaw and van Gastel, 2007). A small plot of parental seed is planted under strict isolation (≤ 800 m) where the plot is inspected and off types is rogued before flowering to prevent out-crossing with true-to-type plants. Isolation can also be ensured using breeding cages. About 100–200 plants that exhibit all varietal characteristics will be selected and threshed individually and further discarded based on off types of seed characters (first year).

After selection, the harvested seed of each plant is divided into two parts: one part is used to plant the progeny rows (part 1) and the remaining seed will be stored (part 2).A progeny test is planted (part1) as individual progeny rows which are closely examined and rows with offtypes/diseased plants/seeds are discarded before and after harvest (Year two). Based on results of progeny test, the stored seed (part 2) is planted as individual progeny rows where strict inspection is carried out before and after flowering and deviating progenies and off types are removed. Material for the next cycle of variety maintenance is selected before bulking the seed of selected progeny rows as breeder seed. Plant the small plot to start the next cycle of variety maintenance and sow the breeder seed to produce pre-basic seed.

Cross pollinated crops (e.g. maize)

Maize is an open-pollinated crop exhibiting high genetic variability. Important consideration during maintenance and different phases of seed production of an OPV is the number of plants or ears required to adequately represent an OPV and the quantity of seed required of a given phase to meet its future needs (Maize Program, 1999). The number of plants or ears to represent an OPV depends on the genetic variability present within the OPV. Theoretical and practical experiences indicate that 100-200 plants or ears would normally be sufficient to represent an OPV and provide adequate breeder's seed and seed of the progenitors of the breeder's seed for future maintenance and seed production (Maize Program, 1999).

Bulk pollination or half-sib ear-to-row crossing block is practiced as described below (Maize Program, 1999).In bulk pollination about 1,000 plants can be grown from the F2 seed bulk or from a balanced bulk of the ears saved as progenitors of breeder's seed (parental or nucleus seed). About 400-500 plants that fit the phenotypic description of the variety are selected and pollinated by bulked pollen harvested from the selected plants. At harvest, 100-200 ears, meeting the ear and kernel characteristics of the variety, are selected from these selected plants. A seed bulk of equal quantity from each ear is prepared to be used as breeder's seed. Approximately 50-75 seeds from each selected ear can be saved separately to serve as progenitors of breeder's seed for use during future varietal maintenance and seed production. In the half-sib ear-to-row crossing block the F2 seeds saved as progenitors of breeder's seed are planted in ear to-row as females and their mixture as males at a ratio of 2 or 3:1. All female plants and 20-30% of male plants are detassled. Select 400-500 plants in 50% of ear-rows and 100-200 ears from them and bulk equal quantities of seed from selected ears to use as breeder's seed. Save 50-75 seeds from selected ears, separately, to serve as progenitors of breeder's seed.

Alternative approaches for variety maintenance such as varietal purification (Bishaw and van Gastel, 2007) or mass selection- positive or negative selection (Almekinders and Louwaars, 1999) have been suggested to address some critical gaps in early generation seed production.

Pre-basic and basic seed production

The breeder seed produced under the maintenance program can be further multiplied into pre-basic seed. The pre-basic seed can be multiplied into basic seed which can be used for large-scale certified seed production. These two generations are subject to official seed quality assurance where the seed fields are inspected and the seed lots are tested against prescribed national field and seed standards and approved by the seed certification agency. NARS should work closely with the seed certification agency to maintain the seed quality of pre-basic and basic seed during EGS production.

Legal framework and institutional arrangements for EGS production

Legal framework for EGS production

The progressive development of the formal seed sector in Ethiopia is described elsewhere (Bishaw and Atilaw, 2016). The development of the national seed industry policy in 1993 streamlined the seed sector and the Seed Proclamation 2000 introduced systematic generation control and prescribed field and seed standards for different seed classes (FDRE, 2000; ESA, 2012). The Seed Proclamation 2013 recognizes four seed classes which conform to the OECD nomenclature (Table 1) except the Quality Declared Seed (QDS). The proclamation defines the seed classes and explicitly elaborates the production and access to breeder seed. It gives, MoANR the authority for registering varieties in National Variety Register and appointing persons responsible for maintaining varieties in the event of failures by the breeders. Moreover, the proclamation states that any seed producer holding a certificate of competence may, subject to any other applicable legislation, access breeder seed, pre-basic seed and basic seed of registered varieties. This opens new opportunities for both public and private sector to enter EGS to overcome the seed shortage.

The Ethiopian Plant Breeder's Right Proclamation (No 481/2006) accepted unequivocally the notion of intellectual property protection of new plant varieties (Bishaw et al, 2008; Bishaw and Atilaw, 2016). Technically, it grants the rights of plant breeders or breeding institutions to protect their varieties but also the responsibility for variety maintenance and EGS production and supply. The protection can be enforced by licensing and/or a royalty collection system on seed use of protected varieties. This may provide economic incentive for an effective EGS production and supply.

Table 1: Seed classes for production and certification in Ethiopia

No.	Seed class	Certification tag
1	Breeder Seed	White, violet mark
2	Pre-basic Seed	White, violet mark
3	Basic Seed	White
4	Certified Seed 1st generation	White, blue mark
5	Certified Seed 2^{nd}-4^{th} generation	White, red mark
6	Quality Declared seed (QDS)[1]	Green background

Note:[1]QDS is not part of OECD seed scheme and not require strict generation control

Institutional arrangements for EGS production

Historically upon a release of a variety, a designated maintainer is ascertained to ensure regular seed supply. Technically a breeder or his designated agent or a breeding institution is assigned the responsibility for variety maintenance and EGS production. During the 1980s EIAR (ex IAR) has limited capacity and experience in EGS production. From the outset, the ESE has recognized the bottleneck in EGS production and established two basic seed farms at Gonde-Eteya (ESE, 1994) and Awassa-Shallo for pre-basic and basic seed production to meet its own needs. The enterprise multiplies further the basic seed on contract to produce commercial seed for distribution to farmers.

In Ethiopia, to date, the national variety register includes the name of a variety maintainer, and usually NARS which bred the variety are legally and technically responsible for maintenance and breeder and pre-basic seed production of public-bred varieties while the public and/or private seed enterprises are mainly involved in basic and certified seed production. Both public NARS and foreign private seed companies are producing the EGS while small to medium domestic private seed companies, however, rely on public institutions (NARS and seed enterprises) for EGS supply.

EIAR started systematic EGS production after the country has formulated the national seed policy in 1993. The major changes achieved were the establishment of the farm management units which is involved in seed production in ARCs of EIAR. Currently, the Technology Multiplication and Seed Research Directorate (TMSRD) of EIAR is responsible for EGS production (breeder, pre-basic, and to a lesser extent basic seed) and carry out research on seed technology. Similar trends can be observed elsewhere in Africa (e.g. Bockari-Kugbei, 1994 in Ghana), Asia (e.g. MoA, 2012 in India) and South America (e.g. Jacobs and Gutierrez, 1986 in Argentina; Lopez-Pereira and Filippello, 1995 in Brazil; Choto *et al*., 1996 in Salvador) where public NARS are responsible for EGS production and supply.

Demand assessment and production planning of EGS

Demand assessment is an essential component in seed production planning and depends on many factors, including the price of seed available from alternative sources, farmers' incomes, preferences, and crops (Alemu *et al*., 2008; Louwaars and Boef, 2012; Rubyogo, Sperling *et al.*, 2010; Tripp, 2006).

Demand assessment of EGS: The production of EGS is dependent on demand for certified seed at a national level. In Ethiopia, demand assessment for certified seed is carried out by the Ministry of Agriculture and Natural Resources (MoANR) through the regional Bureaus of Agriculture (BoA) based on the area sown by different crops and the seed replacement rates achieved in each Regional State. Demand for certified seed is first collated from individual farmers at *Kebele* administration level by development agents and summarized for each district by Office of Agriculture. Aggregated data from the districts will pass on to zonal and then on to regional offices. The demand for regional states will be submitted to the federal MoANR. Currently the process for assessing seed demand from farmers and subsequent seed production targets are often inconsistent and inaccurate, leading to under or overestimation of demand (Alemu and Bishaw, 2016).

The MoANR ensures that the certified seed demand is met to the maximum extent possible working through the National Seed Production and Distribution Technical Committee (NSPDTC), drawn from MoANR, EIAR and ESE hosted by the Ministry itself. The NSPDTC will discuss the demand and production and distribution plan with senior policy makers of MoANR, public and private seed-producers, Agricultural Extension Directorate and EIAR. During the meeting, the amount of certified seed produced is decided based on crop area and production targets set by estimated seed replacement rates; and the amount for each seed class is calculated backwards. The quantity of breeder seed produced is based on the amount of pre-basic seed required; and the basic seed produced is based on the certified seed requirement of the country.

Planning EGS production: According to the certified seed demand, the actual need of EGS to be multiplied by different federal agricultural research centres is planned and communicated to EIAR by the NSMDTC. The TMSRD facilitates the allocation of EGS production to the different centres of EIAR based on the capacity and the availability of breeder seed of a particular variety. A memorandum of understanding (MoU) is signed between EIAR and regional Bureau of Agriculture (BoA) one year ahead of the production season on behalf of all seed producers in the respective regions. After the seeds are multiplied by EIAR, the quantity is compiled by TMSRD, and communicated to NSMDTC.

A similar but independent procedure is followed for EGS planning at the Regional Agricultural Research Institutes, though the planning process starts from the Farm Management Team at ARCs and discussed and reviewed with the management of the centers. Furthermore, the plan is reviewed and discussed at the regional level for final approval. The planning is based on the demand collected from regional BoA or seed users in the previous year.

Currently factors considered in planning EGS and certified production is as shown in Table 2. It takes into account several factors including climatic conditions and rejections and losses during field operations, seed processing and laboratory testing.

Table 2: Factors considered in planning EGS and certified production

Factors	Class of seed			
	Breeder	Pre-basic	Basic	Certified
1. Loss of area due to				
• Drought, pests, etc.	10%	10%	10%	10%
• Field rejection	0	0	5%	20%
2. Loss of seed during				
• Processing	5%	10%	15%	20%
• Laboratory testing	0	0	5%	10%

Source: ESE, 1994

Allocation and distribution of EGS

The NSPDTC, allocates the available EGS from EIAR to seed producers based on the MoU signed between EIAR and regional BoA and demand from other seed producers. The breeder seed produced is primarily provided to the Ethiopian Seed Enterprise whereas the pre-basic and basic seed is allocated to regional public seed enterprises (Amhara, Oromia, SNNRP), Tigray Bureau of Agriculture or private seed producers. If the EGS is produced with the support of projects, it is provided to the projects for specific activities unless otherwise there is shortage to meet the demands by seed enterprises. Part of the remaining EGS is used for research, demonstration or multiplication by respective EIAR and RARIs, HLIs and NGOs which support local seed production (Figure 1).

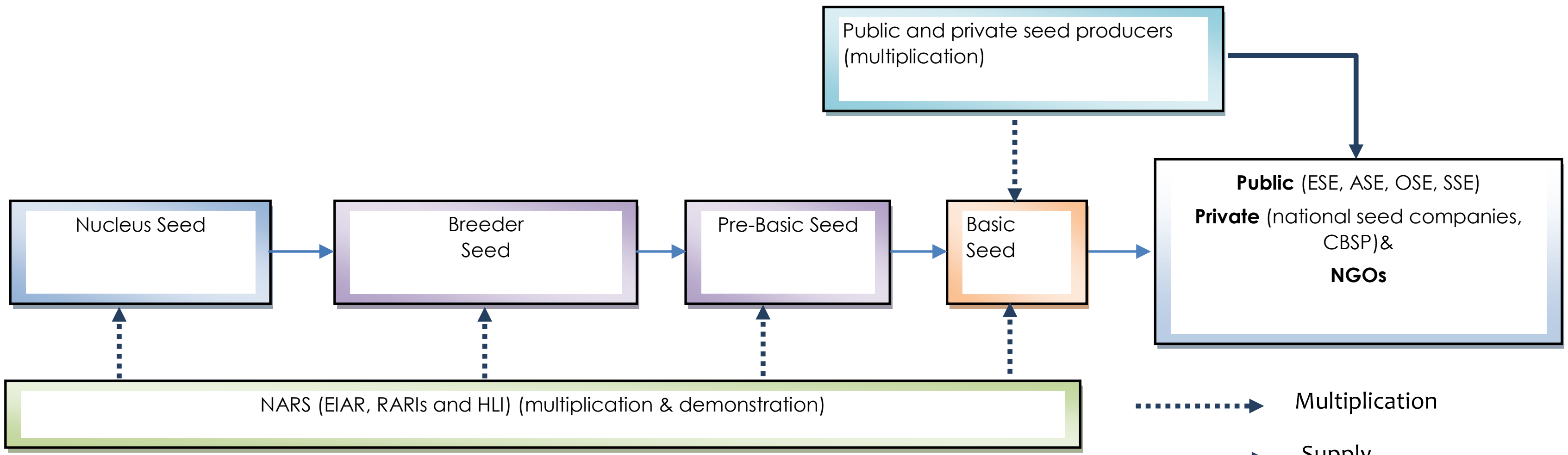

Figure 1: EGS production and allocation
Source: Modified from Abebe, et.al. 2012

Technical procedures in EGS production

EGS multiplication

Applying the recommended technical procedures and agronomic management practices (Bishaw et al, 2006) during variety maintenance and seed production would ensure producing EGS of highest varietal purity and identity and seed quality. This include observing the basic principles of seed production such as seed source, cropping history, isolation, roguing, cleaning, treatment, storage and quality assurance during EGS production.

An optimum crop management practices need to be applied to achieve maximum economic multiplication to reach the highest multiplication factor (MF) - the ratio of yield and seed rate per unit area. The MF can be influenced by the soil fertility and agronomic management practices. The use of low seed rates and use of irrigation to increase productivity or to advance generations are critical for accelerated EGS production. For example, the MF for maize, sorghum, tef, rapeseed and sesame is higher than other crops making it easy to multiply and supply EGS on a limited available land of NARS. On the other hand, the MF for faba bean, field pea and chickpea is low, making EGS supply for these crops difficult on limited land area.

EGS reserve stock

Keeping enough reserve seed stock to guard against losses from crop failures is well recognized in a seed production program. The reserve seed stocks will help ensure the continuity of seed production program in case of natural calamities such as drought or pest outbreak which may lead to total crop failures. Sufficient reserve seed stock of parental material (nucleus seed), breeder seed, and pre-basic seed should be kept under cold storage sufficient for planting for at least two years. Cold storage facilities for breeding materials and EGS are necessary to mitigate the risks.

Available varieties for EGS production

There arepublic sector national crop improvement programs for major agricultural (cereals, legumes, oilseeds, industrial (cotton), tuber and roots) and horticultural (vegetables, fruit trees and aromatic-spices, medicinal) crops (Table 3). Few private seed companies are collaborating with NARS in introducing, testing, releasing and registration of agricultural and horticultural crop varieties.

EIAR is the major source of nationally registered improved varieties while RARIs have released several varieties with specific regional adaptations. Until 2014, about 960 varieties were recommended or released (Table 3) although old varieties from 1970s are still multiplied by some seed producers. This may be due to lack of coordinated action in promoting new improved varieties by the research, extension and seed suppliers and lack of mechanism to drop obsolete varieties (Teklewold and Mekonnen, 2013). Even though, the number of released varieties is considerably high, the variety for which EGS is multiplied is very low. This is associated with the fact that the EGS multiplication is done based on revealed demand from seed producers.

Table 3: Number of varieties released by public and private sector (selected crops)

Crop(s)	Total	Private sector	% Private sector	No of varieties under EGS production (2015)
Cereals (6)	319	29	9	99
Legumes (7)	186	2	1	51
Oilseeds (5)	85	17	20	13
Tuber crops (2)	61	6	10	-
Vegetables (17)	120	63	53	-
Fruit trees	41	4	10	-
Condiments and Medicinal plants	40	3	8	-
Cotton	26	7	27	-
Forage and pasture	33	1	3	-
Total	**911**	**132**	**14**	**163**

Source: MoANR, 2016

Seed quality assurance

Early generation seed is expected to meet high standard of varietal purity and seed quality attributes prescribed by the national seed regulations (ESA, 2012). This includes field standards to maintain varietal purity and identity and seed standards in terms of physical, physiological and health quality. The former is ascertained by field inspection while the latter through laboratory seed testing. Applying the recommended technical procedures and agronomic management practices (Bishaw *et al*., 2006) during variety maintenance and seed production would ensure producing EGS of highest varietal purity and identity and seed quality.

All early generation seed except a breeder seed, expected to be of the highest seed quality standards, the subsequent generation of pre-basic and basic seed need to be inspected, tested and approved by the seed certification agency. The regional seed regulatory agencies in consultation with EIAR and its affiliated ARCs are responsible for quality assurance of EGS in the respective regions.

Achievements in EGS production

EGS production and supply by NARS

The National Agricultural Research System (NARS) is given the responsibility to produce and supply EGS of varieties that are released by the federal and regional public research system. According to the seed production plan, different EGS classes are multiplied by the respective ARCs based on the capacity and agro-ecological suitability of the crops. Most of the national crop improvement programs are coordinated by the EIAR and each program at respective ARCs has the responsibility to produce EGS.

Table 3: Amount of EGS production (pre-basic and basic seed) in tones by EIAR

Year	Maize	Bread Wheat	Durum Wheat	Barley	Faba Bean	Mustard	Haricot bean	Sorghum	Tef	Chickpea	Lentil
2001	265.30	278.91	52.00	3.88	27.54	51.93	57.54	29.57	61.00	17.00	1.50
2002	151.40	263.18	48.00	5.78	10.92	31.05	3.89	8.01	52.40	8.00	0.80
2003	178.80	655.04	45.20	4.15	59.46	104.69	89.99	59.85	59.10	10.00	0.50
2004	147.10	573.65	8.90	1.05	75.52	89.40	50.25	82.01	49.10	9.60	0.10
2005	243.00	461.81	27.20	6.00	49.05	89.36	74.29	35.59	45.00	13.60	-
2006	252.60	437.95	18.90	10.73	76.14	67.34	78.22	24.38	18.80	-	-
2007	234.00	440.83	20.20	15.98	56.92	62.14	70.73	29.24	88.10	-	14.74
2008	241.80	363.45	9.90	63.57	64.50	33.04	66.33	20.60	45.10	34.70	-
2009	236.00	286.07	5.50	111.16	72.07	3.95	58.58	35.25	69.20	66.60	-
2010	467.00	420.35	2.80	37.56	41.14	5.40	50.84	49.90	94.00	56.10	1.15
2011	248.49	273.71	17.50	17.99	16.50	1.51	96.37	8.19	90.70	47.50	3.15
2012	287.38	555.97	20.10	20.18	10.71	9.50	26.85	4.76	88.50	52.50	6.18
2013	63.30	603.80	24.50	13.21	14.91	20.80	62.75	-	87.30	63.90	7.35
2014	12.06	475.78	46.30	33.38	76.77	213.13	58.66	8.70	38.40	34.30	2.90
2015	215.66	203.74	11.70	10.83	20.98	90.70	16.60	12.19	58.10	-	0.85

Source: EIAR Technology Multiplication and Seed Research Directorate (2016)

From the outset, EGS production by EIAR is focused on major cereals and few legumes and oilseed crops (Table 4). Wheat, barley, tef, maize and sorghum are the main crops among cereals while haricot bean, chickpea, lentil and faba bean are from the legumes. The oilseed crops include rape seed (mustard) which is the main rotation crop for large state farms.

There are 17 ARCs under EIAR at four regional states working on major agricultural (cereals, legumes, oilseeds, fiber, forages) and horticultural crops (vegetables, fruit trees, spices, and aromatic, medicinal). To date, ARCs has 1756.4 ha of land for research and EGS multiplication. Out of this area, 751.44 ha of rainfed area and 156 ha of irrigated area is allocated for technology multiplication where a major part of the seed is produced through federal research centers located at the different agro-ecologies of the country.

For cereals, the current EGS production is sufficient to meet the projected certified seed replacement of major crops, if the recommended procedures are followed using standard multiplication rates. However, early generation seed demand for pulse crops cannot be fulfilled due to very high seed rates and low multiplication factors. The EGS production also cannot met the demand because of inadequate varietal choices preferred by diverse group of farmers in different agro-ecological domains and socioeconomic settings. In addition, inadequate planning and unregulated distribution and lack of incentives for production/marketing are some of the constraints.

The requirement of EGS is based on the amount of certified seed derived from crop area estimates using backward calculation. The requirement of breeder and pre-basic seed is expected to increase to 5,400 tons by 2020 with emphasis on improving seed quality and varietal choices, both for seed suppliers and users.

EGS production and supply by ESE

The Ethiopian Seed Corporation (now ESE) was established in 1979 to produce and distribute quality seed of improved varieties to meet the national seed requirement of state farms, producer's cooperatives and private farmers. From the outset, the enterprise recognized the bottleneck in EGS production and established two basic seed farms at Gonde-Eteya and Awassa-Shallo for pre-basic and basic seed production. The enterprise multiplies further the basic seed on contract to produce commercial seed for distribution to farmers.

Currently, ESE produces pre-basic, basic and certified seed of 25 crops and 137 varieties. The enterprise produces basic seed in its seed farms located in Gonde-Eteya, Hawassa-Shallo, Ardayita, Chagni and Kunzila farms. The basic seed is further multiplied to certified seed on its own farmers or through contractual agreement with state farms, private farms and farmers. The figures below demonstrate the pre-basic and basic seed production of ESE during the last 10 years (Table 5). Its contribution to the EGS supply especially for basic seed is considerable.

Table 5: Amount of pre-basic and basic seed produced by ESE (2006 – 2015)

Cropping season	Pre-basic seed (t)				Basic seed (t)			
	Cereals	Pulse crops	Oil crops	Total	Cereals	Pulses	Oilseeds	Total
2006	119	24	4	147	1,279	165	16	1,460
2007	168	27	4	199	1,798	140	13	1,951
2008	228	44	4	275	2,210	209	26	2,444
2009	288	54	7	349	3,669	172	35	3,876
2010	536	84	9	629	3,594	235	144	3,973
2011	613	36	6	655	7,469	308	85	7,862
2012	419	49	7	475	2,948	231	60	3,239
2013	180	34	6	219	3,307	248	132	3,688
2014	308	31	2	341	2,828	228	75	3,131
2015	2,858	383	49	3,290	4,997	149	93	5,239

Source: ESE (2016)

Comparative analysis of experiences in EGS production and implications for Ethiopia

Laverack (1994) presented four different options for integration of variety development and EGS and commercial (certified) seed production. He strongly proposed for the creation of an autonomous 'Breeder Seed Unit' with the main task of EGS production to ensure availability and access by commercial seed producers. The BSU can be established within plant breeding program or within commercial seed production or as an independent specialized self-sustaining entity linking variety development program and commercial seed production.

Experiences from Kenya and India and elsewhere in Africa, Asia and Latin America also clearly demonstrated the need for institutionalization of EGS production (Table 6). In India, seed companies may produce their own EGS of public bred varieties, or may acquire it from public research institutes, universities or state seed corporations (MoA India, 2012). In Brazil, the EMBRAPA, the national research institute, produces and provides EGS for hybrids and open-pollinated public maize varieties to a group of small private seed companies and co-operatives (Lopez-Pereira and Filippello, 1995). The national research institute provides EGS to a co-operative (PRODUSEM) that produces and markets the seed (Jacobs and Gutierrez, 1986). CENTA, the national research institute of El Salvador, provides EGS of maize hybrids to private seed companies and cooperatives (Choto et al 1996). In Ghana, however the Crops Research Institute is responsible for plant breeding, but another organization, the Grains and Legumes Development Board, produces EGS and provides seed to small commercial seed producers (Bockari-Kugbei 1994).In Egypt, for example a Basic Seed Farm of Agricultural Research Centre is fully dedicated for EGS production compared to Pakistan where NARS are responsible for breeder and pre-basic seed production and the Punjab Seed Corporation is responsible for basic seed production and supply to all public or private seed companies (this is currently under review and amendment).

In Ethiopia, the public sector i.e. federal and regional agricultural research institutes, are the major sources of improved crop varieties with little contribution from the private sector, mainly of foreign sources. Commercialization of public-bred varieties remain the big challenge due to lack of clear policy guidance, overlapping institutional responsibilities and binding contractual agreement in EGS production and supply. There is an overlapping arrangements for EGS production between NARS and seed producers, the example being the involvement of NARS and ESE in both pre-basic and basic seed productions. Therefore, institutionalization of EGS production and supply is a must defining the institutional arrangements and assigning the lead and supporting roles and responsibilities to both public and private sector NARS and seed suppliers at the national level is critical for sustainable EGS production. Currently, NARS are focusing on breeder and pre-basic seed production and the ESE on both pre-basic and basic seed productions. It is suggested that in the future NARS will concentrate on breeder seed production whereas ESE along with regional PSEs on pre-basic and basic seed production as they develop technical skills (MoA 2007).Practical experience shows that the responsibility of EGS production may initially have to stay with public institutions, as they are the major sources of improved varieties. The experiences from Kenya and India however show a strategy of moving EGS into a self-sustaining commercial and competitive enterprise. However, any full cost recovery from the program may not be feasible where some government support is desirable for some crops. In addition, joint planning among NARS and seed producers is critical for effective EGS production and supply. In India, the 'breeder seed indent' forum brings together all federal and state level seed sector stakeholders for joint planning of breeder seed production and subsequent generations well ahead of time based on anticipated demand. A national forum of seed producers, EGS providers and plant breeders should be established for such purpose. Such EGS forum for joint annual planning would help in improving the availability of EGS in a sustainable manner in Ethiopia. Related to the current capacity NARS may not able to produce all crop varieties demanded by the users. It is important to decentralize EGS production particularly for public varieties bred by the federal system. RARIs and the private sector may play an important role to meet regional demand for EGS by the public or private sector. There is also a need to develop a mechanism for licensing public bred varieties to the private sector through public-private partnership. It is important to note that EGS production is a specialized task and requires adequate physical, financial and human resources. NARS are operating on a limited budget support from the government and bilateral projects. In 2015, about ETB 33.8 million (about 7% of total EIAR budget) was allocated for the maintenance, multiplication and distribution of EGS (EIAR, 2015). However, adequate fund allocation is necessary to produce sufficient amount of EGS to meet the ever growing certified seed demand in the country. As indicated above, the land holdings for EGS productions are not sufficient and address all agro-ecologies of the country. Therefore, there is a need to have additional land or designate existing government farms for variety maintenance and EGS multiplication. Moreover, all ARCs lack basic infrastructure where adequate facilities such as farm machineries for land preparation, planting and cultivation as well as equipment for harvesting and post-harvesting such as combiners, seed cleaning and treatment machines are essential. Irrigation facilities for accelerated seed multiplication, mini seed laboratories for quality assurance and storage facilities are needed. NARS also do not have sufficient professional staff specialized in seed science and technology. Besides, there is little or no formal seed technology research to address seed quality issues in the country. The current situation is likely to change with expected recruitment of qualified personnel for each ARC. However, a well-planned short and long-term human resources capacity development should be in place. NARS could help to train the public and private seed enterprises in EGS production and management. With the new Seed Proclamation (FDRE,2013), the variety release and seed quality control directorate of MoANR should place more emphasis in establishing and ensuring that adequate field and seed standards are established and the quality of EGS maintained. As stated earlier, while breeder seed is not subjected to quality assurance, both the pre-basic and basic seed production should be subject to certification and must meet the field and seed standards.

Table 6: National and international experiences in EGS production and supply

Criteria for comparison	**Kenya**	**India**	**Ethiopia**
Institutionalization	Seed Unit (KSU) under KARI; and linked to SIDUs to support local seed production	National Seed Program under ICAR; 34 seed production units of IARI and SAUs	TMSR under EIAR; and16 TMSR units at ARCs
Budget allocation	Operates on cost recovery	Operates on cost recovery	Allocated budget from government and projects
Roles and responsibilities in EGS	Produce breeder, pre-basic and basic seed and planting materials Maintains pre-released and released parental lines, populations and varieties Sells breeder seed to public or private seed sector and basic seed to informal sector	Provides financial support for infrastructure for breeder seed production Maintenance of varieties Supports seed research including molecular detection kit for varieties and hybrids	Produce breeder, pre-basic and basic seed Conducts seed research to support seed production and quality assurance
Support to informal seed sector	Build capacity of farmers to produce quality farm saved seed	Creates awareness of quality seed among farming communities in tribal areas through its networks	Provide basic seed to development projects involved in local seed production and scaling up/out
Weaknesses	NA	NA	Poor facility; insufficient staffing and limited seed technology research

Source: Adapted from Glover et al. 2015

Key challenges and opportunities of EGS production

Challenges

Despite five decades of development initiatives, availability of and access to good quality EGS at the right time and place has been one of the major constraints in the seed value chain. Bishaw and Atilaw (2016) identified four principal issues that are important for streamlining EGS production by the federal and regional national agricultural research systems: adequate variety maintenance, coordinated breeder seed production plan, decentralized multiplication and quality assurance. The main issues that hinder EGS production and supply in addition to the need for institutionalization stated above are outlined in Table 7.

Table 7: Challenges in EGS production

Challenge	Reasons
Limited demand for EGS of newly released varieties	Limited incentive for certified seed producers to create demand for new varieties
	Limited demonstration and popularization of new varieties
Limited EGS production capacity	Limited land for EGS multiplication
	Limited facilities (machinery, storage, irrigation and equipment) Lack of sufficient knowledge and skilled staff
Limited access to EGS	Limited EGS production by other actors (private and public sector)
	No provisions for exclusive right or use license
Low quality of EGS	Weak capacity of regional quality control bodies
Weak MoU and enforcement mechanisms	MoU not legally binding and enforced
Lack of incentives for EGS production	No appropriate incentives in the national seed systems for both breeding institutions (e.g. royalty) and staff (e.g. motivation)particularly in public institutions

Opportunities

Enabling policy environment: The national seed policy and regulatory framework provide an enabling environment for the seed sector development. It provides incentives for public and private sector, setting standards for seed production and quality assurance; and supporting the development of infrastructure, inter alia. In addition, the intellectual property rights provide plant breeders the rights to protect their varieties without contravening farmer' rights to save their own seed and to register their varieties.

Strong institutional support for quality seed production: The Ethiopian government has strong commitment to support EGS production. Public agricultural research and plant breeding has been reinvigorated and directed towards the needs of farmers. Community initiatives are also made important contributions to seed development.

Modernization of agriculture and increased seed demand: An enabling government agricultural policy led to the development of the agriculture sector and created huge demand for improved seed which continues increasing over time. The development of the agriculture sector determines the range and types of seed that farmers' demand and the realignment of government responsibilities in the seed sector.

Favorable opportunities for collaborative research partnership: One of the characteristics of seed provision is the need to link public, private and commercial partners. Government policies and specific projects are needed to strengthen, develop, and use linkages with national and international institutions and academia. Currently, the role of public sector is relatively high in wheat seeds (e.g. PSEs), while share of private sector is higher in maize and vegetables. It is expected that the role of public sector in seed multiplication will decline as private and community sectors start growing faster.

Capacity building initiatives: The provision of facilities for seed laboratories for NARS and the initiatives on seed technology training by higher learning institutions such as

Haramaya and Bahir Dar Universities could benefit the overall human resources development needs of the country.

Conclusion and Recommendations

The diversification of certified seed supply for public bred varieties depends on establishing a sustainable strategy for EGS production. In Ethiopia, to date the responsibility for EGS production is shared between public NARS and public seed enterprises. NARS are involved from variety maintenance to basic seed production while some PSEs produce pre-basic and basic seed. There are also trends to allow private seed companies to get access to breeder seed to produce their own pre-basic and basic seed of public-bred varieties. There are some ambiguities and overlapping responsibilities in EGS production and supply which need to be streamlined based on different options.

First and foremost, it is important to clearly define what constitute the EGS in the national seed sector context, and then determine the roles and responsibilities of each institution in EGS production at the federal and regional levels among NARS and public and private seed producers.

Second, there is a need to establish an autonomous seed unit within NARS at federal and/or regional levels. The unit should have adequate physical, human and financial resources to undertake the full responsibility for planning and production of EGS in liaison with seed producers. It should have access to farm machinery for field operations and infrastructure for post-harvest operations and should operate in locations with favorable climatic conditions that permit the use of resources on an economic scale. Therefore, to strengthen the seed unit at EIAR in particular or NARS in general the following interventions are needed for EGS production:

Firstly, allocation of additional land is crucial as current land holdings for research and EGS production of NARS is very limited and competition for land between research and EGS production; secondly, strengthen the infrastructure (irrigation, storage), farm machineries for field operations(tractors, cultivators, combiners, threshers) and equipment for post-harvest operations (cleaners, treaters, seed quality laboratory) are needed; thirdly, strengthen human resources capacity by employing experienced and skilled staff and provide relevant training to enhance capacity of researchers and technicians; fourthly, allocation of sufficient budget for operations and create a mechanism to retain sales of EGS to ensure sustainability; fifthly, demand creation for newly released varieties through popularization and demonstration in partnership with other stakeholders; sixthly, introduce appropriate agricultural technologies (crop diversification, improved cropping systems, integrated crop management, storage management); seventhly, strengthen the seed quality laboratory to undertake the internal regulatory oversight for EGS production and eighthly, improve the monitoring and evaluation of EGS system and undertake a review and reform as desired during the implementation.

Different management options for breeder seed production are available, and could be adopted in developing countries. It would be helpful to integrate a breeder seed unit into plant breeding and seed production as in the private sector, or create a separate unit within the breeding institutions or seed producing organizations. Alternatively, an independent unit could be established, with a clear mandate to take over this responsibility.

Third, there is lack of adequate need assessment for EGS production which is critical for national seed supply. Consultation among NARS and seed producers is necessary for effective and efficient EGS production and supply. It is recommended to establish an EGS platform for annual planning among seed producers, EGS providers and plant breeders. Such an EGS forum would help in improving the availability of EGS in sufficient quantity and quality and in sustainable manner.

Fourth, the Plant Breeder's Right Proclamation (No 481/2006), grants breeders or breeding institutions the right to protect their variety and can be enforced using a licensing mechanism and/or by designing an effective mechanism for royalty collection. It is time to take some initiatives and provide implementation guidelines to enforce PVP. This will encourage and provide incentive for both public NARS and the private sector to investment in EGS production and supply.

Fifth, given the critical role of EGS, in maintaining high standards of seed quality it deserves special attention during production. Seed regulatory and quality control agencies should place emphasis on ensuring that adequate standards and procedures are established and enforced for EGS production through self-regulation or external control.

A recent study commissioned by ATA identified EGS production arch types, priority crops, the economic incentives and the recommended interventions. It classified crops based on potential options for EGS production by the public, private or a combination of both. It is anticipated that the future strategy for EGS production is to provide economic incentives to become a sustainable commercial operation. Moving EGS production gradually towards greater financial independence would improve the availability and quality of EGS. However, any full cost recovery from the program at least in the short-term may not be feasible where some government support is desirable. Implementing the recommendations of the EGS study is the way forward to achieve the desired goal.

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