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Guta Bukero
Agricultural Economics Research Process, Agricultural Research Center, Ethiopian Institute of Agricultural Research, Wondo Genet, Ethiopia

Correspondence Author:
Guta Bukero
Agricultural Economics Research Process, Agricultural Research Center, Ethiopian Institute of Agricultural Research, Wondo Genet, Ethiopia

Varietal turnover analysis for Ethiopian maize (*Zea mays* L.) using DNA finger printing

Guta Bukero

Abstract
Realizing the growing importance of maize in the country's crop production and food security, significant research efforts have been made to develop high yielding varieties and disseminate to smallholder farmers to enhance food security in the country. The study examined the varietal turnover using farmer self-identification and DNA fingerprinting and determinants of maize cultivars turnover in Ethiopia. Secondary data from the household survey data collected by Central Statistical Agency and DNA fingerprinting identified for maize varieties were used in the analysis. To analyze the maize cultivars varietal turnover, a weighted average age Index (WA) was used. The Weighted Average Age for farmer self-identification was compared with DNA fingerprinting in order to check whether the result from DNA fingerprinting approach is different. The multiple linear regression models were used in identifying determinants of maize cultivars varietal turnover. The findings of the study indicate that maize Weighted Age was about 12 years**,** whereas, based on DNA fingerprinting analysis it was about 11 years in Ethiopia for the crop year 2015.

Keywords: DNA fingerprinting, varietal turnover, age of varieties

1. Introduction

Realizing the growing importance of maize in the country's crop production and food security, significant research effort has been done to develop new varieties of this crop that can enhance the food security in the country. The collaborative research efforts of Ethiopian Institute of Agricultural Research (EIAR) and International maize and wheat improvement center (CIMMYT) have resulted in the development of widely adapted hybrid seeds; open pollinated, low-moisture stress resistant and nutritionally enhanced varieties of maize beginning from 2007 onward. Other studies have observed that maize area covered by the improved varieties in Ethiopia is about 40% (Shiferaw *et al*., 2014; Abate *et al*., 2015) [11, 1].

Lack of information about the pace and dynamics of varietal change is a luxury that developing countries in sub-Saharan Africa can ill afford because both the level of modern cultivar adoption and the velocity of improved varietal turnover are low (Walker and Alwang, 2015) [15]. A reason may be that cultivar replacement typically requires farmers to purchase new seed, and their willingness to pay for new seed depends on a number of social and economic factors, including price of not only the seed itself, but also of the complementary inputs and of the output itself when sold in the market and the opportunity costs associated with saving seed from the previous harvest as a substitute for purchasing. Other reasons include more traditional, institutional, and technical factors such as access to credit and technological information (Feder *et al*., 1985) [8].

On the other hand, according to Maredia and Reyes (2015) [10], most varietal adoption and impact assessment studies in the past have relied on farmers' responses at household level surveys to estimate these indicators. Such method of 'farmer elicitation' to estimate varietal adoption can be fairly accurate in a setting where farmers are mostly planting seeds freshly purchased or acquired from the formal seed market as certified or truthfully labeled seed, and the seed system is well-functioning and effective in monitoring the quality and genetic identity of varieties being sold by the seed suppliers. However, in settings where the formal seed system is non-existent or ineffective, and farmers mostly rely on harvested grain (either from their own farms or acquired from other farmers or purchased from the market) as the main source of planting material, the reliability of estimating varietal adoption using this method is challenging. This may indicate that genetic fingerprinting appears to be an accurate method for tracking varietal diffusion (Chilot *et al*., 2016; Frédéric *et al*., 2016) [4, 9] and so was used in this study in crop varietal identification to undertake varietal turnover analysis.

Studies show that there is a widespread use of improved maize varieties (both hybrid and OPVs), but that farmers recall data underestimate the diffusion levels of improved varieties. For instance, according to the study by Chilot *et al*. (2016) [4], preliminary estimates of adoption levels of improved maize varieties based on the farmers' recall information was 56 percent as compared to 61 percent from the DNA fingerprinting approach. This indicates that genetic fingerprinting needs to be applied for tracking varietal diffusion (Chilot *et al*., 2016; Frederic *et al*., 2016) [4, 9]. There is a scarcity of information on the actual number of cultivars grown and their turnover. This study presents detailed accounts of the status of maize cultivars that smallholder farmer's grow at present in the country. Thus, in the earlier studies, maize varietal turnover and its determinants have not been assessed using a unique data from DNA fingerprinting. So, this study focused the research on varietal turnover by calculating an index of the weighted average age of varieties grown by farmers in a given year (measured in years since release), using a recently collected DNA fingerprinting dataset that has wider area coverage in terms of diversity in maize production potentials and administrative regions in Ethiopia.

1.1 Objectives of the Study

The general objective of the study was to analyze the maize varietal turnover in Ethiopia while the specific objectives of the study were:

1. To measure the rate of varietal turnover of maize using DNA fingerprint;
2. To compare the difference between varietal turnover of improved maize as reported by farmers and what DNA fingerprinting identified.

2. Methodology

2.1 Types, Sources and Methods of Data Collection

Following standard CSA procedures, two stage stratified sampling strategy was employed, with enumeration areas serving as the primary sampling units and the households being the secondary sampling units. The sampling enumeration areas in each region was randomly selected following probability proportional to size technique from a list of enumeration areas compiled during the 2007 population and housing census (Chilot *et al*., 2016) [4]. Farmers producing maize were considered from four regions; Amhara, Oromia, SNNP and Tigray, and then, zones, districts and enumeration areas (lowest administrative unit) with the highest number of maize producing farmers were selected randomly.

In this GFP survey, names of cultivars and the proportions of plots of each cultivar mentioned by each household was taken. To determine the age of each cultivar, national as well as regional catalogues was referred to compile the release year. It was confirmed that there are large numbers of cultivars for which release years are not provided. The cultivars were then divided into their respective classes of hybrids, improved open-pollinated varieties (OPVs), and local (farmers', traditional, or obsolete) cultivars. According to the study by Abate *et al*. (2015) [1] the definitions of the different categories of maize are as follows:

2.1.1 Hybrid: Freshly purchased hybrid seed;

2.1.2 OPV: Seed that has not been recycled for more than three seasons; and

2.1.3 Local (farmers' or traditional) cultivars: It includes landraces, recycled hybrids, OPVs recycled more than three seasons, and or those for which no information is available on year of release.

2.2 Sampling Strategy and Sample Size

2.2.1 Farm Household Sampling Strategy

The farm household sampling strategy following Chilot *et al*. (2016) [4] involves several steps. The first step focused on the preparation of a household survey instrument for soliciting farmer knowledge and use of improved varieties of maize. A questionnaire was prepared and circulated for maize for comments and suggestions by the socioeconomics task team of EIAR. Based on the feedback, contents of the questionnaire were refined and determined.

Then, the household survey focused on pretesting and reviewing of the household questionnaires to ensure critical minimum data set is collected in the shortest time possible with a minimum cost. After several reviews, the draft questionnaires were pretested by the socioeconomics task team. The pretesting of the questionnaires was used to evaluate the data collection instrument, estimate average time taken required for administering the questionnaires and identify potential problems that would arise during the actual implementation of the survey. The questionnaires were then revised based on feedbacks from the pre-test.

The next step involved establishing and training the survey teams. The enumerators and supervisors were recruited by CSA that have previous experience in the CSA surveys. A two-day intensive training was given to the selected enumerators and supervisors in the zones of the pilot areas. The training included briefings on the study objectives, a thorough review of the questionnaires, interviewing techniques, and tips on how to fill the structured questionnaires to ensure the collection of quality data. Following the in class trainings, enumerators and supervisors were taken to maize growing areas for on the job training and administering the questionnaires to households that are not part of the sample. The questionnaires are then revised in light of the feedbacks and finally be ready for the survey.

The final step was dealt with administration of the questionnaires to sample households and collection of completed questionnaires. Field data collection was carried out by Central Statistical Agency (CSA) teams. Each team was supervised by the respective head of the CSA zonal branch offices. In addition to the survey teams, one supervisor from the respective enumeration areas stationed in the respective districts assisted the survey team in implementing the household questionnaire. Overall, data collection was supervised and monitored by senior CSA management personnel.

Finally, the required sample respondents in each enumeration areas were determined based on proportions of maize producer households of the respective enumeration areas and simple random sampling technique was applied to identify sample farm households. Accordingly, the sample size was determined based on the proportion of maize producer households to have a total of 1,673 respondent farmers.

2.2.2 Genetic Profiling Sampling Technique

Crop cuts and associated data collection forms the basis for this study. Crop cut involves the use of appropriate sampling techniques for collecting crop samples from randomly selected maize fields (Chilot *et al*., 2016) [4]. The main objective of the crop cut was to collect maize grain samples from farmer fields for extraction of DNA and subsequent laboratory analysis for genetic matching with known reference materials. Crop cuts were taken from maize fields planted during 2014/15 crop season. The method involved demarcating small subplots of rectangular shape from randomly selected crop fields for each crop type and subsequent threshing, drying and weighing and recording the weight of the harvest. In each enumeration area, five maize fields were selected for conducting crop-cutting experiment.

Then after, a 4m x 4m area was randomly piloted within each of the selected cropped fields and was harvested from the plot. The crop cut was then weighed (fresh weight) and the data was recorded in a format prepared for the purpose. Then after two weeks of sun drying, the harvested sample was re-weighed several times and the figure from each weighing is compared to the previous record until a consistent figure is attained. If, a consistent weight is achieved which may suggest further drying and weighing is unlikely to lead to moisture loss, the final weight was considered the correct weight of the sample and recorded. Once, the sample’s consistent weight is attained, 200 grains from each crop was sub-sampled, packed in a paper bag and properly labeled and delivered to the CSA branch offices. Each paper bag bore all the necessary information important for matching the seed sample with the household questionnaire including the household ID, the parcel and field number the crop-cut was taken from.

Besides, grain samples from the crop cuts, maize seed samples from the maize breeding programs responsible for releasing and maintaining improved varieties were collected by the biotechnology task team for the development of a reference library. Grain samples and completed questionnaires were delivered to Ethiopian Institute of Agricultural Research (EIAR) in two ways. In the first case, the research team traveled to CSA branch offices and collected grain samples from the crop cuts along with completed questionnaires. In the second case, CSA experts brought the grain samples, completed questionnaires to Addis Ababa, and delivered it to EIAR. Similarly, seed samples of maize varieties from breeders and the Ethiopian Seed Enterprise (ESE) were collected for developing a reference library. Then, after collected samples were delivered to Holeta, the biotechnology task team labeled the samples properly and stored for DNA extraction at Holeta Biotechnology Research Center laboratory. Then the collected samples were processed for DNA extracts at NABRC by the EIAR biotechnology task team. In order to ensure that the DNA extractions are done properly, an expert from DArT provided hands-on training for the EIAR biotechnology researchers at Holeta. The biotechnology task team processed the DNA extracts, and shipped to Australia for DNA fingerprinting by DArT (Chilot *et al*., 2016 and DNA fingerprinting project) [4].

2.3 Methods of Data Analysis
2.3.1 Specification of Models

In this study a measure of the rate of varietal turnover based on the age of varieties grown by farmers in a given year (measured in years since release), weighted by the area planted to each variety in that year as proposed by (Brennan and Byerlee, 1991) [3] is used. This measure, ‘WA’is computed for a given year, as fol1ows:

$$WA=\sum_{i=1}^{n} P_i R_i \qquad (1)$$

Where,

WA: Weighted Average Age;

P_i: is the proportion of the area sown to variety i in a year t; and

R_i: is the number of years since the release of variety i.

As a result, annual changes in this index are somewhat smoother than in the other two indices, since they are unaffected by the choice of ‘target' period. This is the measure used in the following empirical analysis of maize varietal turnover in Ethiopia.

2.3.2 Definition of Variables

The hypothetical variables that are expected to be included in the analysis of maize varietal turnover in calculating an index of weighted age are:

2.3.3 Weighted Average Age (WA): It is an index to be calculated and is an outcome variable to calculate maize varietal turnover.

2.3.4 Maize varieties: Name of maize varieties include: BH-540, BH-543, BH-660, Shone, Agar and others. It is used to identify the maize varieties that are widely cultivated. Maize varieties release date is about a date of release for each and every maize variety from research institutions and universities. It is used to calculate the weighted age of a maize varieties being cultivated by farmers. Maize area indicates the area allocated for each maize varieties in a given crop year.

Descriptive analyses done include; mean, standard deviation, minimum and maximum for continuous variables and percentages for categorical variables. Analysis of variance (ANOVA) tests were used to test whether continuous variables on farm and farmer characteristics of the study area were homogenous or not. It was also used determine whether continuous variable on farm and socioeconomic characteristics of the households of Amhara, Oromia, SNNP and Tigray regions were homogenous or varied. Chi-square was used to test whether the percentage of categorical variables on socioeconomic characteristics of the households among the regions were homogenous or varied. It was used to determine whether categorical variable on farm and farmer characteristics among the Amhara, Oromia, SNNP and Tigray regions were homogenous or varied.

3. Results and Discussion
3.1 Characteristics of Farm Households

The average age of the sample household heads was about 47 years with minimum of 18and maximum of 97 years. In the same manner, average family size of the sample households was found to be 4.46, with the minimum of 1 and maximum family size of 13 (Table 1). According to Survey results, an increase in family size was directly proportional to allotted productive labor sources for maize production.

Table 1: Household characteristics of the study area (n=1673)

Variable	Mean	St. Deviation	Minimum	Maximum	F-test
Land owned	1.61	2.00	0.0016	50	42.38***
Experience	17.76	13.58	0	83	14.39***
Age	46.88	14.21	18	97	7.02***
Education	1.90	3.04	0	19	12.04***
Family size	4.46	2.14	1	13	4.56***
Livestock	5.15	3.97	0	36.2	10.46***
Distance nearest seed dealer	6.36	6.44	0	96	2.15*
Distance to nearest fertilizer dealer	10.89	8.48	0	90	4.37***

Source: GFP survey, 2014/15

Table 2 shows that the differences in mean age and family size among Tigray, Amhara, Oromia and SNNP households were insignificant. The overall mean number of years the household head had in formal education was 1.93 years. The mean number of years the household head had in formal education was higher for Oromia household heads (2.39 years) than for other regions and the difference was statistically significant at 1% probability level. Therefore, the likelihood of technology uptake would be higher for Oromia farmers.

The overall mean distance traveled by the household heads to get seed was 6.85 km. The mean distance traveled by the household head to seed markets was longer in Amhara (7.47 km) and Oromia (6.99 km) regions than the other two regions and the difference was significant at 1% probability level. The overall mean distance traveled by the household head to fertilizer markets was 6.36 Km. The mean distance traveled by the household heads to fertilizer market was longer in Amhara region (7.17 Km) than in Oromia, SNNP and Tigray regions which are 6.38, 6.50 and 4.32 kilometers respectively. The difference was statistically significant at 1% probability level. The mean differences for land ownership and experience in maize farming across the regions were also statistically significant at 1% significance level.

Table 2: Descriptive statistics of socioeconomic characteristics of the farmers in the selected regions of Ethiopia for continuous variables

Characteristics	Tigray (N=226)	Amhara (N=454)	Oromia (N=634)	SNNP (N=359)	Overall (N=1,673)	F-test
Age	50.64	47.45	45.81	45.45	46.84	7.02***
	(14.54)	(14.83)	(15.04)	(15.09)	(15.02)	
Family size	4.47	4.33	4.68	4.17	4.45	4.56***
	(1.95)	(2.12)	(2.19)	(2.13)	(2.13)	
Education level	1.66	1.32	2.39	2.11	1.94	12.04***
	(2.82)	(2.53)	(3.38)	(3.14)	(3.07)	
Land owned	0.99	1.21	2.09	1.51	1.58	42.38***
	(0.71)	(1.17)	(2.03)	(1.36)	(1.61)	
Farmer's experience	19.86	18.14	18.9	13.62	17.7	14.39***
	(14.85)	(13.22)	(14.11)	(11.32)	(13.59)	
Distance to seed market	6.64	7.47	6.99	5.85	6.85	2.15*
	(7.18)	(11.22)	(8.35)	(7.27)	(8.94)	
Distance to fertilizer market	4.32	7.17	6.38	6.5	6.36	4.37***
	(4.42)	(11.2)	(7.37)	(12.02)	(9.41)	
Livestock	4.57	4.68	5.82	4.92	5.14	10.46***
	(2.84)	(3.4)	(4.89)	(3.14)	(3.96)	

Source: GFP survey, 2014/15

Note: *** and * Significant at 1% and 10% probability level respectively

Figures in parentheses are the standard deviation

The overall mean total number of livestock owned by the household head was 5.14 units and the majority of the farmers owned cattle, goats and sheep a picture typical of smallholder mixed farming. The mean total number of livestock units owned by the household heads was the highest in Oromia region (5.82 units) followed by (4.92 and 4.68 units) in SNNP and Amhara regions respectively and the difference was significant at 1% probability level. These results could be explained from the point of the view that, household heads of Oromia region had more land hence, more pasture that could accommodate more livestock units.

Descriptive statistics of socioeconomic characteristics of the farmers in the selected regions of Ethiopia for categorical variables in (Table 3) indicate that the difference in percentage in terms of gender of household head and whether agriculture is source of income among regions were insignificant. But the difference in percentage in terms of farm asset ownership, access to extension services, and access to credit and status of farmer among regions' households were significant.

Table 3: Descriptive statistics of socioeconomic characteristics of the farmers in the selected regions of Ethiopia for categorical variables

Characteristics	Tigray (N=226) %	Amhara (N=454) %	Oromia (N=634) %	SNNP (N=359) %	Overall (N=1673) %	χ2-value
Sex						
Female	2.38	4.52	6.12	4.63	17.65	5.22

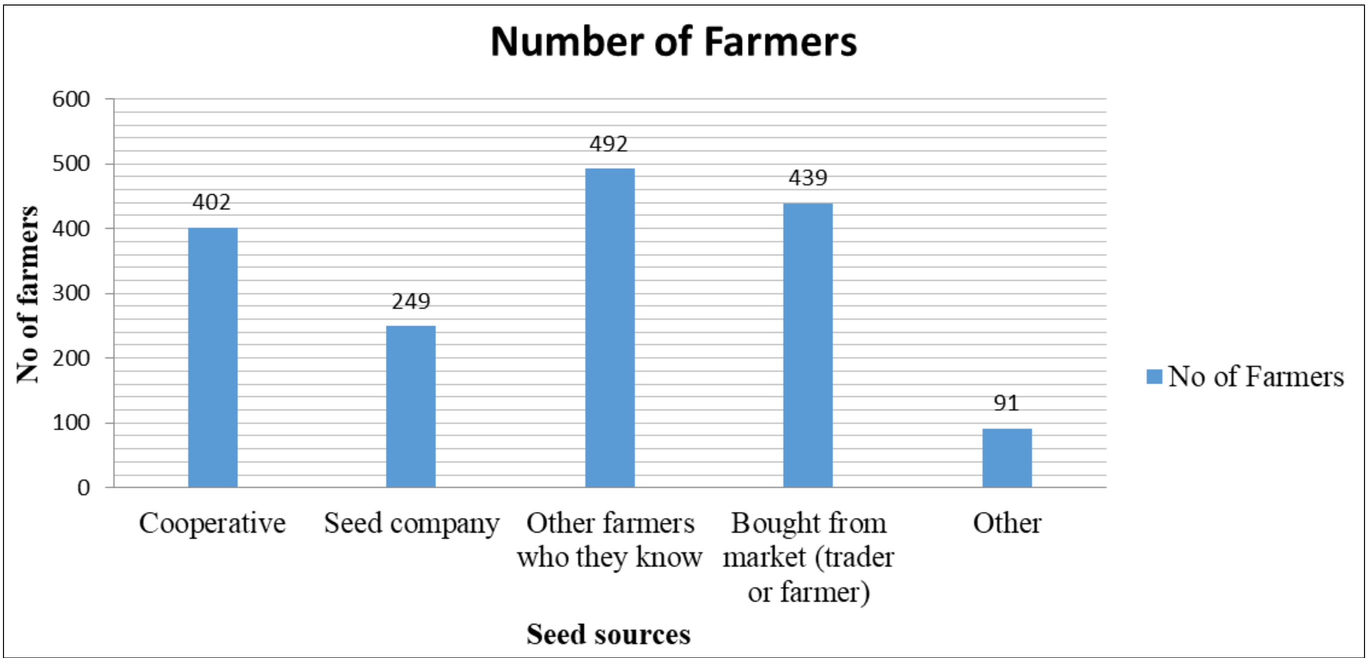
Male	11.05	22.82	31.67	16.82	82.35	
Access to extension						
No	8.14	13.95	17.93	6.59	46.62	57.63***
Yes	5.34	13.36	19.83	14.85	53.38	
Household's status						
Follower	10.21	23.1	34.14	18.94	86.4	33.03***
Model	3.27	4.22	3.62	2.49	13.6	
Whether agriculture is hh head's source of income						
No	0.65	1.01	1.66	0.53	3.86	2.95
Yes	12.83	26.31	36.1	20.9	96.14	
Asset ownership						
No	8.31	20.07	23.28	13.3	64.96	20.17***
Yes	5.17	7.24	14.49	8.14	35.04	

Source: GFP survey, 2014/15

Note: *** Significant at 1% probability level

3.1.1 Farmers' Seed Sources and Seed Management

Seed source is an important variable hypothesized to have an important bearing on varietal turnover. Among the farmers who have reported the main source of seed, 24% reported cooperatives, 29.4% obtained from other farmers who they know, 26.2% bought from the market either from traders or farmers, 14.9% reported from Seed Company and the rest got from other sources (Figure 1). However, the reality of this study was that, only 249 (14.9%) of the farmers sourced their seeds from recommended sources. About 492 (29.4%) of the sample households used seeds they purchased from other farmers which were originally distributed by woreda bureau of agriculture and saved from previous harvest.



Source: GFP survey, 2014/15

Fig 1: Sources of maize seed

During the 2014/15 production season, 55.6% of the farmers reported using saved maize seed; from the saved seed users, 75% reported application of some sort of seed management to ensure quality seed. The most common seed management practices reported are related with selection of field, better cultivation, rouging, threshing in separate place, and storing seed separate from grains (Table 4). Seed management practices are very important for saved seed to avoid loss of crop vigor and varietal contamination in the production, threshing and storing.

Table 4: Maize seed management by sample households

Seed production measures	Number of farmers (n=733)	
	Number	%
Plant seed fields separate from grain fields	114	15.55
Keep isolation distance to reduce varietal contamination	26	3.55
Better cultivation and weeding of seed	283	38.61
Rouge off-types in seed fields	61	8.32
Thresh seed in separate place	37	5.05
Clean seed separate from grain	30	4.09
Treat seed before storage	2	0.27

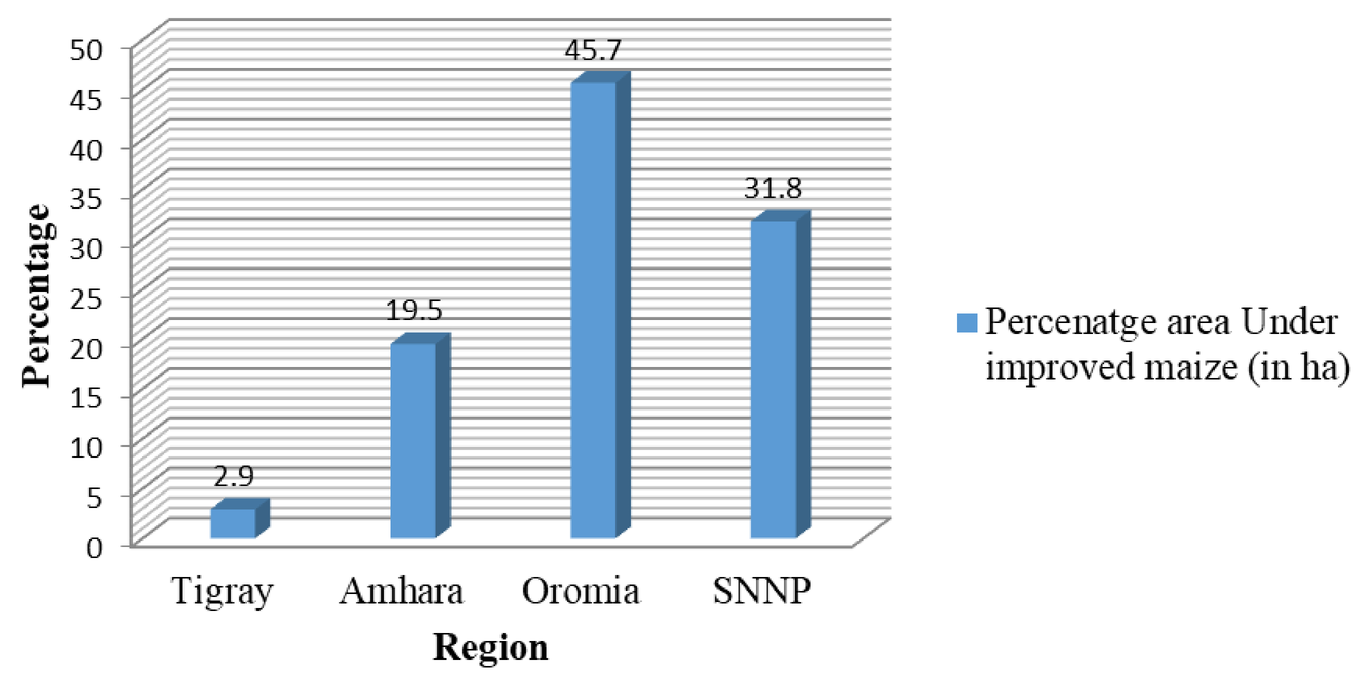
Store seed separate from grain	109	14.87
Clean seed before planting	49	6.68
Other	22	3
Total	733	100

Source: GFP survey, 2014/15

3.1.2 Maize Varieties Grown by Farmers

The study results indicate farm households cultivate many maize varieties**.** About 52.0 percent of the respondents claimed to have grown local and unknown local maize varieties. Unknown local and local variety was not a particular maize variety since any maize variety whose name the farmers did not know was classified as unknown local or unknown. Improved maize germplasm has played a key part in catalyzing change in production practices by replacing traditional varieties with input-responsive, stable and high yielding improved varieties. The Ethiopian NARS has released a total of 61 maize varieties between 1973 and 2013. The first locally developed hybrid (BH140, in the early to intermediate-maturity group) was released in 1988, followed by a late- maturing hybrid (BH660) in 1993, and BH540 and the Ethiopian hybrid marketed as Jabi (the Pioneer Hi-bred Seed).

Figure 2 below depicts the area coverage by improved varieties by administrative regions in Ethiopia in 2014/15 cropping season. The Oromia Region with 45.7% of the maize area under improved varieties comes first followed by SNNP and Amhara with 31.8% and 19.5%, respectively.



Source: GFP survey, 2014/15

Fig 2: Area under MVs in hectare in 2014/15 in selected regions of Ethiopia

3.2 Maize Varietal Turnover

3.2.1 Maize Varietal Turnover Analysis Using Farmers Perception

The availability of recommended varieties of maize alone would not imply varietal diversity, if they were not available at the farm level and grown by farmers. The total number of maize cultivars grown in Ethiopia during the study main crop season was more than 60 of which sixteen were hybrids; eight were OPVs, with more than 40 cultivars including known and unknown local varieties. The intermediate maturity group hybrid BH660 occupied the largest area (more than 20%). This cultivar was released in 1993 and currently due for replacement, with recently released more robust and higher-yielding cultivars such as BH661 and BH546. In Ethiopia, the WA calculated for modern maize varieties (both hybrid and OPVs) showed a low level of varietal turnover of about 11 and 14years respectively, according to the farmer responses (Table 5). This figure also indicates that although Ethiopian farmers are growing modern varieties of maize, it is slow in changing to new varieties released in recent years or having difficulty to get quick access to improved seeds.

Table 5: Maize varietal turnover analysis using farmer perception

Hybrid	Mean area (ha)	Release year	Years since release	WA
Aba Raya	1.00	2006	9	1.4
Agar	0.18	2006	9	0.2
Shone	0.43	2006	9	0.6
Welel	0.25	2006	9	0.3
BH140	0.21	1988	27	0.8
BH540	0.58	1995	20	1.7

BH541	0.05	2002	13	0.1
BH543	0.33	2005	10	0.5
BH545	0.32	2008	7	0.3
BH660	0.45	1993	22	1.5
BH661	1.08	2011	4	0.6
BH670	0.69	2002	13	1.4
Chindi	0.51	2001	14	1.1
Jabi	0.14	1995	20	0.4
Limu	0.44	2012	3	0.2
Total Hybrid	6.66			11.2
OPVS				
Katumani	0.54	1974	41	6.0
Fetene	0.27	1996	19	1.4
Kuleni	0.15	1995	20	0.8
Melkasa-1Q	0.12	2001	14	0.4
Melkasa-3	0.50	2004	11	1.5
Melkasa-4	0.39	2006	9	0.9
Melkasa-5	0.25	2008	7	0.5
Morka	1.48	2008	7	2.8
Total	3.70			14.3

Source: GFP survey, 2014/15

In the same manner, the combined WA calculated for modern maize (both hybrid and OPV) varieties showed a low level of varietal turnover of 12 years (Table 6). This figure again indicates that although Ethiopian farmers are growing modern varieties of maize, they are slow in changing to new varieties released in recent years or they are having difficulty to get quick access to improved seeds.

Table 6: Combined Weighted Average Age (WA) of maize varieties grown by farmers in Ethiopia

Hybrid	Mean area (ha)	Release year	Years since release	WA
Aba Raya	1.00	2006	9	0.9
Agar	0.18	2006	9	0.2
Shone	0.43	2006	9	0.4
Welel	0.25	2006	9	0.2
BH140	0.21	1988	27	0.5
BH540	0.58	1995	20	1.1
BH541	0.05	2002	13	0.1
BH543	0.33	2005	10	0.3
BH545	0.32	2008	7	0.2
BH660	0.45	1993	22	1.0
BH661	1.08	2011	4	0.4
BH670	0.69	2002	13	0.9
Chindi	0.51	2001	14	0.7
Jabi	0.14	1995	20	0.3
Katumani	0.54	1974	41	2.1
Limu	0.44	2012	3	0.1
Fetene	0.27	1996	19	0.5
Kuleni	0.15	1995	20	0.3
Melkasa-1Q	0.12	2001	14	0.2
Melkasa-3	0.50	2004	11	0.5
Melkasa-4	0.39	2006	9	0.3
Melkasa-5	0.25	2008	7	0.2
Morka	1.48	2008	7	1.0
Total	10.36			12.3

Source: GFP survey, 2014/15

3.2.2 Maize Varietal Turnover Analysis Using DNA Fingerprinting

Number of varieties released and adoption rate have often been used as a measure of success for maize technologies in the past. Never the less, experience from the literature suggests that high adoption does not necessarily always translate into productivity growth. Number of cultivars released is only one part of the equation in productivity growth. It is witnessed that sustained adoption and subsequent productivity gains depend largely on conducive government policy (De Groote *et al.*, 2013) [6] that would enable increased national government investment in agriculture, availability of inputs (like seed) at affordable price, a strong extension system, and market outlets for products.

The maize variety Katumani, released in 1974, was the oldest cultivar that was being grown in 2014/15 in Ethiopia, but it occupied less than 2% of the maize area. Similarly, Shalla maize variety (released in 2011) and Melkassa-6Q (drought-tolerant and quality protein maize cultivar released in 2008) were also identified by the DNA fingerprinting technology, but they both covered less than 1% of the total

area. In Ethiopia, the WA calculated for modern maize varieties i.e., hybrid maize and OPVs showed varietal turnover of 11and 11years respectively using DNA fingerprinting (Table 7).
These figures indicate that although Ethiopian farmers are growing modern varieties of maize, they are slow in changing to new varieties released in recent years or having difficulty to get quick access to improved seeds. Generally, the present area weighted average age of hybrids in Ethiopia was similar to the result reported by (Abate *et al*., 2017) [13] but showed improvement as opposed to 18 years reported for OPVs. This lagging in varietal turnover needs attention since it is critical in attaining dynamism in varietal diffusion as well as development in the medium and longer term in Ethiopia.

Table 7: Weighted Average Age (WA) of maize varieties grown by farmers in Ethiopia

Hybrid	Mean area (ha)	Release date	Years since release	WA
AMH-760	0.30	2008	7	0.4
Argane	0.35	2008	7	0.5
BH-140	0.53	1988	27	3.0
BH-540	0.40	1995	20	1.7
BH-660	0.46	1993	22	2.1
BH-661	0.53	2011	4	0.4
BH-670	0.28	2002	13	0.8
MH-130	0.28	2012	3	0.2
Shala	0.41	2011	4	0.3
Shone	0.30	2006	9	0.6
Wenchi	0.25	2008	7	0.4
Jibat	0.25	2009	6	0.3
Limu	0.47	2012	3	0.3
Total hybrid	**4.82**			**10.9**
		OPVs		
Abo Bako	0.27	1985	30	1.3
Kulani	0.37	1995	20	1.2
Gambela	0.32	2002	13	0.7
Gibe1	0.31	2001	14	0.7
Melkassa-1Q	0.42	2001	14	1.0
Melkassa-2	0.36	2004	11	0.7
Melkassa-3	0.48	2004	11	0.9
Melkassa-4	0.30	2006	9	0.5
Melkassa-5	1.05	2008	7	1.2
Melkassa-6Q	1.90	2008	7	2.2
Melkassa-7	0.17	2008	7	0.2
Total	5.95			10.7

Source: GFP survey, 2014/15

Similarly, the overall WA calculated for modern maize varieties showed a varietal turnover of 11years (Table 8) this is also suggesting Ethiopian farmers are slow in changing to new varieties released in recent years. On the other hand, it is interesting to note that more recent releases of drought-tolerant cultivars were mentioned by farmers during this study in the selected regions, even though their area coverage was low. Such varieties included BH-661, Limu and Shalla.

Table 8: Combined Weighted Average Age (WA) of maize varieties grown by farmers in Ethiopia

Hybrid	Mean area (ha)	Release date	Years since release	WA
Abo Bako	0.27	1985	30	0.5
AMH-760	0.30	2008	7	0.1
Argane	0.35	2008	7	0.2
BH-140	0.53	1988	27	0.9
BH-540	0.40	1995	20	0.5
BH-660	0.46	1993	22	0.7
BH-661	0.53	2011	4	0.1
BH-670	0.28	2002	13	0.2
Gambela	0.32	2002	13	0.3
Gibe1	0.31	2001	14	0.3
Hora	4.00	2005	10	2.6
Javi	0.46	1995	20	0.6
Jibat	0.25	2009	6	0.1
Kulani	0.37	1995	20	0.5
Limu	0.47	2012	3	0.1
Melkassa-1Q	0.42	2001	14	0.4
Melkassa-2	0.36	2004	11	0.3
Melkassa-3	0.48	2004	11	0.3

Melkassa-4	0.30	2006	9	0.2
Melkassa-5	1.05	2008	7	0.5
Melkassa-6Q	1.90	2008	7	0.9
Melkassa-7	0.17	2008	7	0.1
MH-130	0.28	2012	3	0.1
Shala	0.41	2011	4	0.1
Shone	0.30	2006	9	0.2
Wenchi	0.25	2008	7	0.1
Total	15.23			10.9

***Source*:** GFP survey, 2014/15

3.2.3 Comparison of Maize Varietal Turnover Estimates from the Two Approaches

When comparing weighted age of maize varieties from the household survey (farmer recall) with DNA fingerprinting, it still gives similar insights on the level of differences from using either approach. The comparison can be made in terms of the size of the estimated figure as well as whether there is match in variety identification. Table 9 compares maize WA estimates from the DNA fingerprinting analysis with farmer perceptions. As noted, according to the household survey, the WA was about 12 years**,** whereas, based on DNA fingerprinting analysis it was about 11 years. The estimate for WA of hybrid and OPV maize varieties is 11 and 11 years respectively using DNA analysis. Increasing varietal age is associated with declining marginal returns to crop breeding. The weighted average age of maize cultivars reported here is older than what is generally practiced in the United State of America or other regions such as South America and Asia; the result similar to (Abate *et al*., 2017) [13]. Approximately more than half of cultivars listed in this study were released before 2005.

Table 9: Comparison of maize varietal turnover estimates from the two approaches across selected regions in Ethiopia

Regions	Variety	Farmer response		DNA fingerprinting	
		Number	**WA**	**Number**	**WA**
Tigray	Hybrid	53	9.5	104	19.22
	OPVs	5	31.1	35	16.97
Amhara	Hybrid	159	16.50	255	12.99
	OPVs	19	26.68	114	11.19
Oromia	Hybrid	199	12.31	430	14.63
	OPVs	23	14.57	148	11.30
SNNP	Hybrid	110	14.38	252	11.09
	OPVs	11	26.52	66	12.5
Overall	Hybrid	522	11.2	1042	10.9
	OPVs	61	14.3	363	10.7

WA by Farmer response approach≈12 years
WA by DNA fingerprinting approach≈11years (t= -2.1***)
***Source*:** GFP survey, 2014/15

The measure of varietal turnover through the two approaches of farmer self-varietal identification and DNA fingerprinting showed a significant difference at 1% probability level indicating that farmer self-varietal identification underestimates varietal turnover measurement in years validating the importance of DNA fingerprinting technique than farmer self-varietal identification. Both approaches showed that although there is high adoption rate of improved maize varieties, maize varietal turnover is older than 10 years as the majority of improved maize varieties were released in 1990s.

4. Conclusion and Recommendation

The survey result showed that, the WA was about 12 years**,** whereas, based on DNA fingerprinting analysis it was about 11 years and there is significant difference in results between the two approaches at (1% probability level)**.** This again indicates that the household self-identification underestimates the level of use of improved varieties although both of them show that, on an average, the maize cultivars on the farmers' field are older than 10 years. The estimate for WA was found to be 11years using DNA fingerprinting analysis for both hybrid and OPV maize varieties.

Based on the findings and conclusions of the study, the differences were observed when comparing maize varietal turnover estimates from the DNA fingerprinting analysis with farmer perceptions. This could be an indication of poor information accessibility in transferring technology from the researchers to the farmers. Thus, there is a need to strengthen information delivery services. This shows that extension agents need to target not only the farmers who have not adopted the technology but also try to increase the use of recent technology by the farmers who have already adopted.

5. References

1. Abate T, Shiferaw B, Menkir A, Wegary D, Kebede Y, Tesfy K, *et al.* Factors that transformed maize productivity in Ethiopia. Food Security. 2015;7(5):965-981.
2. Wahab A, Abaseen N, Hayat M, Khan B, Luqman M. Advances in understanding the DNA-repair mechanism activated by CRISPR/Cas9. Int. J Biol. Sci. 2022;4(2):01-10. DOI: 10.33545/26649926.2022.v4.i2a.68
3. Brennan JP, Byerlee D. The rate of crop varietal replacement on farms: measures and empirical results for wheat. Plant Varieties and Seeds. 1991;4:99-106.

4. Chilot Y, Dawit A, Oruko L, Negisho K, Taxler G. Tracking the Diffusion of Crop Varieties Using DNA Fingerprinting. Research Report; c2016, 112.
5. Nuru Seid Tehulie. Review on critical period of weed competition and management in maize (*Zea mays* L.). Int. J Hortic Food Sci. 2021;3(2):44-48.
6. De Groote H, Dema G, Sonda GB, Gitonga ZM. Maize for food and feed: the farmers' perspective. Field Crop Research. 2013;153:22-36.
7. Dixon J, Nalley L, Kosina P, Larovere R, Hellin J, Aquino P. Adoption and economic impact of improved wheat varieties in the developing world. Journal of Agricultural Science. 2006;144:489-502.
8. Feder G, Just RE, Zilberman D. Adoption of agricultural innovations in developing countries: A survey. Economic Development and Cultural Change. 1985;33(2):255-298.
9. Frederic K, Abiyot A, Andrzej K, Alemayehu A, John I, Biratu Y, *et al*. Varietal Identification in Household Surveys Results from an Experiment Using DNA Fingerprinting of Sweet Potato Leaves in Southern Ethiopia. Policy Research Working Paper 7812; c2016.
10. Maredia M, Reyes B. Agriculture in an Interconnected World. International Conference of Agricultural Economists. Universita Degli Studi Di Milano; c2015 Aug. p. 8-14.
11. Shiferaw B, Kassie M, Jaleta M, Yirga C. Adoption of improved wheat varieties and impacts on household food security in Ethiopia. Food Policy. 2014;44:272-284.
12. Eleduma AF, Aderibigbe ATB, Sanni KO, Obabire SO. Effect of cattle manure on soil nutrients dynamics and performances of maize (*Zea mays* L) grown on sandy loam soil in forest-savannah transition zone southwest Nigeria. Int. J Hortic Food Sci. 2020;2(2):05-09. DOI: 10.33545/26631067.2020.v2.i2a.41
13. Abate T, Fisher M, Abdoulaye T, Kassie GT, Lunduka R, Marenya P, *et al*. Characteristics of maize cultivars in Africa: How modern are they and how many do smallholder farmers grow? Agriculture and Food Security; c2017. p. 1-17.
14. Muslumova ZH, Mammadli SA, Farajov MF. Effect of sodium and potassium humate in adaptive reaction of Zea mays under radiation stress. Int. J Biol. Sci. 2022;4(1):9-15.
DOI: 10.33545/26649926.2022.v4.i1a.35
15. Walker T, Alwang J. Crop improvement, adoption, and impact of improved varieties in food crops in Sub-Saharan Africa. CABI. Wallington, UK; c2015 p. 427-450.