

Assessment of Varietal Replacement Rate for Major Crops in Central Ethiopia

Lemma Zemedu¹, Endeshaw Habte², Aklilu Nigussie¹, Solomon Abiy¹

¹Ethiopian Institute of Agricultural Research, Debre Zeit Research center

²Ethiopian Institute of Agricultural Research, Head Quarter

Abstract

Improved seed is one of the key agricultural technologies that can significantly enhance crop productivity. Several varieties of major cereal crops (tef, bread wheat, and durum wheat) and pulse crops (chickpea and lentil) have been released through national agricultural research systems in Ethiopia. This study aimed to assess the degree of these varietal replacement for major crops grown in central Ethiopia. This study generated information from a data collected from two districts (Gimbichu and Lume) of East Shewa zone, a total of randomly selected seven kebeles and 234 sample respondent farm households interviewed face-to-face during 2020/21 cropping season. Area weighted average variety age (AWAVA) in years was calculated in aggregate for both districts by considering total area of improved varieties for all major crops and found 11.03 (Tef), 8.49 (durum wheat), 10.71 (bread wheat), 15.48 (lentil) and 21.3 (chickpea). Almost all varieties currently under-production for all major crops aged more than ten years. The result highlighted the extent to which older varieties dominate production, potentially impacting productivity and resilience. Hence, the older age of varieties under production demands an immediate solution in dissemination of recently released improved varieties seed and release of a new variety that has pest resistance and high-yielding attributes than those under current production.

Key words: AWAVA, Chickpea, Lentil, Tef, Variety replacement, Wheat

Introduction

Agricultural productivity enhances with the use of improved technologies such as improved seeds, fertilizer, chemicals and mechanization. Improved seeds are the key inputs around which all other inputs are brought together. Such improved seeds are assumed to have high potential in increasing yield, resisting to adverse conditions and have nutritious to satisfy demand of consumers. Crop improvement research program develop and release new crop varieties with intentions of achieving increased agricultural productivity having an assumption of any latest variety beating the earlier released one in those parameters.

It takes long time to commercialize new varieties. There are a number of activities involved between the release and wider cultivation by the farmers. These include a lengthy process in varietal registration, quality assurance regulations, early generation seed multiplication, pre-extension demonstration of new variety and seed enterprises capacity to reach farmers with affordable and quality improved seeds.

Studies by different scholars (Heisey, 1990; Brennan and Byerlee, 1991; Hartell et al., 1998; Simale et al., 1998; Meng and Brennan, 2009, Endeshaw et al., 2023), raised concern on slow replacement of varieties and compared varietal turn over with longevity to disease resistance. Average time for varietal replacement is associated with crop productivity; the longer time it takes thought to negatively affect yields and make varieties susceptible to disease. Public investment in crop improvement programs will also provide higher return with high speed of varietal turn over.

In Ethiopia, the informal seed distribution system is predominant as compared to the intermediate (community based) and the formal seed system. Farmers exchange seed among each other expecting better productivity. Access to improved seed from the formal seed sector has not been affordable and available at the right time. Profits being a key driver, formal seed enterprises tend to supply popular varieties that were adopted by majority of farmers which often tend to be old. This action of distributing old crop varieties delays access to latest released varieties. In other words, the challenge of delayed access to newly released crop varieties is a significant issue that can hinder agricultural innovation and productivity. This study is designed to examine the speed with which new varieties enter the production system (to farmers' hand) particularly in the central Ethiopia.

Materials and Methods

The study was conducted in two districts of East Shewa Zone, Oromia region, central Ethiopia. From the two districts (Gimbichu and Lume), a total of seven kebeles and 234 sample respondent farm households (with a minimum of 30 households per kebele) were selected for a face-to-face interview during 2020/21 cropping season.

The study used well trained enumerators for the survey and utilized secondary information to discuss the finding of this study. Both descriptive and economic analysis were done to describe the overall status of major crop production, major varieties in the hand of farmers, how long varieties has been in the hands of farmers by categorizing them into two periods (in the past and recent past or the present), area under such varieties and since when the recent varieties under production for each crop were started to be cultivated?

In addition, quantity produced for grain and seed, quantity sold, purchased and prices, experience in crop farming and preferred traits for future varieties and other prominent variables were captured in the study.

Variety turnover rate was also calculated for major crops using the formula developed by Brennan and Byerlee (1991), called area weighted average variety age (AWAVA). For a given year AWAVA is computed as:

$$AWAVA_t = \sum P_{it} R_{it} \dots\dots\dots \text{Eq (1)}$$

Where P_{it} is the share of the crop area cultivated in variety i in year t and R_{it} is the number of years at time t since the release of variety i .

The major crops grown in the study area that were considered in the present study are three cereals (Tef, Durum and Bread wheat) and two pulse crops (Lentil and Chickpea). These crops quantity produced and sold at household level, experience of farming these crops and farmers reported attribute preference on the future to be released varieties for these major crops were also considered in this study.

There are dynamics in crop varieties use for some crops and almost constant for others. Sample households were asked to report which variety of specific crop they used to grow before shift to the current variety they are growing. They were also asked for how long they have been growing the current variety under the sample household production for the specific crop together with area covered by the current variety.

Results and Discussion

Table 1 presents the comparisons between the variety used earlier with frequency and percent of that specific crop in comparison with the current in-use varieties of the same crops. For example, during previous production periods variety Quncho took the largest share from improved tef varieties with the proportion of 42.3 % in the study area. During the current production period (study year), variety Boset took over Quncho covering more than 50% of area under tef production; while Quncho declined from the previous 42.3% tef area coverage to less than 10% of tef area under the current production.

From improved bread wheat varieties, Kubsa was widely cultivated variety covering 44% of sample households in the previous periods. However, recently the new bread wheat variety known as Dendea is the dominant variety, which covered 46.7% of fields under bread wheat production by the sample households. Mangudo variety is taking the highest proportion of other durum wheat varieties during both past and present periods, where under the current durum wheat production period Mangudo variety alone covered over 70% of total durum wheat cultivation fields.

From chickpea varieties Arerti, Red and Shasho took proportionally similar coverage during previous production. During recent chickpea production Arerti dominated other chickpea varieties; where it still cultivated by more than 40%

sample households. Coming to lentil varieties; Alemaya variety still preferred to other lentil varieties by sample households, though its proportion declined from 67% in the past to 46 % under current production.

Table 1: Selected crop varieties under the farmers in the earlier and recent production periods

Crop	Earlier used variety name			Current variety in production (name)		
	Earlier used variety	Frequency of its growers	% from total growers	Current variety in production	Frequency of its growers	% from total growers
Tef	<i>Bunegn</i>	35	14.96	Boset	112	50.68
	Quncho	99	42.31	<i>Bunegn</i>	22	9.95
	Enatit	14	5.98	Quncho	32	14.48
	Key Tef	30	12.82			
Bread wheat	Kubsa	94	44	Dendea	98	46.65
	Hidase	15	7	Hidase	14	6.64
	Hara	20	9.35	Kekeba	65	30.81
	Dendea	36	16.82			
Durum wheat	Mangudo	31	23.85	Mangudo	85	71.43
	Gerado	14	10.77	Utuba	10	8.4
Chickpea	Arerti	38	23.5	Arerti	38	43.68
	Red	41	25.3	Habru	13	14.9
	Local	26	16	Shasho	15	17.2
	Shasho	35	21.6	Red	6	6.9
	Habru	6	3.7			
Lentil	Alemaya	91	66.9	Alemaya	25	46.3
	Local	29	21.3	Derso	16	29.63

Source: own survey, 2021

It was found that almost all crops produced by sample households were supplied to market. The sample farmers claimed to have supplied more than 50% of their produce in case of tef, chickpea and lentil to the market. The corresponding figure for wheat was more than 45% of produce (Table 2) from the study area.

The farmers in the central Ethiopia are surplus producers or commercial oriented as they sale almost above 50 % of their produce for most of the major crops in the study area. However, the productivity of major crops grown in the central Ethiopia is lower than the potential under research station and even lower than the national average for some crops.

Table 2: Selected crops quantity produced and sold during 2020/21

Crop	Average quantity produced in ton					Average quantity sold in ton			% Sold
	N	Mean	Sd	Min	Max	N	Mean	Sd	
Tef	230	1.44	1.89	0.2	15	211	0.74	1.24	51.63
Wheat	226	2.34	1.90	0.2	12	206	1.06	1.35	45.35
Chickpea	71	0.74	0.58	0.05	3	63	0.50	0.42	67
Lentil	42	0.36	0.31	0.02	1.8	35	0.31	0.29	81
Faba bean	50	0.51	1.07	0.01	0.75	34	0.18	0.18	34.55

Source: own computation from survey, 2021

The sample households average experience in use of improved variety is less than 15 years; since improved variety has been under production (Table 3). There is wide variability among households in use of improved varieties from one year until more than 40 years. This possibly suggests the seed delivery scheme is not performing well. Hence, additional efforts are required in terms of technology demonstration, scale up and improved seed distribution system.

Table 3: Experience in improved varieties farming (N=234)

	N	Mean	Std. dev	Min	Max
Improved Tef farming	228	11.83	8.6	1	40
Improved Durum Wheat	193	9.76	6.78	1	40
Improved Bread Wheat	228	12.34	7.17	1	40
Improved Chickpea	208	11.65	8.03	1	42
Improved Lentil	201	12.28	8.43	1	42

Source: Own survey data, 2021

Farmers attribute preference for major crops in central Ethiopia

Farmers expressed their traits preference for improved seed with score between one and ten where ten refers to the highest preference and one the least. For trait such as disease and pest resistance the farmers gave on average highest score close to the maximum ten for chickpea and lentil varieties followed by bread and durum wheat in terms of disease resistant improved variety release (Table 4). In terms of drought resistance trait average score given for all crops is around and below average five points suggesting farmers attached higher importance to disease and pest resistance than drought tolerance in central Ethiopia.

Table 4: Farmers traits preference score for pest and drought resistance (score 1 to 10, with 10 the highest score)

Crop attribute	Crops	N	Mean	Std. dev	Min	Max
Disease and other pest resistance	Tef	226	7.15	1.85	1	10
	Durum Wheat	225	7.95	1.75	2	10
	Bread Wheat	225	8.05	1.66	1	10
	Chickpea	215	9.10	1.27	5	10
	Lentil	214	9.22	1.25	4	10
Drought resistance	Tef	219	4.85	2.15	1	10
	Durum Wheat	218	4.88	2.35	1	10
	Bread Wheat	214	5.04	2.33	1	10
	Chickpea	205	5.69	2.54	1	10
	Lentil	206	5.63	2.64	1	10

Source: own survey data, 2021

When it comes to grain yield, farmer showed the highest preference for tef and wheat followed by chickpea and lentil. The minimum score given for grain yield trait preference for tef was five points and averaged 9.5 out of maximum 10 points (Table 5).

Table 5: Farmers preference score for grain yield and fodder quality traits ranking (10) the highest and (1) the least

Crop	N	Mean	Std. dev	Min	Max
Grain yield					
Tef	232	9.5	0.99	5	10
Durum Wheat	226	9.06	1.4	3	10
Bread Wheat	227	9.08	1.47	3	10
Chickpea	215	8.46	1.36	4	10
Lentil	212	8.42	1.34	4	10
Fodder quality					
Tef	227	6.33	2.24	1	10
Durum Wheat	220	5.47	1.97	1	10
Bread Wheat	219	6.03	2.12	1	10
Chickpea	191	4.85	2.18	1	10
Lentil	200	4.9	2.18	1	9

Source: Own survey data, 2021

Among sample households limited farmers involved in purchasing of improved seeds. There is high variability in prices of grain and seed due to market fluctuation between immediately after harvest and lean periods (Table 6).

Table 6: Selected crops grain selling price, seed quantity purchased in 2020/21

Crop	Average grain selling price in Birr/ 100 kg			Seed quantity purchased and average price			
	N	Mean	St. Dev	N	Quantity purchased (Kg)	Mean Price/kg	St. Dev
Tef	211	3464.24	690.34	109	45.99	49.95	34.87
Bread wheat	204	1771.43	378.27	113	133.62	20.49	5.58
Durum wheat				46	117.5	21.36	4.28
Chickpea	63	2647.47	722.89	14	119.28	27.41	7.06
Lentil	35	3847.43	1020.78	12	28.08	42	8.89

Source: Own survey data, 2021

Major crops varietal turn-over rate

Among bread wheat varieties currently under production in central Ethiopia area weighted average varietal age (AWAVA) was analyzed to know varietal turnover rate. We computed the AWAVA based on two scenarios. The first one considers the proportion out of area covered in improved varieties alone; and the second one takes the proportion out of area covered in improved and landraces. We preferred to put these two scenarios because what farmers consider land race could potentially be improved and vice versa given the possibility that farmers could misidentify the varieties they grow. Thus to provide a perspective, we put the result by considering area covered by only the varieties they reported as improved, on one hand, and area covered by the improved and land races, on the other.

Accordingly, improved bread wheat varieties such as Dendea and Kekeba were longer in the production compared to all other varieties released earlier or later than them. The overall area weighted average varietal age (AWAVA) for bread wheat is 10.71 (~11) years by considering total area as covered only under improved bread. Considering total area under bread wheat for land races and improved bread wheat, the AWAVA for bread wheat is 7.3 (~seven) years.

Table 7. Bread wheat area weighted varietal turn over at household level

Variety of Bread wheat currently under production	Year released	Area weighted average varietal age (years) (Total area under improved variety alone)	Area weighted average varietal age (years) (Total area under improved variety and land races)
Dendea	2010	4.45	3.03
Hidase	2012	0.55	0.37
Kekeba	2010	4.07	2.77
Kingbird	2015	0.12	0.08
Kubsa	1995	1.02	0.69
Lume	2016	0.05	0.03
Ogelcha	2012	0.38	0.26
Senate	2014	0.07	0.05
Overall AWAVA (for Bread wheat)		10.71	7.29

Source: Own survey data, 2021

Among several tef varieties currently under production Boset is dominant followed by Quncho variety. As presented in Table 8, area weighted average varietal turnover rate for tef considering only area under reported improved tef variety is 11.03 (~11) years in central Ethiopia. The corresponding AWAVA by considering total area under land races and improved tef varieties is 9.47 (~10) years.

Table 8. Tef area weighted varietal turn over at household level

Farmer reported improved tef variety	Year released	Area weighted average varietal age (years) (Total area under improved variety alone)	Area weighted average varietal age (years) (Total area under improved variety and land races)
Bora	2019	0.02	0.02
Boset	2012	6.63	5.69
Dagem	2016	0.13	0.11
Dima	2005	0.23	0.20
Enatit	1970	0.49	0.42
Flagot	2017	0.05	0.04
Key Tef	2002	0.22	0.19
Kora	2014	0.06	0.05
Magna (Dz-01-196)	1978	0.58	0.50
Quncho	2006	2.11	1.81
Tesfa	2017	0.01	0.01
Tseday (DZ-Cr-37)	1984	0.50	0.43
Overall AWAVA (for Tef)		11.03	9.47

Source: Own survey data, 2021

There are only two durum wheat varieties currently under production by households in central Ethiopia, where Mangudo variety being the dominant one. Table 9 presents the AWAVA for durum wheat considering only area under improved durum wheat where the AWAVA is 8.49 (~9) years, and 7.57 (~ 8) years by considering total area under land races and improved varieties.

Table 9. Area weighted average varietal age for durum wheat at household level

Farmer reported improved durum wheat variety	Year of released	Area weighted average varietal age (years) (Total area under improved variety alone)	Area weighted average varietal age (years) (Total area under improved variety and land races)
Mangudo	2012	8.18	7.29
Utuba	2015	0.31	0.28
Overall AWAVA (for Durum wheat)		8.49	7.57

Source: Own survey data, 2021

Two varieties of chickpea (Arerti and Habru) were found prominent in central Ethiopia, with Arerti variety being dominant. Table 10 presents the AWAVA for chickpea which was found to be 21.29 (~21) years considering total area only under improved chickpea and 16.26 (~16) years while considering total area under landraces and improved varieties of chickpea.

Table 10. Area weighted average varietal age for chickpea at household level

Farmer reported improved chickpea variety	Year released	Area weighted average varietal age (years) (Total area under improved variety alone)	Area weighted average varietal age (years) (Total area under improved variety and land races)
Arerti	1990	18.15	13.86
Habru	2004	3.15	2.40
Overall AWAVA (for Chickpea)		21.30	16.26

At household level study two improved varieties of lentil are currently under production. Table 11 indicates that AWAVA for lentil by considering total area of lentil under improved varieties alone is 15.48 (~16) years. While by considering area under land races and improved varieties of lentil the AWAVA of lentil is reduced to 9.23 (~9) years at household level.

Table 11. Area weighted average varietal age for lentil at household level

Farmer reported improved lentil variety	Year Released	Area weighted average varietal age (years) (Total area under improved variety alone)	Area weighted average varietal age (years) (Total area under improved variety and land races)
Alemaya	1997	13.16	7.85
Derso	2012	2.32	1.39
Overall AWAVA (for lentil)		15.48	9.23

Varietal turnover rate at district level for improved tef varieties indicated in Table 12 is 8.69 (~9) years for Gimbichu district and 10.15 (~10) years for Lume district. Out of 12 improved tef varieties under production in Gimbichu districts, Boset and Quncho were dominant tef varieties. While in Lume only three improved tef varieties grow, dominated by Boset.

Table 12. Tef varietal turnover by geographic domain in central Ethiopia

Tef variety	Gimbichu AWAVA	Lume AWAVA
Boset	3.13	7.93
Magna (Dz-01-196)	0.31	0.67
Quncho	2.11	1.55
Bora	0.03	-
Dagem	0.23	-
Dima	0.42	-
Enatit	0.91	-
Flagot	0.09	-
Key Tef	0.41	-
Tesfa	0.02	-
Tseday (DZ-Cr-37)	0.92	-
Overall	8.69	10.15

Source: Own survey data, 2021

Varietal turnover rate at district level for improved bread wheat varieties as indicated in Table 13 is 5.97 (~6) years for Gimbichu district and 10.29 (~10) years for Lume district. Where, Dendea and Kekeba varieties were dominant in Gimbichu and Lume districts, respectively.

Table 13. Bread wheat varietal turnover by geographic domain in central Ethiopia

Bread wheat variety	Gimbichu	Lume
	AWAVA	AWAVA
Dendea	4.55	0.50
Hidase	0.57	0.04
Kekeba	0.15	7.12
Kubsa	0.07	1.73
Kingbird	-	0.22
Lume	0.55	-
Ogelcha	-	0.68
Senate	0.08	-
Overall	5.98	10.29

Source: Own survey data, 2021

Varietal turnover rate at district level for improved durum wheat varieties as indicated in Table 14 is 7.6 (~8) years for Gimbichu district and 6.65 (~7) years for Lume district. Where, Mangudo is the only variety in Gimbichu and Mangudo and Utuba are the two improved varieties in Lume district.

Table 14. Durum wheat varietal turnover by geographic domain in central Ethiopia

Durum wheat variety	Gimbichu AWAVA	Lume AWAVA
Mangudo	7.60	4.12
Utuba	-	2.53
Overall	7.60	6.65

Varietal turnover rate at district level for improved chickpea varieties as indicated in Table 15 is 13.68 (~14) years for Gimbichu district and 18.72 (~19) years for Lume district. Where, Arerti variety was dominant in Gimbichu and Lume districts.

Table 15. Chickpea varietal turnover by geographic domain in central Ethiopia

Chickpea variety	Gimbichu AWAVA	Lume AWAVA
Arerti	13.26	14.43
Habru	0.43	4.29
Overall	13.69	18.72

Varietal turnover rate at district level for improved lentil varieties as indicated in Table 16 is 12.21 (~12) years for Gimbichu district and 1.14 (~1) years for Lume district where, Alemaya variety was dominant in both districts.

Table 16. Lentil varietal turnover by geographic domain in central Ethiopia

Durum wheat variety	Gimbichu AWAVA	Lume AWAVA
Alemaya	10.32	1.14
Derso	1.90	-
Overall	12.21	1.14

The AWAVA result for pulse crops in the study area showed the highest values as compared to cereals; chickpea with more than 20 years and lentil with more than 15 years old improved varieties (IV) grown by sampled farmers (Figure 1). The durum wheat varieties grown seem to have relatively faster turnover with the average weighted varietal age being less than 10 years. Tef and bread wheat varieties grown were found to have average age of about 11 years. This implies recently released varieties have not reached or adopted by the households in central Ethiopia.

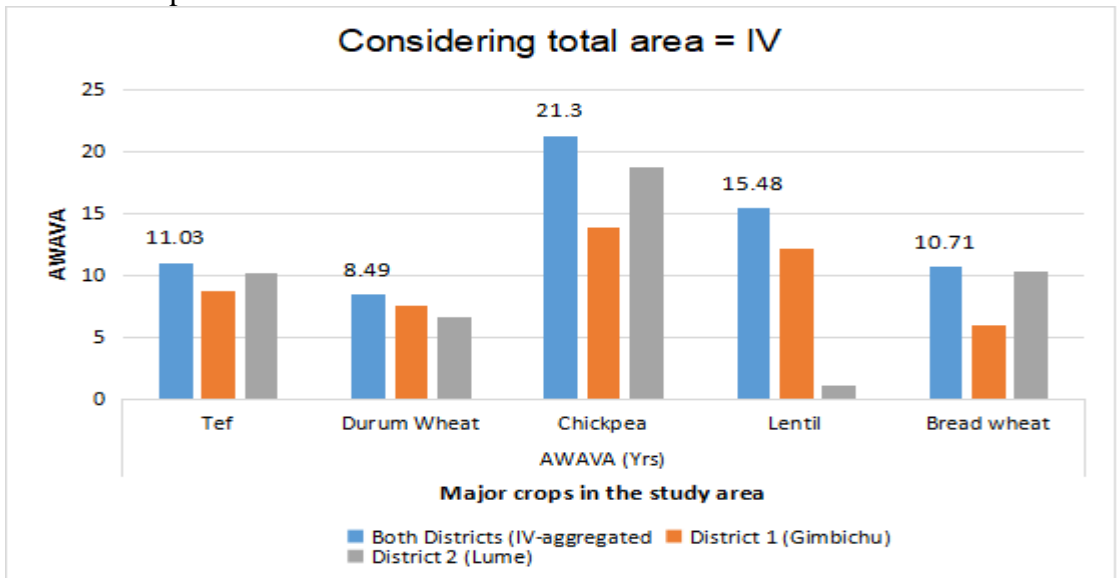


Fig 1. AWAVA for major crops grown in central Ethiopia

Farmers in the study area have experience of, on average, more than ten years of using improved varieties for the major crops produced in the central Ethiopia. The varietal turn over for the major crops is ten years and above except for durum wheat. This result is in agreement with studies by Endeshaw et al. (2023), who reported that according to the farmer response, the area weighted average age of wheat varieties in use was about nine years at the national level and eight years at the regional state level. However, similar study reported that the corresponding figure from genotyping was fourteen and thirteen years, respectively. The longer the varietal age, the higher susceptibility of these crops to disease and the lower

their productivity; where we recognize pulse crops (lentil and chickpea) are currently suffering from disease may be due to longer varietal turn-over rate.

Sample farmers in the study area are looking for varieties with high traits of grain yield and disease resistance to replace the existing varieties under production. Coupled with household related factors, improved seed availability significantly impacts agricultural productivity and farmers' livelihoods. The limited availability of improved seeds especially for pulses serve as a critical indicator of the poor performance of seed distribution systems for chickpea and lentil. Hugo and Omondi (2023) found that land size affects varietal turn-over, where larger commercially oriented farmers grew younger varieties (Smale and Olwande, 2014). New varieties also have to compete with older released varieties (Walker and Alwang, 2015), especially when production is mainly for subsistence (Spielman and Smale, 2017)

Varietal replacement rate serves as performance indicator of the seed system and the dominance (or not) of varieties developed by plant-breeding in a given cropping system (Spielman and Smale, 2017).

Conclusion and Recommendations

There is evidence that farmers replace some old varieties of major crops in central Ethiopia with relatively younger (recently released) varieties. However, the varietal turnover rate for these crops is very slow, almost more than 10 years for most crops in the study area. The productivity of these crops is also lower than the national average for most crops. There is a need to replace old varieties with the latest that are high yielding and having better disease and pest resistance attributes.

Hence, breeding system need to focus on the release of limited varieties that are highly productive and tolerant to the major disease. And most importantly, the seed system that ensures availability and access to newly released well performing varieties need to be strengthened. The seed system needs to distribute varieties where they perform better in terms of environmental condition and include better performing recently released varieties in the seed distribution system.

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