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Yield Performance and Adoption of Released Sorghum Varieties in Ethiopia

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Abstract

Sorghum national average productivity in Ethiopia is 2.1 tons/ha which is far below the global average of 3.2 tons/ha due to the problem of drought, striga, insect pest (stalk borer, midge, and shoot fly),diseases (anthracnose and smut), soil fertility decline, inadequate adoption of existing improved varieties, lack of high yielding and good quality sorghum varieties. The Ethiopian government is pursuing a strategy of improving Sorghum productivity primarily through agricultural intensification, involving an increased use of inputs, including seeds of improved crop varieties and involved sorghum plant breeding since 1976 with different objectives and released many improved sorghum varities. However the yield performance, adoption intensity and adoption rate of the released sorghum varieties at regional and national level were not well studied. So this research intiated with the following objectives:

- To summarize the trend of sorghum production and productivity in Ethiopia.
- To asses performance of improved sorghum varieties yield and their level of adoption.
- To evaluate factors that determines adoption of improved sorghum in Ethiopia.

The assessment was also done using secondary data from different sources. So, as a conclusion to increase the adoption rate and intensity of the released sorghum varieties across their suitable agro ecology and based on the objective of the target improved sorghum varities at the time of variety registration, agricultural extension should be strength and linkage between the department of integrated crop improvement with socio economics and agricultural extension should be improved. With this at variety development farmers better to participate and include their selection criteria, interest, problem and increase adoption of the improved sorghum varieties. Socio economic, demographic and institutional factors also played negative impact on slow adoption of the improved sorghum varieties.

Keywords: Improved, Varieties, Sorghum, Adoption.

Introduction

Sorghum [*Sorghum bicolor (L.) Moench*] is classified under the family Poaceae (grass family), tribe andropogoneae, genus bicolor, species bicolor [1]. It the fifth most important staple food crop after wheat, rice, maize and barley [2]. The world average annual yield for sorghum was 1.37 tonnes per hectare in 2010. FAO reported the United States of America as the top sorghum producer with a harvest of 9.7 million tones followed by India, Nigeria, Sudan, and Ethiopia. The productivity of sorghum varies across the different parts of the world. Doggett (1988) suggested that sorghum was domesticated and originated in the northeast quadrant of Africa, most likely in the Ethiopian-Sudan border regions. The presence of wild and cultivated sorghums in Ethiopia reveals that Ethiopia is the primary center of origin and center of diversity [3]. Given the diversity of sorghum, studying genetic diversity (Ayana, 2001) and biochemical composition of sorghum germplasm from Ethiopia is very important for several reasons. The world average yield being 1314 kg/ha, and yield of developed countries is 3056 kg/ha and that of developing countries is 1127 kg/ha. The low productivity of sorghum in the developing countries can be attributed to biophysical, socio-economic and policy related factors affecting directly and indirectly sorghum production. One reason could be the low level of sorghum research investment in human, financial and material resources development and low input production system.

Agriculture is a driver of the Ethiopian economy [4]. It is run by small holder majority who undertake subsistence mode of life. Despite its importance, agriculture suffers from low productivity. Crops are playing a significant role and it is believed that adoption of new agricultural technologies, such as high yielding varieties, could lead to significant increases in agricultural productivity and stimulate the transition from low productivity subsistence agriculture to a high productivity agro-industrial economy [5]. Among others, seeds are critical determinants of agricultural productivity. Consequently, several improved crop varieties have been developed by the national and international research institutes and disseminated to the farmers through different programs and projects. The diverse crop varieties released that are under production in Ethiopia can be found in the Variety Register developed by the Ministry of Agriculture [6].
In sub-Saharan Africa, agricultural production is dominated by cereal-based systems, which are 97% rainfed [7]. Sorghum is the

fourth primary staple food crop in Ethiopia after tef, maize, and wheat, both in area coverage, and production [8]. In the country cereals comprise 78.23% (8.8 million ha) of the field crops of which sorghum accounts for 14.41%. In Ethiopia sorghum is grown in almost all regions occupying an estimated total land area of 1.6 million ha [8]. The major sorghum production regions of the country are Oromia at 38.5%, Amhara (32.9%), Tigray (14.1%), and Southern Nations and Nationalities People (S.N.N.P.) region (7.6%).Sorghum is usually grown in arid and semi-arid parts of the tropics and sub-tropics where it is affected by drought during various growth stages [9]. The growth and yield of Sorghum, one of the major crops in these dry land regions of Africa, is often limited by drought. In the dry land environments, drought is not only the result of limited annual rainfall, but is also due to the rainfall characteristics, mainly the delay in the onset and early cessation of the main rainfall. The damaging effect of a drought period depends on its duration, on how much water is stored in the soil and the proportion that the crop can access, and on the sensitivity of the crop development stage at that time. If agricultural systems are to be sustained in this region, the rain water and critical growth stages of crops need to be addressed simultaneously.

Sorghum appears to have been domesticated in Ethiopia about 5000 years ago. Now sorghums are widely distributed throughout the tropics, sub tropics, and warm temperate areas of the world. According to the Central Statistics Authority of Ethiopia [10], sorghum ranks third after maize and tef in total production, after maize in yield per hectare and after tef and maize in area harvested. It accounts for 19 percent of the total cereal produced in the country and covering some about 20 percent of the total area under cereals. Sorghum production has significantly increased in recent years, from 1.7 million tonnes in 2004/05 to nearly 4.0 million in 2010/11(130 percent). The national average sorghum productivity in Ethiopia is 2.1 tons/ha [8] which is far below the global average of 3.2 tons/ha. This is because of a number of factors. Several productions constraints were identified as in hindrance for sorghum production and productivity enhancement. The major constraints include drought, striga, insect pest (stalk borer, midge, and shoot fly),diseases(anthracnose and smut),soil fertility decline, inadequate adoption of existing improved varieties ,lack of high yielding and good quality sorghum varieties ,and post-harvest management practices. Ethiopia has a diverse wealth of sorghum germplasm adapted to a range of altitudes and rainfall conditions. Of the five morphological races of sorghum (bicolor, guinea, caudatum, durra and kafir), all, except kafir, are grown in Ethiopia. Important traits reported from the Ethiopian sorghum include cold tolerance, drought resistance, resistance to sorghum shoot fly, disease and pest resistance, grain quality and resistance to grain mould, high sugar content in the stalks, and high lysine and protein content.

In Ethiopia sorghum used for making injera, kitta, kollo and locally made beverages (such as Tela and Areke). Being an indigenous crop, tremendous amount of variability exists in the country. As a result, large number of accessions has been collected by the joint efforts of the Ethiopian Sorghum Improvement Project (ESIP) and the Institute of Biodiversity Conservation (IBC). Many of these accessions have been evaluated in the country and some were released as commercial cultivars for the highlands. Still others have been used in supplementing the germplasm base of the international and national agricultural systems around the globe. Gebrekidan (1973) elucidated the importance of the Ethiopian sorghum germplasm in the world collection.

The Ethiopian Sorghum Research was incepted in 1957 by Alemaya University and then, sorghum breeding activities were done in the different ecological parts of the country by different national and international organizations (Institutes). Then Up to now more than 36 improved sorghum Varieties released and the collection, evaluation, characterization and conservation were one of the primary activities. Closer to 8000 indigenous collections were made (PGRC/E, 1986). Various types of crossing programs were undertaken to solve sorghum production problems. Hence, the objectives of this study were to:

1. To summarize the trend of sorghum production and productivity in Ethiopia.
2. To asses performance of improved sorghum varieties yield and their level of adoption.
3. To evaluate factors that determines adoption of improved sorghum in Ethiopia.

Literature Review

Sorghum production and Productivity in Ethiopia

Sorghum is one of the major staple crops grown in the poorest and most food insecure regions of Ethiopia. The crop is typically produced under adverse conditions such as low input use and marginal lands. It is well adapted to a wide range of precipitation and temperature levels and is produced from sea level to above 2000 m.a.s.l [11]. Its drought tolerance and adaptation attributes have made it the favourite crop in drier and marginal areas. Ethiopian is often regarded as the centre of domestication of sorghum because of the greatest genetic diversity in the country for both cultivated and wild forms [11].

The large improvement in sorghum production is driven by both land expansion and yield improvement: yield increased from an average of 1.4 tonne/ha in 2004/05 to an average of 2.1 tonne/ha in 2010/11, increasing by 50 percent, while area under sorghum production increased by 51 percent (from 1.2 million ha in 2004/05 to 1.9 million ha in 2011. It should be noted that FAOSTAT yield and production figures during the period 2007 to 2011 are lower than the government. With this based on the report of (CSA, 2013) the production, area coverage and productivity increase in the last 15 and 10 years are presented in **Table 1 and 2** respectively.

Year	Area coverage (ha)	Production-Qt	productivity (Qt/ha)
1995	1,317,350	18,020,410	14
1996	1,399,950	29,616,500	14
1997	954,740	10,697,400	11
1998	1,042,390	13,208,410	13
1999	995,410	11,811,430	12
2000	1,332,890	15,382,810	12
2001	1,367,270	18,048,630	13
2002	1,071,957	10,397,993	10
2003	1,283,654	17,424,536	14
2004	1,253,620	17,159,543	14
2005	1,468,070	21,735,987	15
2006	1464318	23,160,409	16
2007	1,533,537	26,591,292	17
2008	1,615,297	28,043,510	17
2010	1,897,734	39,598,974	21
2011	1,923,717	39,512,942	20.54

Sources: CSA, 2012

Table 1: Sorghum Production and productivity in Ethiopia in last 15 years (1995-2011).

In those years the annual sorghum production growth rate ranged from 2.1 % (Dire dawa astedader) to 27.7% (Afar) and the average national sorghum production growth rate was achieved with 7.7 %. But, each regions of the Ethiopia regions the expansion of sorghum acreage low and the ten years mean annual growth is 4% only.

And most of regions showed decrease in area expansion at the end of interval years and indicated the increase of sorghum production and productivity was due to genetic and agronomic improvement of the crop rather than area increase. Similarly, productivity of sorghum increased in most regions and highest in Afar (8.24 %) and followed by S.N.N.P (6.09%) and mean annual growth rate of 3.48%.While, some regions were low increase in yield/ha but their yield achievement was attained to the national sorghum productivity like Amhara, Tigray and Oromia regions as shown in **Table 2** in the years of 2010/11 and 2011/12.

Sorghum is cultivated by nearly 4.5 million smallholders located in the eastern and northwest parts of the country shows Oromiya, Amhara and Tigray regions are the three major producers of sorghum covering 86.4% of the total area and 89% of the total production in the last nine years. There has been a steady expansion in area at a similar rate across the major sorghum regions at around 5% annually in terms of acreage and 7% in production. Sorghum yields in Ethiopia range close to 2 mt/ha at national level. Tigray and Amhara in the North have yield levels somewhat higher (2.1 and 2.2 mt/ha) (**Table 1 and 2**).

Year	**2001/2**	**2003/4**	**2004/5**	**2005/6**	**2006/7**	**2007/8**	**2008/9**	**2009/10**	**2010/11**	**2011/12**	**Annual growth rate%**
Production in metric tons											
TOTAL	1,565	1,742	1,713	2,174	2,316	2,678	2,801	2,970	3,960	3,950	7.7
Afar	1	3	1	1	1	21	0	0	5	0	27.7
Amhara	526	604	567	852	789	791	913	792	1,534	1,432	7.6
BG	67	54	51	72	89	95	95	133	118	111	5.1
D. dawa As	9	7	4	7	9	9	10	9	15	14	2.1
Gambella	3	0	0	4	4	5	10	9	8	5	8.6
Harari	4	4	0	5	6	7	9	7	10	15	10.2
Oromia	636	757	795	818	945	1,305	1,251	1,466	1,581	1,627	8.6
Somali	29	27	14	18	15	34	35	57	48	76	5.8
Tigray	192	194	184	293	335	271	306	281	466	474	6.5
SNNP	98	92	98	103	123	139	173	217	175	197	6.2
	Average in ha										
TOTAL	1,165	1,281	1,249	1,468	1,464	1,532	1,613	1,618	1,898	1,923	4
Afar	1	3	2	2	2	0	0	0	3	0	6.8
Amhara	415	457	412	538	481	499	547	486	711	733	3.7
BG	52	48	50	53	59	60	59	60	67	60	1.5
D.dawa As	6	7	7	7	8	7	7	9	9	9	2.7
Gambella	3	0	0	3	3	3	4	5	4	3	3.3
Harari	4	5	0	5	5	6	6	6	7	8	4.5
Oromia	437	501	522	542	563	650	677	755	739	743	5
Somali	22	31	22	30	24	34	22	33	35	28	3.2
Tigray	114	129	142	184	207	171	180	155	217	215	5.1
SNNP	109	100	92	103	111	102	111	109	108	123	0.1
	Yield in metric tons/ha										
TOTAL	1.34	1.36	1.37	1.48	1.58	1.75	1.74	1.84	2.09	2.05	3.48
Afar	0.78	0.94	0.62	0.64	0.5				1.72		8.24
Amhara	1.27	1.32	1.38	1.58	1.64	1.58	1.67	1.63	2.16	1.95	3.57
BG	1.28	1.13	1.03	1.37	1.5	1.59	1.61	2.21	1.77	1.84	3.5
D.dawa As	1.46	1.1	0.64	1.01	1.24	1.32	1.37	0.9	1.73	1.47	-0.6
Gambella	1.25			1.43	1.43	1.67	2.62	1.98	2.33	1.65	5.09
Harari	0.87	0.8		0.9	1.17	1.21	1.53	1.11	1.5	1.93	5.3
Oromia	1.45	1.51	1.52	1.51	1.68	2.01	1.85	1.94	2.14	2.19	3.37
Somali	1.3	0.87	0.63	0.59	0.61	1.01	1.62	1.75	1.4	2.67	2.68
Tigray	1.69	1.51	1.29	1.59	1.61	1.59	1.7	1.81	2.15	2.2	1.14
SNNP	0.9	0.93	1.06	1	1.1	1.36	1.56	1.99	1.63	1.6	6.09

Keywords: S.N.N.P = South Nation and Nationality Peoples, D.dawa As = Dire Dawa Astedader.

Table 2: Sorghum Production, Acreage and Yield by Region (2001/2-2011/12)

Sorghum Research in Ethiopia

Breeding efforts have been directed towards developing high yielding, photo period insensitivity, abiotic and biotic stress resistant cultivars for adaptation to diverse agro climatic conditions. The discovery of dwarfing genes in sorghum has led to the development of several short statured sorghum hybrids, which are responsive to high input agriculture.

Ethiopia, with one of the largest national agricultural research systems in Africa in terms of staff and budget, has been following an agricultural-led growth strategy for years (Weijenberg et.al., 1995), with crop breeding for modern varieties a major focus of efforts. Due to the importance of sorghum in food security the government has allocated considerable resources to the breeding program [12]. Approximately one million hectares are sown to sorghum, making it the third most important crop grown in the country and it is a major staple in the diet of the population - particularly the poor. A breeding program for sorghum has been in place since the 1950s with somewhere between 27 to 30 modern varieties of the crop released since then [12]. The entire sorghum breeding program in Ethiopia starting in 1971 with the beginning of the variety Gambella-1107 and looking into the future until 2040 generates net research benefits at the magnitude of 762 million USD. There are four OPV varieties suited for the highlands, all registered and released between 1998 and 2005. Six OPV varieties were breed for the Intermediate altitudes, three of them rather old varieties released between 1989 and 2001, and the other three between 2006 and 2011. There is only one variety for the moist lowlands though the moist lowlands cover a significant part of the sorghum area and production. It is the variety Gambella-#1107 released in 1976. Despite its long existence in the market, Gambella-#1107 has only captured a small share in the moist-lowland variety mix. There are three groups of improved sorghum varieties for the dry lowlands, namely the first seven are OPV varieties with high yield potential, and the last two (ESH-1 and ESH-2) are hybrids with even higher yields, and finally three striga resistant varieties.

However how much of the improved varieties adopted at farmers field and their adoption intensity and rate is not quantified. Even if there is no quantified data on impact of Improved Varieties (IVs), the majority of the farmers are growing Farmers Varieties (FVs) in the three sorghum ecologies [13]. Not with standing this fact, formal breeding (FOB) is still continuing with the same objectives and strategy [14]. Similarly, farmers have been doing continuous selection and improvement of their varieties for years to meet their changing needs, climate and farming systems. As opposed to FOB, the varieties developed in the Farmer Breeding (FAB) have been well adopted by farmers and are being grown still. For the last half century variety development for lowland parts of Ethiopia has focused on the selection of early maturing varieties that can escape drought. A number of early sorghum open-pollinated varieties were developed and released for these areas [15]. There are, however, disadvantages to early maturity. Cultivars that mature extremely early tend to be lower in yield because the plants have a shorter growth period to flower and store nutrients in the grain [16]. So, currently in Ethiopia sorghum research increased even their adoption were not quantitatively evaluated **Table 3**. Based on table 3 improvement of sorghum nationally was increased with different objectives (early maturity, diseases and pest resistance, grain yield and quality, striga resistance, malt, stalk sugary, and stay greenness etc.) and targeted for different adaptation areas based on the classification of ethiopia agro ecological zones. With this until now the most potential contributor research centers are Melkassa National Agricultural Research center, Srinka Agricultural research center, Jimma Agricultural research center, Haromaya University and Sinana Agricultural Research center. Yield potential of the most improved sorghum varieties also good and attained above the yield national bench mark especially at the shortage of rain fall and drought incidence as relatively with farmers varieties (**Table 3**).

Official name of the release variety		Year of release	Released Research center	Agro ecological Zones	Avg. Yield -l	Adaption area	selected traits
1	Muyra-2	2000	HU	High lands	4000	highland areas	earliness
2	Chelenko	2005	MARC/EIAR	High lands	4600	HL Arsi negele, Harerge	High yield
3	IS9302	1981	MARC/EIAR	Intermediate	4500	Intermediate areas	High yield
4	Birmash	1989	MARC/EIAR	Intermediate	5250	Birr vally & Similar areas	High yield
5	Baji	1996	MARC/JARC/EIAR	Intermediate	5350	Intermediate areas	High yield
6	Geremew	2007	MARC/EIAR	Intermediate	5750	Bako, Jimma	High yield
7	76T1#23	1076	MARC/EIAR	Low lands	3500	moisture stressed dry lowlands	Earliness
8	Gambella 1107	1076	MARC/EIAR	Low lands	3900	moist lowlands of the country	High yield & good quality grain
9	Seredo	1986	MARC/EIAR	Low lands	3250	Lowland areas	Bird Tolerance
10	Meko	1997	MARC/EIAR	Low lands	3650	Lowland areas of Wollo	Earliness &high quality grain
11	Teshale	2002	SARC/ARARI	Low lands	5150	lowland areas of Wollo	High yield
12	Melkam	2009	MARC	Low lands	5150	lowland areas of Wollo	High yield
13	Gobiye	2000	MARC/EIAR	Low lands	2050	Striga prone areas of Wollo	Striga resistance
14	Abishire	2000	MARC/EIAR	Low lands	1900	Striga prone areas of Wollo	Striga resistance
15	Red Swazi	2007	MARC/EIAR	Low lands	3150	low land areas	Malt
16	Macia	2007	MARC/EIAR	Low lands	4300	low land areas	Malt
17	EH-1	2009	MARC	Low lands	5300	dry low land areas	High yielding hybrid
18	EH-2	2009	MARC/EIAR	Low lands	5200	dry low land areas	High yielding hybrid
19	Dekeba	2012	MARC/EIAR	Low lands	4100	low altitude areas	High yielding, earliness, stay green traits
20	Gedo	2007	SARI/ARARI	Low lands	3400	Low land areas of Wollo	High yielding & earliness
21	Emahoy	2007	PARC/EIAR	Humid low lands	4200	Humid low lands areas	High yield & tannin(bird resistant)
22	Misikire	2007	SARC/ARARI	Low lands	4073	Low land areas of Wollo	High yield
23	Girana-1	2007	SARC/ARARI	Low lands	4086	Low land areas of Wollo	High yield & good injera making
24	Lalo	2006	BARC/OARI	Intermediate	4600	Western Oromia-Gute, Bako, lalo, bilo etc	High yield & stay green
25	Dano	2006	BARC/OARI	Intermediate	4500		High yield
26	Berhan	2002	SARC/ARARI	Low lands	4000	Striga prone areas of Wollo	Striga resistant
27	Abuare	2002	SARC/ARARI	Low lands	4150	lowland areas	High yield
28	Hormat	2005	SARC/ARARI	Low lands	2330	lowland areas of Wollo	Striga resistant
29	Abamelko	2001	JARC/EIAR	Intermediate	6250	Intermediate areas	Stalk borer & grain disease resistant
30	Chiro	1996	MARC/EIAR	High lands	5000	High land areas	sugary stalk
31	Muyra-1	2000	HU	High lands	4700	High lands areas	earliness
32	Yeju	2000	SARI/ARARI	Low lands	5000	lowland areas of Wollo	Diseases resistant
33	Abuare	2003	*SARC/ARARI**	Low lands	4000	lowland areas of Wollo	Diseases resistant
34	Raya	2007	*SARC/ARARI*	Low lands	2975	Low land areas of Wollo	D & Pest resistant
35	Mesay-Me x Go	2011	*SARC/ARARI*	Low lands	3900	lowland areas of Wollo	D& Pest resistant
36	Dagem	2011	MARC/EIAR	Intermediate	4000	Intermediate areas	GM &L Resistant

Keywords: MARC-Melkassa Agricultural research center, Hu-Haromaya University, SARC-Agricultural research center, BARC-Bako Agricultural Reserch center,JARC=Jimma agricultural Resaerch center, Sirinka and Sinana*-incollabration sirinka and sinana.

Table 3: Some of the released sorghum Varieties with their Yield potential in Ethiopia.

Assessment of Yield Stability in improved Sorghum varieties

Yield stability is one of the setbacks facing plant breeders in developing widely adapted varieties with superior yield. The present study was carried out to review the yield mean performance and stability of released sorghum at different part of Ethiopia. The Agricultural Census Survey for Smallholders, Meher season 2009/2010 (CSA, 2010b) [7] Reports that 16,390 ha of sorghum by 72,000 smallholders are under improved varieties. The same report for the season 2010/11 [17] indicate a much small number, only 910 ha by 5,800 smallholders. For medium/large scale commercial farms, the numbers from CSA, are 100 ha and 680 large farms using improved sorghum seeds. Hence, the researcher tried to review yield performance and yield stability from the different part of Ethiopia as follows. The mean performance of selected ten nationally released sorghum varieties at Northern western Tigray of Ethiopia at three locations showed the yield superiority of the improved sorghum varieties over the local check. And then their individual locations mean performance also summarized in **Table 4** as follows.

At Sheraro location varieties mean performance, all varieties except Geremew are early maturing than local checks (zer adis). Grain yield also ranges from 1459.6 kg/ha (Gobiye) 2802.0 kg/ha (red swazi) and six of the improved varieties such as red swazi (2802.0kg/ha), Gambella #1107 (2579.6kg/ha), Macia (2469.7kg/ha), Melkam (2428.5kg/ha), IS-9302(2749.6 kg/ha), and Birmash (2402.3kg/ha) varieties had better yield performance at the given location. With this Plant height ranges from Baji (121.3 cm) to local checks (226.1 cm) all the improved sorghum varieties are short than the local checks (zeri adis). Besides, with Maianbessa location Days to maturity varied from red Swazi (111.00cm) to 147.00 cm (local checks of zeri adis). Similarly the improved varieties had least days to maturity than the local checks. Their plant height is shorter than zeri adiss. Grain yield performance ranged from 1429.2 kg/ha (Baji) to 3752.6 kg /ha (Macia), But in this location out of the candidate improved sorghum varieties nine varieties recorded least amount of yield than the zeri adiss. On the same way at Emba madre location all varieties except Geremew had least days to maturity as compared with zeri adiss. In plant height character, all the improved sorghum varieties recorded short plant stature and indicates those varieties contained root and stalk lodging resistant gene. While the traits of grain yield the improved varieties poorly performed than zeri adis and sheraro and mai anbessa locations as summarized in **Table 4**.

		DM-Days			PH-cm			GY-kg/ha		
S.N	**Var. Name**	**Sheraro**	**M/abesa**	**E/madre**	**Sherar**	**M/bessa**	**E/madre**	**sheraro**	**M/bessa**	**E/madre**
1	Gambella-1107	113.33	121.67	123.667	175.9	182.800	176.1	2579.6	2748.3	1392.1
2	Geremew	143.00	140.67	139.667	143.1	150.133	121.1	1537.5	2625.6	258.5
3	Red-swazi	100.67	111.00	121.333	131.4	142.800	126.5	2802.0	3151.7	1851.2
4	Macia	110.33	122.67	123.000	134.8	149.267	134.5	2469.7	3752.0	1464.6
5	76T1#23	1011.3	115.67	121.000	139.6	149.333	131.9	2089.3	1670.6	1755.4
6	Gobiye	105.00	120.00	124.667	140.7	147.400	132.9	1459.6	1938.2	954.1
7	Baji	108.67	125.33	121.333	121.3	139.000	116.6	2004.5	1427.2	680.3
8	Melkam	115.67	119.00	125.000	147.9	157.600	147.2	2428.5	2647.9	1360.7
9	IS-9302	106.00	124.67	122.333	168.9	157.333	149.2	2749.6	2573.7	681.9
10	Birmash	109.00	127.33	121.333	139.7	157.933	126.1	2402.3	2539.5	733.2
11	Local(zeradis)	128.67	147.00	139.333	226.1	303.800	212.9	2141.5	3194.99	1942.8
Grand Mean		111.03	125.00	125.70	151.7	167.036	143.	2242.2	2569.98	1188.6
CV%		1.29	10.10	2.20	1.29	6.37	7.90	20.6	22.75	30.6

Keywords: Var=Variety, M/abessa= Maianbessa, E/madre= Embamadre, DM days to maturity (days), PH=Plant Height (cm), Gy=Grain Yield kg/ha, N.W=Northern Western.

Table 4: Yield and Yield related traits performance of improved sorghum varieties across locations at N W Tigray, 2004/5, Tigray, Ethiopia.

Yield performance of improved and local Sorghum

To date, it has been very difficult to determine the actual figure of improved sorghum grain yields versus local landrace sorghum varieties. Generally, evidence indicates that areas occupied by local landrace sorghum varieties are relatively larger than those occupied by improved sorghum varieties. Even if the yield performance of the released sorghum varieties over the local land races were not clearly studied, But as table 3 indicated the average on farm and on research station yield potential is greater than the farmers varieties and sorghum yield bench marks. Especially Baji, Geremew, Chelenko, Birmash Chiro, Teshale, Melkam, Abamelko, Dano, Lalo, ESH-1 and ESH-2 have good potential with application of proper agronomic practices. While those and the remaind improved sorghum varities still not well accepted and scalling up at farmers field. And the adoption rates have been low, and farmers maintain the use of Landraces (LR) for many crops and in many areas of the country [18]. LRs are the product of centuries of selection by farmers and the natural environment. They are typically adapted to specific agro-ecological conditions and usually grown with very little capital inputs, such as fertilizers, pesticides, or irrigation. There are several reasons why farmers may prefer LRs over improved varieties. The countrys tremendous variation in altitude, temperature, rainfall, soil type, and ecological settings, as well as the diverse “environments in which Ethiopian farmers cultivate their crops gives rise to the need for a wide range of adapted crop varieties, which the formal plant breeding system is incapable of meeting.

Farmers varieties are an important element of crop genetic resources and are valued by plant breeders and farmers because of diversity (a heterogeneous population), rarity (embodying unique traits) and adaptability (exhibiting wide ecological and socio-cultural adaptation). Farmers throughout the world continue to maintain and manage farmers varieties within their production systems

. Yet the value they contain for the farming communities that maintain them has not been fully capitalized on. Not all landraces and improved varieties are equally valued by farmers for yield and yield related components and seed quality attributes. Some landraces are adapted to marginal ecosystems. Others have cultural, religious, or nutritional value.

The recent movement in participatory and decentralized plant breeding over the last decade has shown that improving varietal performance in low input systems can help improve local livelihoods. Varieties can be improved by selection of preferred traits from the heterogeneous populations, collected locally before any crop improvement programme is initiated. However, insufficient attention has been given to the potential use of the existing landrace variability in production systems to provide direct benefits to local communities. In general, research efforts to breed improved varieties have primarily concentrated on more favored and high-potential environments in which the increase in productivity and yield response to complementary inputs is high. In contrast, LRs are generally the product of farmer selection for adaptation to specific environments [19-20].

As the researcher tried to discuss in the above nationally there was no more study conducted on performance variety evaluation among FVs and improved varieties for yield, marginal area adaptability and seed quality. Variability in adaptation and quality for socio-cultural preferences is the main concern of consumers and market entrepreneurs. Regarding this, FVs and IVs, total amount of 14, were evaluated in 5m x 3m plots in Randomized Complete Block Design (RCBD) with three replications in the year 2000 and 2001 on 2 sites of eastern Ethiopia. Then mean performance data of two years of two sites at Alemaya is used for performance comparison. There was a significant difference among varieties for plant height, biomass, seed weight and grain yield on two sites in Alemaya, out of the first seven improved sorghum varieties (IVs) chirro and Al70* recorded high yield advantage over the rest improved varieties and farmers varieties. While improved variety of IS 9323 poorly performed and gave minimum yield (1144kg/ha) (Table 5).

Varieties	Variety type	Seed color	Seed size	Grain Yield	Plant height	Biomass	TKW
				(kg/ha)	(cm)	(Kg/ha)	
ETS 3235	IV	White	Large	3336	168	14511	29.72
ETS 2752*	IV	White	Large	3605	254	16832	27.2
Al 70*	IV	White	Large	4673	261	20754	25.38
Chirro*	IV	Light Brown	Large	4675	239	25244	27.22
Awash 1050	IV	White	Medium	2611	192	8664	27.52
IS 9302	IV	Light Brown	Small	1361	155	6568	23.25
IS 9323	IV	Light Brown	Small	1144	151	5884	23.89
Red Muyra L	FV	Light Red	Large	4074	243	21768	29.34
White Muyra L	FV	White	Large	4460	259	22532	32.51
Red Wegere	FV	Red	Large	4498	234	24341	29.43
White Wegere	FV	White	Large	3368	261	16643	25.14
Red Fendisha	FV	Red	Small	4354	286	31915	22.92
White Fendisha	FV	White	Small	4355	269	35716	21.86
Short muyra	FV	Light red	Large	3163	162	16528	27.52
			Mean	3461	222.43	17901	26.51
			F-test	S	S	S	S

Key: IV=Improved Varieties; FV=Farmers Varieties, TKW=Thousand Kernel Weight, *= formally released FVs of eastern Ethiopia.

Table 5: Mean performance of IVs and FVs at two years of 2000 and 2001 and 2 sites at Alemaya, Eastern Ethiopia.

Adoption of Improved Sorghum Varieties in Ethiopia

Technology adoption: A more meaningful definition may be that a technology is asset of new ideas. New ideas are associated with some degree of uncertainty and hence a lack of predict ability on their outcome. For a technology to impact on the economic system, blending into the normal routine of the intended economic system without upsetting the systems state of affairs is required. Technology as “the general knowledge or information that permits some tasks to be accomplished, some service rendered, or some products manufactured”. Most technologies are therefore consequently termed labor-saving, time-saving, capital-saving or energy-saving and so forth. To economists this implies saving on resources that are scarce. Much scholarly interest on adoption falls in two categories: rate of adoption, and intensity of adoption.

Adoption is defined as a mental process in which an individual passes through a series of stages from first hearing about an innovation, called an awareness stage, to collecting information about the technologys perceived benefits in terms of its profitability and fit into the farmers operation, the evaluation stage.

If the information is found to be adequate and the evaluation is positive, the farmer will experiment with the technology at a small scale called the trial stage before he/she moves to the final full-scale adoption stage. In making a decision, farmers are assumed to weigh the consequences of adoption of an innovation against its economic, social and technical feasibility [21].

Feder et al. [22] distinguish between farm level and aggregate adoption of a technology and define farm level adoption as "the degree of use of a technology in long-run equilibrium when the farmer has full information about the new technology and its potential".

Adoption is measured as the proportion of sorghum area under new sorghum cultivars and the proportion of cropland fertilized. The choice of the explanatory variables is guided by economic theory and the adoption literature.

The explanatory variables can be broadly categorized into farmer and farm characteristics, technical factors and fanner perceptions of technology characteristics and weather risk.

Improved Sorghum varieties and their adoption

Sorghum experts from EIAR developed a list of sorghum varieties that includes all relevant varieties from the start of the National breeding program (1970s) until now (**Table 6**). Relevant varieties are those that have been adopted at a commercially relevant level and with proper seed multiplication and maintenance in place. All those varieties that have been developed but never made it to the market have been set aside. The same holds true for the more recent and varieties under development that exhibit inferior traits compared to those that actively promoted and distributed.

The Ethiopian extension service ESE, the research centers in Melkassa, Srinka and Fedis other public institutions like the OSE, and from private seed companies produced around 1,100 mt of improved seed. Over 7,700 mt are from private seed companies, the rest from public sources. 96 % of this seed are varieties for the dry lowlands and the rest for all other three AEZ groups. As in **Table 6** indicated currently adoption of improved sorghum varieties in Ethiopia is too low and the predicted maximum adoption level percent is after 2-3 years and after 5-6 years will also start to decline their adoption level.

	Begin of Research	Year of Release	Year of max. adoption	Begin of adoption decline	Maximum Adoption	Current Adoption level in %
IV	Highlands				20	6
1. Chiro	1991	1998	2015	2020	7	2.5
2. Chelenko	1991	2005	2018	2024	5	0.5
3. Muyra-1	1977	2000	2017	2024	4	1.5
4. Muyra-2	1977	2000	2017	2022	4	1.5
	Intermediate Altitude				10	2
1. Baji	1982	1996	2008	2012	0.2	0.25
2. Geremew	1984	2007	2018	2026	3	0.5
3. Birmash	1978	1989	1999	2006	0.25	0.5
4. Dagim	1994	2011	2016	2006	3.3	0
5. Abamelko	1989	2001	2011	2022	0.25	0.25
6. Lalo	2001	2006	2017	2015	3	0.5
	Lowlands				4	5
Gambella-	1971	1976	1996	2006	4	5
	Dry Lowlands (High potential varieties)				38	10.5
1. Teshale	1972	2002	2018	2022	3	1.5
2. Meko-1	1988	1997	2018	2030	6	2
3. Melkam	1999	2009	2017	2023	5	1.5
4. Dekeba	2005	2012	2017	2027	6	0
5. Girana-1	1995	2007	2017	2022	5	1.5
6. Misikir	1995	2007	2017	2022	3	1
7. 76T1#23	1973	1976	1996	2006	2	3
8. ESH-1	1997	2009	2017	2027	4	0
9.ESH-2	2006	2014	2019	2029	4	0
	Dry Lowlands (Striga resistant varieties)				12	4.5
1. Gobiye	1989	2000	2015	2021	6	3
2. Abshir	1989	2000	2015	2020	3	1.25
3. Birhan	1989	2002	2016	2021	3	0.25

Table 6: Complete List of Improved Varieties and Adoption Information.

This fast decline of adoption may due to deteriorate of the purity and quality of the seeds and due to existence of weak seed multiplier and supplier in the country. According the report of Alemu *et at* 2014 [23], Gambella #1107, meko-1 and Gobiye had good current adoption level percentage among the moist and dry low land released sorghum varieties and owned 5, 2 and 3 % level of adoption percentage respectively. From high lands relatively Chiro, Muyra-1 and 2 slightly practiced and popularized at farmers field. While sorghum varieties released for the intermediate areas of Ethiopia still not familiarized with farmers. Additionally, Based on the improved sorghum varieties adoption cross different agro ecological zones, improved varieties for dry low land areas showed high current adoption level (7.24) and followed by intermediate altitude areas and the final country current improved sorghum adoption level reached 9.47% as shown in **Table 7**.

Agro-ecological zones-Ethiopia	Area under sorghum(ha)	Share of improved Varieties (%)
Highland	96,186	0.69
Intermediate altitude	288,558	0.85
Moist lowland	288,558	0.69
Dry lowland	1,250,416	7.24
Total	1,923,718	9.47

Table 7: EIAR Assessment of Current Share of Improved Sorghum Varieties in Ethiopia.

So, as the report of EIAR experts at the work shop of 2014 indicated the wide national adoption and share of sorghum improved varieties will increase with short periods and tried to justify the optimistic view and strong dynamic they expect in the further spread of improved varieties, because:

- Government commitment/priority for sorghum as food security crop
- Emerging of private seed companies
- Emerging of commercial farms
- Climate change that will shift the cultivation away from local late maturing to early maturing improved varieties
- Improved seed and grain market for sorghum (for example the Ethiopian Commodity Exchange/ECX)
- Further improvement in the formal and informal seed system

Determinants of adoptions

EIAR experts considered the official numbers as too low and re-calculated the current adoption level based on their information on seed production from formal (extension and research centers) and informal sources (exchange between small scale farmers and replanting and commercial farms). The decision of whether to adopt modem varieties depends, among other things, on the physical characteristics of soils. Light and medium textured soils have low moisture retention capacity and thus shorter growing periods, with water moving out of the root zone quickly and therefore not available to the plant [24]. On the other hand, heavy crusty vertisols have low infiltration capacity and are prone to water logging problems. Farmers who have soils with low water holding capacity are more likely to adopt early maturing varieties and other technologies that improve the water holding capacity of the soil such as manure. They may also avoid adopting inorganic fertilizers since they can be easily leached away. Because of their water logging problems vertisols may not be suitable to short cycle varieties whose yield can be negatively affected with excess water. However, the heavier soils are expected to have more pay off to fertilizer. Soil type is used as a control variable.

A variety of studies are aimed at establishing factors underlying adoption of various technologies. As such, there is an extensive body of literature on the economic theory of technology adoption. Several factors have been found to affect adoption. These include government policies, technological change, market forces, environmental concerns, demographic factors, institutional factors and delivery mechanism. They include:

Farmers Socio-demography Characteristics

According to Doss *et al.* (2003) [25], numerous studies of technologies adoption in developing countries have used farmers socio-demography characteristics (e.g., household heads gender, age, education, household size) to explain household adoption behaviours. A few of these studies report that the rate of technology adoption is higher among male-headed households, compared to female-headed households because of discrimination (i.e., women have less access to external inputs, services, and information due to socio-cultural values). Female farmers were much less involved in local administration and so was their participation in on-farm demonstration than their male counterparts. Significantly lower proportion of the female farmers used hired labor than the male farmers s despite the fact that they have shortage of family labor, probably because they have smaller cash incomes. According to Feder et al. (1985) [22], some new agricultural technologies, including improved varieties, are more labor intensive, compared to traditional varieties. Thus, labor shortage may prevent farmers from adopting new agricultural technology. The authors argue that a household with a large number of family members who are available to work on the farm are more likely to adopt new technologies than household with a small number of family members.

Similarly with this, there was an assessment survey on metema wereda with the objective of the adoption and utilization of improved sorghum varieties (Gobiye, Abishire and Teshale) over local varieties at two resettlement Pas i.e Kokit and Kumer Aftit PAs, Majority (91.7%, 78.6%) of the respondents who stopped using those varieties and went back to local such as Zole and wedi Akere varieties. Whereas, only 2 (8.3%) and 3(21.4%) of respondents from Kokit and kumer Aftit PAs respectively, were using those varieties only or using both local and improved varieties together or interchangeably. The respondents also mentioned the problems associated with the improved striga resistant and early maturing sorghum varieties were identified during group discussions held in kokit PA, with both previous Male Household (MHH) and Female House Hold (FHH) settlers. The participants identified and ranked three major problems that existed in the improved sorghum varieties like bird attack, seed non-availability and striga infestation.

Farmer Perception of Characteristics of Technologies

Feder et al. (1985) [22] argue that yield performance (or expected yield of new varieties) is one of the characteristics of improved varieties that affect farmers technological adoption behaviours. Several empirical studies show that the adoption rate of improved varieties is high, if the varieties meet farmers expectations. An improved variety will be adopted at exceptionally high rates, if the new variety is technically and economically superior to local varieties. Improved varieties are technically superior if they produce higher yield to traditional varieties. The small area planted to the new cultivars indicates that farmers are still at the experimenting stage of the adoption process. On average only 9% of the sorghum area or 2 % of the total crop land is planted to the new sorghum cultivars. According the survey on farm level adoption of New sorghum cultivars on tahtay adiabo wereda, Tigray region, from 90 sample size farmers 61% of the farmers were non adopters due to lack of information. Farmers participation in local administration was a significant variable in explaining adoption of the new sorghum cultivars. The variable was used as a proxy for access to information in place of the number of extension visits. The new cultivars were introduced relatively recently (1998 season) and many of the sampled non-adopter farmers didnt know that the cultivars existed. Both variables relating to farmers perceptions, i.e. their perceptions of the technology characteristics and rainfall risk are significant variables explaining the adoption decisions. These results are consistent with the choice of the shallower soils for planting the varieties and avoidance of fertilizer use. If farmers tend to have higher subjective estimate of probability of rainfall failure, it would follow that they adopt early maturing and drought tolerant cultivars. These short season cultivars have yield advantages over the traditional cultivars principally in bad rainfall years and are used as a portfolio mix combined with the traditional cultivars.

Adoption of technologies may be conceptualized at two different levels: aggregate and individual (farm-level) levels of adoption. Aggregate adoption is defined as the adoption of an agricultural technology by a population within a region. In contrast, farm level new technological adoption is defined as when an individual farmer adopts a new technology. The farm-level new technological adoption is an important factor affecting the level of economic return to agricultural research. Factors affecting farm-level adoption include off-farm economic constraint and opportunities that are communicated through off-farm input and output markets. Also, the rate of new technology adoption at the farm-level depends on the extent to which the new technology enables farmers to respond to the evolving preferences of off-farm clients for different product characteristics, as reflected in market prices.

Socio-economic characteristics of adopters and non-adopters of improved sorghum varieties

Based on the assessment of the adoption of improved sorghum varieties at awbre, North western somalia showed, Out of the 180 households interviewed, 37.2% were adopters and 62.8% were non-adopters of improved sorghum varieties. Out of the adopters of improved sorghum varieties, 44 (65.7%) were literate or can read and write. This shows that adopters were more educated than non-adopters, and better educated farmers show better positive response to improved technology adoption. The existence of a literate in the household enhances the technology adoption, since the information delivered by members of the household to the household head is highly accepted than other sources of information, because of the trust that exists between them.

The age structure of the sample farmers showed that the largest proportion of the respondents, 73% of the adopters were in the age group of 20 to 35 years and 75% of the non-adopters were above 35 years. Hence, younger farmers are more optimistic and risk takers to adopt new technologies whereas older farmers are pessimistic and resistant to change in their farming practices. This finding is similar with the study results of Million and Belay (2004) [26] and Feleke and Zegeye (2006) [27]. Hence, younger farmers are more optimistic and risk takers to adopt new technologies whereas older farmers are pessimistic and resistant to change in their farming practices.

Institutional Factors

Regarding the distance taken to travel from home to the nearest input market place, the sample farmers reported that they had to travel an average of 63.7 km (adopters 56 km and non-adopters 68 km). This shows that the adopters were nearer to the input market than the non-adopters by about 10 km. The nearest input market in the study area is Jijiga town. farmers far away from market centers are less likely to adopt improved sorghum varieties than those who are located near to input market centers. Tesfaye et al. (2001), and Feleke and Zegeye (2006) [27,28] have also reported similar findings from their respective similar studies. With regards to access to credit the percentage of those who had access to credit was higher for the adopters (68.7%) than for the non-adopters (34.5%).Only 25.4% of the adopters and 19.5% of the non-adopters had contact with extension agents.

Summary and Conclusion

The Ethiopian government is pursuing a strategy of improving agricultural productivity primarily through agricultural intensification, involving an increased use of inputs, including seeds of improved crop varieties [12,18]. Considerable resources have been devoted to the development and dissemination of modern varieties (MV), however adoption rates have been low, and farmers maintain the use of landraces (LR) for many crops and in many areas of the country [18]. The reasons may be, the expected benefit of higher yields of the traditional varieties is larger than the improved varieties during years of moderate and good rains. According to farmers own estimates, they expect moderate and good rains. This means that longer season varieties that respond better to the good rainfall and fertilization condition in those years increase the productivity and income of farmers. Additionally based on the farm level adoption of new sorghum varieties at different corners of ethiopia, a large number of influential farmers among the adopters pointed out unequal access of farmers to extension information as extension agents tend to choose to work with those "model" farmers at the neglect of others less influential farmers. Nearly half of the non-adopters reported that they were not aware of the existence of the improved sorghum such as Striga-resistant cultivars. Therefore, the extension program should work more on exposing the non-adopter farmers to the new technologies.

Farmers look for specific technology characteristics when making adoption decisions. The earliness and grain characteristics were the most desirable traits of the new cultivars sought by farmers. On the other hand, higher yields, larger biomass and thicker stalk for wind resistance were the qualities they preferred in the traditional varieties. Varieties combining the desirable characteristics of higher grain and biomass yields of the traditional cultivars with Striga resistance quality could be more successful. But, currently even agricultural extension have less consideration, variety improvement and technology generation is selected as main national strategic for food security and agricultural growth. Then since few years number of released sorghum varieties that are developed based on different objectives increased nationally at different parts of the country. Some of the sorghum research nationally contributed agricultural research centers are Melkassa agricultural research centers, Srinka agricultural research center, Haromaya University, Jimma, Pawe and Humera agricultural research centers. However how much of the improved varieties adopted at farmers field and their adoption intensity not quantified clearly. So, as a conclusion to increase the adoption rate and intensity of the released sorghum varieties across their suitable agro ecology and based on the objective of the target improved sorghum varities at the time of variety registration, agricultural extension should be strength and linkage between the department of integrated crop improvement with socio economics and agricultural extension should be improved. With this at variety development farmers better to participate and include their selection criteria, interest, problem and increase adoption of the improved sorghum varieties.

Recommendations

Finally, to increase the adoption rate, intensity and utilization of the released sorghum varieties across their suitable agro ecology; the following points should be practiced further.

- The service of extension agents and diffusion of improved in puts to the model and non-model farmers with their implementation should regularly monitored and follow-up the higher experts and agricultural extensionists.
- Creating new markets for the new sorghum might accelerate the diffusion of the cultivars. For instance, in Humera the grain qualities of the new varieties were found desirable for making pastries and thus command a premium over the traditional cultivars.
- If the current diffusion system is changed (instead of top down, to practical involvement of farmers) and relations with neighboring Eritrea are normalized and the road infrastructure to Sudan is improved, it might create export market opportunities and hence higher price incentives for farmers.
- Continuous Surplus pure basic improved sorghum multiplier seed company in each regions is mandatory to feed the demand of farmers whose dont have access to road and since the purity of the improved seeds deteriorates over time by storage insect pests and improper seed selection, maintenance and seed replacement.
- Thus in addition to stabilizing the yield and incomes of farmers during the bad years researchers have to generate new technologies to increase productivity during the moderate and good year in order to extricate farmers from subsistence farming and cycles of poverty.
- Investors should establish a brewing industry at least in the sorghum potentials areas of the country This will encourage farmers to grow more sorghum and supply it to the nearby factory, as happened with the barley beer and cotton factory at Amhara region.
- The government should create credit facilities for farmers to enable them invest in sorghum production and processing of high-quality sorghum grain.
- Training farmers and traders and other stakeholders on grain quality control and management should be increased.
- Finally popularize and strengthening the principle of participatory agricultural development in technology development and adoption is the best choice for the fast tracking of agricultural development. Since, respecting voice of farmers and sharing their idea by forming Farmers research Group (FRG), Farmer Field School (FFS) and Participatory Rural Appraisal (PRA) helps:
- It ensures effective utilization of available resources;
- It makes the development more effective by granting farmers involvement in planning and implementation;
- It increases farmers awareness, self-confidence and control of development processes; and
- It ensures availability of resources to wider coverage and the flow of the benefits to the target groups, and generates a sense of ownership over the development process among farmers, which is essential for the sustainability after external interventions cease.

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