

Exploitation of Ethiopian Coffee Land-race Potentials: Market Demand Oriented Specialty Variety Development

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Abstract

Coffee (*Coffea arabica* L.) is the major cash crop of Ethiopia. The country is ecologically very diverse which allows the coffee plant to grow under wide range of environments between altitudes of 550 to 2600 m. a.s.l. Ethiopia, being the place of origin for Arabica coffee, is endowed with genetic pool wealth of the crop and with enabling environmental conditions to sustainably produce and supply fine specialty coffee that can address emerging international market demand. The prevailing wide range of ecological condition in the country has allowed the production of coffees of different types that are with uniquely distinctive quality profile, resistance to major diseases, plant growth and yield potential among many other desirable traits. Of the coffees produced in Ethiopia, the most popular internationally branded types (named depending on area of production) are; Sidama, Yirga-cheffe, Limmu, Gimbi and Harerghe coffees. These specific coffee localities, despite their valuable potential and the recognition they deserved on the world market, were lacking their own improved local varieties where they had been using coffee varieties released for other areas (south-western region) until the 2010. However, most of southwest varieties showed multitude of constraints such as poor adaptation and inherent quality adulteration under the locations. Cognizant of this problem, local land race variety development program was designed and implemented to promote sustainable production of the distinct coffee types by origin maintaining inherent qualities of the specific localities for enhanced export market expansion. Through this breeding approach so far, outstanding achievements were recorded in germplasm collection, evaluation for desirable agronomical traits, and generation of basic information on the genetics aspects, and development and release of 12 speciality varieties suiting for the specific coffee landraces in Ethiopia, i.e., 4 Harerghe, 4 Wollega/Gimbi, 3 Sidama/Yirgacheffe and 1 Limu coffees. As the main focus areas of future Arabica coffee landrace improvement program, it would be vital to give due attention to further

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identification of new and distinctive landraces, extensive collection of coffee genetic resource from unaddressed localities, application of molecular breeding techniques such as marker assisted selection and breeding for major /emerging/ diseases and stress tolerance, among others.

Keywords

Coffea Arabica L, Genetic Diversity, Local Landrace, Specialty Coffee

1. Introduction

Arabica coffee in Ethiopia is the most important agricultural commodity, contributing around one quarter of the total export earnings. Coffee production is a vital business and wealth creation opportunity that directly or indirectly contributes to poverty reduction in the country the livelihoods of small scale coffee farmers are determined by the income from coffee sales. Ethiopia, being the center of origin and genetic diversity for *Coffea arabica*, is endowed with immense opportunities that can promote sustainable production and supply of quality coffee to meet the ever increasing market demand for specialty coffee. The Ethiopian Arabica coffee gene pool provides enormous sources of traits needed to cope with biotic and abiotic calamities including emerging diseases and insect pests as well as adverse climate change to ensure long-term survival and productivity of the crop in particular and the global coffee industry in general [1]. The presence of remarkable genetic diversity of the crop coupled with the diverse climate and soil types in the country allow to sustainably produce and supply fine specialty coffees with potential of producing all coffee types of the various world coffee growing origins [2].

Ethiopian coffee breeding program during the first three decades of coffee research was aimed at development of improved coffee cultivars with wider adaptation, disease resistance and stable yield across all coffee growing regions by concentrating on coffee germplasm sourced from the southwestern part of the country [1, 3]. However, this breeding approach didn't fully address all coffee environments especially in providing cultivars suiting to specific localities which are uniquely different from one another, as in the case of the eastern and the southern coffee growing regions of the country. The most popular and already known brands of Ethiopian coffee in the world market include; Sidama and Yirgacheffe (in southern), Limmu (in south-western), Gimbi (in western) and Harerghe/Harer (in eastern) that are named depending on area of production [4, 7, 9]. These specific coffee land races, despite their valuable potential and recognition they deserved on the world market, had been lacking their own improved local varieties where the coffee varieties released for other areas (south-western region) had been in use until the 2010. However, most of southwest varieties showed a multitude of constraints such as poor adaptation and

inherent quality adulteration. Hence, the national coffee research program initiated Arabica coffee local landrace variety development strategy to establish coffee improvement programs addressing each of the specific coffee growing regions [5]. Hence, this approach had been implemented as a crash program for priority areas lacking their own improved varieties, viz., Harerghe, Sidama/Yirgacheffe, Wellega/Gimbi and Limu coffees aiming at development of improved local varieties maintaining typical quality of each area and thereby promote the growing specialty coffee market [5, 6].

2. Breeding Approaches for Implementing Landrace Variety Development

The previous conventional breeding approach used commonly had several drawbacks: (1) difficulty to develop a number of varieties that adapt to all environments, (2) low preference of the released varieties by the local farmers when released to all areas, (3) adulteration of the typical quality of specific and known areas by introducing improved varieties originated in other areas. The method largely focused on the development of widely adapted varieties, and consequently, improved local varieties for each specific agro-ecology were lacking in most of the coffee growing areas. Cognizant of this fact, the new/modified breeding approach 'local landrace development program' was designed to address the specific potential localities [5]. This approach of breeding was implemented for the first time for priority areas, viz., Harerghe, Sidama/Yirgacheffe, Wellega/Gimbi and Limu coffee land races, which had no improved varieties of their own local landrace but owing the best quality coffee types fetching premium price on export market [6]. The breeding program activities were conducted at coffee research centers, sub-centers and testing sites that were already established in the representative coffee agro-ecologies of the country (Table 1).

Table 1. Coffee Research Centers, Sub-centers and testing sites established in the major coffee producing areas.

Research Center	Year established	Altitude (m.a.s.l)	Land holding (hectare)	Region/Land race/ representative)
Main center - Jimma	1967	1753	183	Southwestern (Jima, Illuababor, others)
Sub-centers				
Gera	1974	1900	166	Southwestern (Highland coffee)
Tepi	1976	1200	40	Southwestern (Lowland coffee)
Awada	1997	1740	31	Southern (Sidama/Yirgacheffe)
Haru	1998	1750	69	Western (Wellega/Gimbi)
Mechara	2005	1800	50	Eastern (Hare)
Testing sites				
Agaro	1973	1630	27	Southwest (Limu)
Mettu	1974	1550	32	Southwestern (Illuababora)
Mugi	1973	1553	27	Western (West Wellega)
Wonago	1974	1850	10	Southern (Sidama/Yirgacheffe, Gedeo)

Source: Bayetta and Labouisse, 2006 [5].

3. Germplasm Collection and Preliminary Screening

The Jimma Agricultural Research Center (JARC) and its sub-centers have been undertaking annual coffee germplasm collection program in the major growing across the nation with the aim of conserving coffee genetic materials beside evaluation for desirable traits. In effect, around 7130 coffee accessions have been collected across the country [3, 10]. As a major breeding pillar of land race improvement program, accessions collected from Harerghe/Harer, Sidama-Yirgacheffe, Wellega/Gimbi and Limu coffee land race origins were field established across centers and sub-centers of coffee research (Table 2). Initial screening for yield potential, CBD and CLR resistance, growth performance, branch die back and leaf retention has resulted in the identification of several promising accessions. Further evaluation of these materials was carried out using actual measurement over 2 – 3 years for the most desirable characters such as yield, coffee berry disease (CBD) resistance and cup quality. Evaluations made over series of years across locations enabled to identify the most few promising selections promoted to variety verification trial at coffee research sub-centers of Mechara, Awada, Haru and Agaro, which are representing coffee land races of Harer, Sidama-Yirgacheffe, Wellega/Gimbi and Limu, respectively [8, 9] (Table 2).

Table 2. Coffee Germplasm collected and evaluated across locations through landrace variety development program.

Landrace Origin	Year of collection	Number of accessions	Pipe line varieties
Wellega/Gimbi	1998-2017	1628	36
Limmu	2001-2005	2003	9
Hargehe/Harer	1998-2020	2132	20
Sidama/Yirgacheffe	1996-2020	1803	38
Total		7566	103

4. Development and Release of Specialty Coffee Varieties

In Ethiopia, coffee research started around 1970 basically to overcome different development challenges of the coffee sector such as disease problems (main objective), low yield and quality-related disputes in major coffee-producing regions of the country [13-16]. Twelve improved landrace varieties (one Limu, four Wollega, three Sidama-Yirgacheffe and four Harer coffees) were released for production by JARC through selective breeding, with the goal of improving coffee yields and disease resistance combined with their high-quality cupping scores. While it is intended to use the rereleased coffee varieties in production, it is critically important to take in to account the ecological suitability and recommendation

domain of each variety under its respective land race origin as reviewed by [11, 12]. Owing to the great demand of farmers for improved varieties due to lack of improved landrace varieties accompanied with the increasing export market demand and premium price from the specialty coffee, the coffee breeding program was necessitated to develop improved local varieties for each of the distinctive coffee land races as described below.

East Ethiopian /Harer/ Coffee

Harerghe coffee accessions of the 1998 collection batch were established initially at Jima (Southwest) and Awada (South) Research Centers where preliminary screening for major important traits was conducted. During this early screening period, progenies of more than 200 accessions were selected and extensively tested for their resistance to coffee berry disease (CBD) employing hypocotyles seedling test in the growth room and attached berry test (ABT) in the field at JARC. Based on results of evaluations made 14 Harerghe coffee selections which had consistently good yielded and relatively resistant to CBD were promoted to on-farm verification trial established at two sites (Mechara and Micheta) in west Harerghe in 2005. These top selections had been evaluated in verification plot for yield /yield components, adaptability and resistance/tolerance to common coffee diseases/insects and cup quality.

Based on results of past extensive evaluation at JARC and good early stage performance in the verification plots under the original habitat (Harerghe), a total of four improved varieties of Harerghe coffee land race origin (H674/98, H739/98, H823/98 and H857/98) were released in 2010 for production and use under eastern Ethiopian coffee growing areas. In the selection processes, traits considered as bases of evaluation were quality (as primary criteria), yield performance and disease reaction Tables 3, 4 and 5. All of the released varieties were top yielders over the years in progeny plots at JARC (Melko). These released selections, during their early growth periods in verification trial at Mechara and Micheta, showed good yield potential and good vegetative growth habit having large number of bearing branches/trees. The yield level under on-farm condition for all the varieties was lower as compared to the on-station yield level which was mainly due to the fact that the yield data taken was only on the first two early cropping years during which the trees might not have attained full bearing potential age. Generally, the released varieties were with typical quality profile of Harer coffee "Mocha" type (Table 4). Each variety scored high flavor well representing the typical quality profile of Harerghe coffee. It was noted three to four times to suit the mocha flavor during the sample assessment by different coffee quality panels.

West Ethiopian /Gimbi/ Coffee

In this study, efforts were made to address the problem of improved local variety and there by maintain the inherent quality characteristics of Wellega coffee. It was achieved that a total of four superior local varieties (W66/98, W76/98, W92/98 and 78/84) were identified and released for different

coffee growing areas of Wellega. The performance of the released varieties for various desirable traits (yield, diseases and quality) are shown in Tables (6, 7 and 8). The yield advantage (%) of released varieties over the check variety was 4.54, 3.81, 7.34 and 9.68 (on-station) and 67.83, 57.80, 85.43 and 90.17 (on-farm) for W66/98, W76/98, W92/98 and 78/84 coffee varieties, respectively. As revealed from the study, varieties; W66/98 and W76/98 exhibited good field resistance to CBD across locations and hence can be recommended for mid to high altitude areas where CBD problem is believed to be severe. On the other hand varieties W92/98 and 78/84 showed moderate resistance to CBD and thus limiting their recommendation range from low to mid altitude areas where severe CBD problem is not expected. They were susceptible to CWD which restricts their use in CWD prone areas. Moreover, these two varieties were vigorous growing types (tall tree with high primaries and branching) that require regular pruning to obtain sustainable yield. Varieties W92/78 and 78/84 showed relatively good resistance to coffee leaf rust (CLR) disease and thus recommended for production under CLR disease hot spot low land areas. These released varieties full fill the requirements for acceptable Wellega/Gimbi coffee quality profile which our international clients deserve for premium prices. Coffee varieties, mainly W92/98 and 78/84, had a fruity flavor that distinguishes the quality profile of Gimbi coffee land race.

South Ethiopian /Sidama-Yirgacheffe/ Coffee

From series of experiments conducted over locations on south Ethiopian coffee materials, a total of three improved landrace varieties (971, 974 and 85257) were released for coffee growing areas of Sidama/Gedio zones and similar areas in the southern region. Summary of their performance for yield, quality and disease resistance is shown in Tables 9, 10 and 11. They were high yielding varieties as compared to the check and had relatively consistent yields over years mainly in the progeny trial plots. The released materials showed considerable yield advantages over the check variety (>50% in verification trial and, >11% in preliminary screening). As revealed from the quality assessment made, all the released varieties had an acceptable export standard screen size (>85%) as screen size is one of the criteria to meet export market quality standard. They were with good and acceptable range of overall raw and cup quality standard having typical flavor representation of Sidama quality profile which is spicy. Coffee variety 974 in particular, represents both typical quality profile of Sidama and Yirgacheffe coffee types as shown from the cup quality test (spicy at Awada and Flora at Konga). All the three released coffee varieties were highly suited to mid altitude (1740-1850 m.a.l.) coffee growing areas of Sidama and Gedio zones of the southern region. Besides, varieties 971 and 974 have fairly good resistance to coffee berry disease (CBD) as compared to the check from seedling hypocotyle inoculation test made at JARC and therefore may have better performance in highland areas like Wonago and Konga (Yirgacheffe) where prevalence of the disease is expected to be

very high. Variety 85257 was with a moderate resistance to CBD and hence, recommended for use under the mid-altitude environments of Sidama and Gedio coffee growing areas. Moreover, varieties 791 and 794 showed good resistance to coffee wilt disease (CWD) under greenhouse condition during the study period.

Southwest Ethiopian /Limu/ Coffee

Limu coffee is a typical coffee flavor found in Jima and its neighboring zone, Illuababor. This distinctive coffee type however, had been lacking its own improved landrace variety that aid to sustain its productivity and traceability for inherent quality characteristics. To address this problem JARC and its sub-centers have made tremendous efforts starting from preliminary screening of limu coffee landrace accessions for the most desirable traits such as yield/yield components, resistance/tolerance to major diseases and quality. Results of the previous preliminary evaluation conducted at Agaro and Gera areas enabled to identify promising selections which had consistently good yielded and relatively resistant to CBD.

Accordingly, 11 top selections of Limu coffee were promoted to on-farm verification trial at four locations in Jima (Melko, Haro, Agaro and Gera) where they were evaluated over years. Results of evaluations carried out in different stages of experiment over locations and years for important agronomical traits such as yield and yield components, quality and resistance/tolerance to major coffee diseases are summarized in Tables 12, 13 and 14. These confirmed the superiority and outsmarting performance of Limu-1 coffee variety that was officially released for use in production under Limu and similar coffee growing environments in southwestern areas. Limu-1 coffee variety was a top yielder and showed good stand establishment at Melko, Agaro and Gera test locations with relatively large number of bearing trees/branches. This variety showed good resistance for CLR disease and moderate resistance for coffee berry disease (CBD) in visual assessment made in field condition. The overall quality of Limu-1 variety was among the top, 81.08 out of 100, which is very acceptable quality standard.

Table 3. Mean clean coffee yield (Qt/ha) of released Harerghe coffee varieties in verification plots at Harerghe (Mechara and Micheta) and in progeny plot at Jima (JARC).

Coffee Varieties	Verification trial in Harerghe									Preliminary trial at Jima	
	Mechara				Micheta				Over Location Mean	Six year (2002-2008) Average Yield	CV
	2007/08	2008/09	2009/10	Mean	2007/08	2008/09	2009/10	Mean			
H674/98	3.23	1.90	6.30	3.81	1.29	0.90	4.42	2.20	3.01	16.02	88.10
H739/98	1.42	1.54	3.55	2.17	0.75	1.12	4.43	2.10	2.13	13.46	59.75
H823/98	1.57	1.57	3.17	2.11	3.95	3.88	6.64	4.83	3.47	11.89	47.26
H857/98	1.70	1.76	2.50	1.98	1.11	1.50	5.02	2.54	2.26	17.06	55.89
74110 (Check)	0.51	0.14	0.11	0.25	0.31	0.50	0.27	0.36	0.31	-	-
Mean	1.25	1.45	2.94	1.88	0.89	1.20	3.42	1.83	1.86	-	-
LSD (5%)	1.05	1.05	NS	1.96	1.54	1.55	NS	1.71	1.16	-	-
CV (%)	5.35	26.38	86.47	111.79	103.81	77.21	59.65	99.72	94.82	-	-

Table 4. On-station and on-farm yield /yield component performance and quality test of released Harerghe coffee varieties.

Coffee Varieties	Clean coffee yield (Qt/ha)		Bearing trees /Survival rate (%)		Quality test					
	On-station	On-farm	Mechara	Micheta	Above screen size No. 14	Raw (40)	Cup (60)	Total (100)	Flavor	Typicity
H674/98	16.02	3.01	90.58	53.19	87.3	35	35	70	3.5	Mocha
H739/98	13.46	2.13	87.45	55.76	93.8	35	60	95	4.1	T.Mocha
H823/98	11.89	3.47	83.33	80.02	91.3	35	45	80	3.8	Mocha

Coffee Varieties	Clean coffee yield (Qt/ha)		Bearing trees /Survival rate (%)		Quality test					
	On-station	On-farm	Mechara	Micheta	Above screen size No. 14	Raw (40)	Cup (60)	Total (100)	Flavor	Typicity
H857/98	17.06	2.26	83.62	57.50	82.5	25	30	55	3.7	Mocha
74110 (Check)	-	0.31	29.72	27.00						
Average			75.52	52.35						

Table 5. CBD and CLR diseases infection levels of released Harerghe coffee varieties in progeny plot at Jima (2003-2009).

Coffee Varieties	Progeny plot at Jima							Verification plot at Harerghe		
	Attached Berry Test (ABT) CBD			Hypocotyle seedling Test CBD			CLR (2003-06) Visual score (%)	CLR Visual score (%)		
								Mechara	Micheta	
	2003	2004	2005	2004	2005	2009		2008	2009	2008
H674/98	95.6 (77.9)	26.5 (30.4)	14.0 (20.6)	90.6	95.2	-	8.28	5.9 (13.7)	4.1 (11.5)	5.1 (12.7)
H739/98	30.9 (33.8)	8.5 (15.2)	0.0 (0.0)	71.6	83.3	-	9.23	3.0 (9.6)	13.4 (21.4)	1.8 (6.3)
H823/98	17.3 (24.7)	14 (21.8)	9.6 (14.8)	72.7	85.3	77.5	24.18	1.7 (7.3)	31.6 (33.6)	2.3 (8.6)
H857/98	56.9 (49.0)	5.0 (10.5)	3.8 (9.2)	82.8	92.0	-	13.4	5.1 (12.5)	14.9 (22.5)	1.8 (6.0)
74110 (Check)	-							0.0 (0.0)	-	0.0 (0.0)
741 (Check)						15.3				
Mean	(42.3)	(21.2)	(21.4)	79.6	84.74	53.2	14.56	(10.4)	(18.9)	(7.37)
LSD (5%)	(28.4)	(13.8)	(21.6)	15.8	12.29	12.67		(11.6)	(13.8)	(NS)
CV (%)	(42.0)	(39.9)	(62.3)	14.0	8.96	13.37		(66)	(43.8)	(72.7)
SD							5.43			

Means in the brackets are the arcsine transformed of actual values.

Table 6. Quality performance of released Wellega/Gimbi coffee varieties at Haru research sub-center.

Variety	Quality					Over-all Quality	Typicity
	Above screen No. 14	Raw (40)	Cup (60)	Total (100)			
W66/98	96	26	30	56			Spicy
W76/98	86	23	27	50			
W92/98	91	26	33	59			Fruity
78/84	86	26	27	53			Fruity
74110 (Check)	90	22	40	62			

C= Released CBD resistant Check variety.

Table 7 Mean clean coffee yield (QT/ha) of released Wellega coffee varieties under verification plots at three locations in Wellega (Irecha, Duchi and Mugi) over 2 years and in preliminary trial for 4 years at Haru research center.

Clean coffee yield (Qt/ha)											
Trial Name	Location (L)	Year (Y)	Varieties					Mean	LSD 5%	LSD 1%	CV (%)
			W66/98	W76/98	W92/98	78/84	74110 (Check)				
Verification Trial	Irecha	1	6.01	5.63	5.82	4.29	3.98	5.15	NS	NS	35.3
		2	2.27	1.19	2.42	1.47	1.6	1.79	NS	NS	6.14
		Mean (LxY)	4.14	3.41	4.12	2.88	2.79	3.47	NS	NS	45.9
		Percent yield increase over check	48.3	22.1	47.7	3.3					
	Duchi	1	3.34	2.36	3.04	3.12	1.73		2.81	2.8	NS
		2	5.04	6.4	4.14	4.97	2.26		4.11	3.5	4.8
		Mean (LxY)	4.19	4.38	3.59	4.04	2		3.46	2.3	2.9
		Percent yield increase over check	109.4	118.9	79.7	102.2					
	Mugi	1	6.5	5.32	10.9	10.6	3.83	7.44	3.3	4.5	30
		2	4.02	4.24	5.59	8.52	3.38	5.15	2.8	3.7	42
		Mean (LxY)	5.26	4.78	8.26	9.57	3.61	6.3	2.1	2.8	34.1
		Percent yield increase over check	45.8	32.4	128.9	165					
Progeny Trial	Haru	1	5.01	4.33	6.02	1.25	4.95	3.88	2.7	3.5	34
		2	10.75	11.33	10.78	11.91	8.39	11.34	5.8	7.6	34
		3	16.72	11.88	21.7	23.76	15.19	16.81	8.8	11.6	32.5
		4	30.18	34.67	25.84	28.78	31.38	32.01	14	18.4	30
		Mean	15.66	15.55	16.08	16.43	14.98	16	5.09	6.7	20.5

Table 8. CBD infection levels of released Wellega coffee varieties in progeny plot at Haru Research Center (Two-year).

Attached berry test (ABT)-CBD						Seedling Test			CBD Visual score (%)				CLR Visual (%) at Mugi
Coffee	Progeny plot	Verification plot				CBD	CWD	IP	Haru	Dechi	Irecha	Mugi	
Varieties	Haru	Dechi		Irecha									
		Y1	Y2	Y1	Y2								
W66/98	1.96 (5.62)	8.96 (17.22)	0.54	15.3 (23.45)	0.0	47.50 (43.56)	45.40 (42.32)	88.67	0.01	1.54	1.83	1.73	1.25
W76/98	8.02 (16.03)	5.26 (13.24)	0.15	6.26 (14.47)	0.11	49.77 (44.73)	88.33 (70.69)	83.33	0.03	1.51	1.33	3.60	0.81
W92/98	9.72 (14.49)	18.12 (25.15)	0.15	18.55 (27.49)	2.5	95.53 (78.19)	91.67 (80.00)	62.00	0.06	2.11	1.74	4.00	2.09
78/84	13.18 (15.87)	2.31	0.25	13.27	0.0	86.17		-	0.27	1.29	0.53	1.40	1.16

Attached berry test (ABT)-CBD						Seedling Test			CBD Visual score (%)				CLR Visual (%) at Mugi
Coffee	Progeny plot	Verification plot				CBD	CWD	IP	Haru	Dechi	Irecha	Mugi	
Varieties	Haru	Dechi		Irecha									
		Y1	Y2	Y1	Y2								
		(8.69)		(23.18)		(68.53)							
74110a	10.71 (18.19)	5.35 (13.07)	1.77	28.39 (36.89)	0.12	-	-	-	0.02	1.99	3.04	6.93	0.98
370b	-	-	-	-	-	100.00 (90.00)	-	-	-	-	-	-	-
H11c	-	-	-	-	-	-	0.00 (0.00)	0.00	-	-	-	-	-
SN5d							75.97 (61.77)	111.33					
Mean	(41.23)	(15.58)	0.64	(21.6)	1.85	(58.66)	(55.46)	83.37					
LSD (5%)	(14.51)	(10.06)	NS	(8.94)	NS	(7.9)	(16.99)	44.47					
CV (%)	(30.61)	(38.60)	85	(24.70)	61.80	(8.35)	(19.00)	33.06					

CBD=Coffee Berry Disease, CWD=Coffee Wilt Disease, IP=Incubation Period; CLR Coffee Lea Rust; indicates no data; Means in the brackets are the arcsine transformed of actual values, The data were means of two years except ABT in verification plots and seedling test.

Table 9. Mean yield in Qt/ha (On-station and On-farm) and quality performance of released South Ethiopian coffee varieties.

Variety	Qt/ha clean coffee		Quality*				
	On-station	On-farm	Above screen No. 14	Raw (40)	Cup (60)	Total (100)	Typicity at Awada/Konga
974	20.21	3.06	92	28	33	61	Spicy/Flora
971	19.47	3.34	93	30	32	62	Spicy
85257	21.15	2.39	95	31	35	66	Spicy
75227 (Check)	17.51	1.50	93	28	28	56	-

*= Quality assessment was done for 3 years.

Table 10. Mean yield (Qt/ha) of released South Ethiopian coffee varieties over years in verification trial (at Korke and Konga) and in progeny plot at Awada.

Trial	Location	Year	Variety				LSD 5%	LSD 1%	CV (%)
			974	971	85257	75227 (Check)			
Variety Verification	Korke	1	3.63	3.41	2.28	1.3	2.28	3.09	43.76
		2	0.57	0.64	0.79	1.55	1.31		88.58

Trial	Location	Year	Variety				LSD 5%	LSD 1%	CV (%)
			974	971	85257	75227 (Check)			
Preliminary Screening	Konga	Mean	2.1	2.02	1.54	1.43			
		1	5.68	8.43	4.99	2.57	2.46	3.33	27.66
		2	2.34	0.89	1.47	0.53	1.09		42.76
		Mean	4.01	4.66	3.23	1.55			
		% yield increase over check	104	123	59				
	Awada	1	9.34	13.32	16.39	4.68	4.85	6.41	30.89
		2	18.49	7.92	22.35	6.12	6.75	8.93	49.88
		3	24.67	25.46	15.01	20.6	10.02	13.25	29.57
		4	40.2	27.34	20.34	18.13	11.04	14.59	43.38
		5	11.02	19.56	31.65	27.71	10.61	14.03	40.28
		6	32.36	24.75	-	39.63	11.56	15.29	24
		7	5.4	17.92	-	5.68	6.23	8.31	85.5
		Mean	20.21	19.47	21.15	17.51			
		% yield increase over check	15.41	11.19	20.79				

Table 11. Coffee berry disease (CBD) infection level (%) of released south Ethiopian coffee varieties tested at different locations.

Variety	CBD- Attached berry test (ABT)		CBD-Seedling Test in green house				CBD (%) Visual Assessment			CLR (%) Visual Assessment		
	Wonago (2 year)	Awada (2 year)	CBD	CWD	IP	CLR	Wonago (3 year)	Awada (2 year)	Konga	Wonago (3 year)	Awada (2 year)	Konga
971	-	30.03 (29.25)	32.22 (28.43)	5.71 (2.90)	14.00	40.78 (43.3)	-	0.04	0.33	-	32.17	0.0
974	-	32.96 (34.48)	39.37 (39.03)	9.26 (7.25)	41.00	52.78 (63.3)	-	3.06	5.87	-	10.94	0.0
85257	26.34 (23.34)	-	48.95 (56.83)	-	-	-	0.77	-	0.03	1.63	-	0.0
75227 (Check)-a	15.66 (11.85)	10.02 (3.64)	39.42 (40.80)	-	-	-	0.35	-	-	0.18	-	0.0
Geisha-b	-	-	-	-	-	6.14 (3.30)	-	-	-	-	-	-
LSD (5%)	11.30	15.05	10.46	15.45	NS	28.90	-	-	-			
CV (%)	30.00	32.37	10.18	29.10	29.10	36.32	-	-	-			

a=CBD resistant check; b= CLR disease resistant check; IP=Incubation Period; CLR Coffee Lea Rust; indicates no data; Means in the brackets are the arcsine transformed of actual values.

Table 12. Mean Yield of released Limu-1 variety in verification trial at four locations in Southwest Ethiopia.

Clean coffee in Q/ha over years/ locations																					
Variety	Melko					Agaro					Haro					Gera					Over location Mean
	2014	2015	2016	Mean	SD	2014	2015	2016	Mean	SD	2014	2015	2016	Mean	SD	2014	2015	2016	Mean	SD	
L-1/01	13.8	12.3	26.2	17.4	7.7	6.9	20.4	23.4	16.9	8.8	3.2	2.8	11.2	5.7	4.8	11.5	17.4	25.3	18.1	6.9	14.53
L-3/01	15.3	15.3	15.2	15.3	0.0	10.0	11.2	34.7	18.7	13.9	7.2	1.9	15.4	8.1	6.8	16.4	10.2	17.5	14.7	4.0	14.19
L-32/01	6.6	5.9	19.3	10.6	7.6	10.0	9.8	25.3	15.0	8.9	3.3	3.2	13.4	6.6	5.9	9.4	8.0	17.8	11.8	5.3	11.01
L-45/01	9.0	12.6	36.1	19.2	14.7	3.7	19.2	29.8	17.6	13.1	6.2	4.7	15.8	8.9	6.1	13.9	20.9	17.8	17.5	3.5	15.80
L-52/01	24.0	23.4	27.5	24.9	2.2	9.8	23.5	30.8	21.4	10.7	6.0	8.4	15.6	10.0	5.0	13.8	20.9	29.6	21.4	7.9	19.42
L-54/01	15.5	14.7	20.7	17.0	3.2	14.1	10.4	29.9	18.1	10.4	8.7	3.0	13.4	8.4	5.2	12.6	19.4	18.0	16.7	3.6	15.03
Limu-1	15.2	14.7	30.2	20.0	8.8	7.3	21.7	42.1	23.7	17.5	7.6	5.6	19.1	10.7	7.3	20.4	22.6	31.2	24.7	5.7	19.80
L-56/01	20.9	15.0	30.8	22.2	8.0	12.8	17.8	31.0	20.5	9.4	8.8	6.8	18.4	11.4	6.2	22.7	11.0	33.1	22.3	11.0	19.10
L-63/01	21.6	15.9	25.3	20.9	4.7	13.1	20.9	32.5	22.1	9.8	4.9	2.2	11.1	6.1	4.5	16.7	13.8	21.0	17.2	3.6	16.57
L-67/01	17.0	14.5	28.2	19.9	7.3	5.2	19.3	33.1	19.2	14.0	10.0	4.5	22.1	12.2	9.0	10.3	11.4	29.3	17.0	10.6	17.06
L-68/01	12.3	10.8	15.9	13.0	2.6	7.5	21.4	31.9	20.3	12.2	2.3	3.3	15.8	7.1	7.5	6.6	9.9	18.9	11.8	6.4	13.04
Checks																					
744	13.9	14.9	18.4	15.7	2.4	10.6	9.6	36.8	19.0	15.4											17.4
Dessu	25.0	18.6	33.9	25.8	7.7	12.9	24.9	45.6	27.8	16.5	10.3	12.2	20.9	14.5	5.7						22.7
M/Cheriko											6.8	3.6	15.9	8.7	6.4	13.1	10.4	11.8	11.8	1.4	10.3
75227																17.6	13.3	29.7	20.2	8.5	20.8
Mean				18.6					20.0					9.1					17.3	8.5	16.25
F-test				**					Ns					*					*		**
CV (%)				32.1					37.6					22.8					18.0		39.5
LSD (0.05)				6.9					-					4.5					6.9		3.6

The checks used were; At Melko & Agaro (Dessu & 744), at Haro (Dessu & Merdachariko) and at Gera (75227 & Merdachariko).

Table 13. Reaction of released Limu-1 variety to major diseases (CBD and CLR) under verification trial at four locations in Southwest Ethiopia.

Selection	Gera				Melko				Agaro				Haro			
	CBD (%) - Visual			CBD ABT %	CLR %		Selection	Mean CBD %	CBD %	CLR %	CBD %	CLR %	CBD %	CLR %	CBD %	CLR %
	2015	2016	Mean		2016	2015	2016									
L1/01	10.75	8.84	9.8	5.7	10.5	3.13	4.33	3.7	0.37	1.01	L1/01	5	0.41	0.41	9.8	
L3/01	0	1.07	0.5	3.84	5.77	6.69	8.89	7.8	0.36	1.47	L3/01	17.5	0.51	0.51	8.815	

Selection	Gera				Melko								Agaro		Haro	
	CBD (%) - Visual				CLR %											
	2015	2016	Mean	CBD ABT %	2016	2015	2016	Mean	CBD %	ABT %	Selection		CBD %	CLR %	CBD %	CLR %
L32/01	3.8	0.73	2.3	2.62	15.79	1.75	5.97	3.9	0.35	0.35	L32/01	12.06	0.37	0.37	10.95	
L45/01	0.39	3.05	1.7	4.05	22.57	2.13	6.72	4.4	0.36	0.35	L45/01	16.55	0.39	0.39	15.07	
L52/01	11.65	24.5	18	0.94	3.26	2.22	10.61	6.4	0.4	1.08	L52/01	4.4	0.59	0.59	11.27	
L54/01	0.27	2	1.1	1.21	7.67	3	6.81	4.9	0.38	0.83	L54/01	4.4	0.37	0.37	9.05	
Limu-1	0.15	2.4	1.3	2.25	3.1	5.57	8.61	7.1	0.35	1.83	L55/01	11.6	0.36	0.36	10.89	
L56/01	8.13	9.5	8.8	1.34	8.21	29.38	11.47	20.4	0.37	1.56	L56/01	28.15	1.44	1.44	3.5	
L63/01	0.17	1.74	0.1	1.74	5.82	32.19	8.31	20.3	0.35	0.35	L63/01	19.25	0.9	0.9	15.1	
L67/01	0.88	3.45	2.2	0.81	4.15	11.69	5.56	8.6	0.36	1.31	L67/01	14.02	0.4	0.4	17.19	
L68/01	11.95	19.45	15.7	3.34	1.59	10.32	8.92	9.6	0.36	4.35	L68/01	12.8	5.29	5.29	6.2	
Checks																
M/Chariko	0.06	1.48	0.8	1.35	18.86	-	-	-	-	-	-	-	-	-	-	-
75227	10.99	17.6	14.3	3.4	4.11	-	-	-	-	-	-	-	-	-	-	-
744	-	-	-	-	-	3.21	7.58	5.4	0.38	0.97	0.09	6.45	0.2	0.2	7.6	
Dessu	-	-	-	-	-	7.65	7.28	7.5	0.36	2.3	0.38	6.3	2.4	2.4	8.5	
Mean	4.55	7.37	5.9	2.5	8.57	9.15	7.77	8.5	0.37	1.37	mean	12.69	1.21	1.21	10.05	
CV (%)	1.86	5.58	-	20.8	16.6	34.3	3.06	-	39.9	26.6	CV (%)	34	33	33	10	
LSD (0.05)	18.79	0.9	-	1.15	NS	6.84	18.04	-	NS	NS	LSD	15	NS	NS	2.2	

Table 14. Raw and cup quality of released Limu-1 variety under Limu coffee under verification trial at four locations in Southwest Ethiopia.

Selection	Screen 14				Raw 40%				Cup 60%				Overall 100%			
	Melko	Agaro	Haro	Gera	Melko	Agaro	Haro	Gera	Melko	Agaro	Haro	Gera	Melko	Agaro	Haro	Gera
L-1/01	98.0	97.0	98.0	98.0	37.3	38.7	35.8	37.0	47.2	46.3	45.3	48.3	84.5	85.0	81.2	85.3
L-3/01	99.0	98.0	98.0	97.0	37.0	37.0	36.0	36.7	45.7	44.3	43.0	44.3	82.7	81.3	79.0	81.0
L-32/01	96.0	97.0	98.0	96.0	36.3	36.7	33.8	37.3	46.7	47.4	45.7	45.0	83.0	84.1	79.5	82.3
L-45/01	99.0	99.0	99.0	99.0	36.7	36.7	35.3	36.3	46.1	45.0	45.7	44.5	82.8	81.7	81.0	80.8
L-52/01	98.0	98.0	99.0	99.0	35.7	35.7	35.3	35.0	48.9	43.7	45.0	46.8	84.6	79.3	80.3	81.8
L-54/01	98.0	98.0	99.0	99.0	37.0	37.5	35.7	36.3	46.3	44.2	46.2	45.2	83.3	81.7	81.8	81.5
Limu-1	97.0	96.0	97.0	90.0	38.0	38.0	36.2	35.7	45.9	45.0	46.3	43.6	83.9	83.0	82.5	79.3
L-56/01	98.0	99.0	97.0	99.0	36.0	36.2	35.3	37.7	49.5	45.2	42.8	47.0	85.5	81.3	78.2	84.7
L-63/01	99.0	99.0	99.0	98.0	37.3	37.0	36.3	36.3	46.9	44.8	48.5	46.9	84.3	81.8	84.8	83.2
L-67/01	99.0	99.0	99.0	99.0	37.3	36.0	35.7	36.7	47.3	46.8	46.3	46.8	84.6	82.8	82.0	83.5
L-68/01	99.0	99.0	98.0	98.0	39.0	38.2	37.7	37.0	47.9	44.9	44.8	48.5	86.9	83.1	82.5	85.5
Checks																

Selection	Screen 14				Raw 40%				Cup 60%				Overall 100%			
	Melko	Agaro	Haro	Gera	Melko	Agaro	Haro	Gera	Melko	Agaro	Haro	Gera	Melko	Agaro	Haro	Gera
744	99.0	98.0			35.0	35.7			43.3	38.1			78.3	73.8		
Dessu	97.0	99.0	99.0		37.0	37.7	44.7		43.0	44.3	44.7		80.0	81.9	81.8	
M-Cheriko			99.0	99.0			39.0	37.3			39.0	46.7			75.0	84.0
75227				99.0				36.0				43.5				79.5
Mean																
CV (%)					3.90	3.89	4.46	2.6	5.88	6.91	7.14	5.06	4.47	4.79	4.93	3.20
LSD (0.05)					2.41	2.41	2.33	0.76	4.59	5.34	4.48	1.85	6.26	6.56	5.78	2.10

The checks used were; At Melko & Agaro (Dessu & 744), at Haro (Dessu & Merdachariko) and at Gera (75227 & Merdachariko).

Table 15. Agro-ecological suitability and recommendation domain of released specialty varieties of Harerghe, Wollega/Gimbi, Sidama/Yirgacheffe and Limu coffee.

Region/Land Race Name	Variety		Suitable Altitude			Recommended coffee producing areas
	Accession No.	Breeder's Name	High-land (>1750 m.a.l.)	Mid-land (1500-1750 m.a.l.)	Low-land (1000-1500 m.a.l.)	
Harerghe/Harer	H674/98	Harusa				West Hararge
	H739/98	Mocha				West Hararge
	H823/98	Mechara-1				West Hararge
	H857/98	Bultum				West Hararge
Wollega/Gimbi	W66/98	Haru-1				West Wellega, Kelem Wollega
	W76/98	Chala				West Wellega, Kelem Wollega
	W92/98	Sinde				West Wellega, Kelem Wollega
	78/84	Mena sibu				West Wellega, Kelem Wollega
Sidama/Yirgacheffe	971	Feyate				Southern (Sidam/Yirgacheffe)
	974	Odicha				Southern (Sidam/Yirgacheffe)
	85257	Koti				Southern (Sidam/Yirgacheffe)
Limu	L55	Limu-1				Southwestern (Limmu)

5. Conclusion and Recommendation

Ethiopia is widely regarded as the birthplace of Arabica coffee, and it is home to a diverse range of local landraces that have evolved naturally over time in specific regions or areas. These coffee landraces that are acclaimed for having such unique characteristics, often named after the region or area where they are grown, include Sidama, Yirgacheffe, Hararge,

Ghimbi and Limu. Local landraces have been cultivated in Ethiopia for thousands of years, and they play a critical role in the country's coffee industry. They have become increasingly popular among specialty coffee roasters and are prized for their unique flavors and the fact that they are well-suited to the local climate and soil conditions, which helps to create a more sustainable and resilient coffee industry. Studies made over time reflect a growing understanding of the unique genetic diversity and distinctive quality profiles of coffee in Ethiopia and the importance of preserving these varieties. Conserva-

tion of the germplasm though not large enough to represent the available diversity, would also serve as an immediate source of breeding material in the future breeding program.

The entire released specialty coffee varieties suit for mid-altitude (1550-1750 m.a.l.) coffee growing areas under their respective locality. Besides, varieties; H823/98 and H857/78 of Harerghe, W66/98 and W76/98 of Wollega/Gimbi and, 974 and 85257 of Sidama/Yirgacheffe coffees would be recommended for CBD prone high land areas (>1750 m.a.l.) in their respective area of origin whereas varieties W92/78 and 78/84 of Wollega/Gimbi would be recommended for production under CLR disease hot spot low land areas (1000-1500 m.a.s.l.) like 'Mugi' district in Kelem Wollega Zone.

Findings of the local landrace improvement program acknowledge the fact that these coffee varieties have evolved in specific local environments over thousands of years, resulting in sustainable coffee production with distinct regional flavor profiles that are highly valued by coffee lovers around the world. The release of these improved land races address the variety problem the specific environments and is also believed to avoid the problem of quality adulteration, environmental adaptability and preference/resistance by the local farmers.

6. Future Direction

In Arabica coffee landrace improvement program, the main focus areas of future breeding work, among others, would be;

- (1) Exploration of coffee land races and further identification of new localities with a distinctive quality profile would be of great value. Moreover, further evaluation of local coffee germplasm for yield, quality and disease resistance must continue to provide sufficient amount of improved cultivars for coffee growers of each region. Extensive collection and maintenance of coffee genetic material from unaddressed areas would help to minimize the risk of losing indigenous genetic materials which is being challenged by the severe competition with cash crops like chat (*Catha edulis*) especially in Hararge coffee growing districts.
- (2) The application of molecular breeding techniques such as marker assisted selection and breeding for major/emerging/ diseases and stress tolerance, among others, has immense potential in the genetic diversity analysis of coffee germplasm and shorten the lengthy conventional breeding scheme. Moreover, molecular characterization is vital so as to confirm results obtained through the conventional breeding and thus avoid duplication of genotypes. Similarly, biochemical compounds diversity analysis should be taken in to consideration to determine those compounds attributing to quality variations of coffee from different geographic origins. In the face of the predicted climate change, designing of breeding strategies addressing the expected challenges would en-

able to bring about sustainable development of the coffee sector in Ethiopia and beyond.

Abbreviations

CTA	Coffee and Tea Authority
EIAR	Ethiopian Institute of Agricultural Research Center
JARC	Jimma Agricultural Research Center

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Conflicts of Interest

The authors declare no conflicts of interest.

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