International Journal of Genetics and Genomics
2024; 12(1): 8-12
http://www.sciencepublishinggroup.com/j/ijgg
doi: 10.11648/ijgg.20241201.12
ISSN: 2376-7340 (Print); ISSN: 2376-7359 (Online)

Review Artice

Over View of Coffee (Arabica Coffee) Breeding in Ethiopia

Meseret Degefa Regassa

Crop (Breeding), Ethiopian Institute of Agricultural Research, Awada Agriculture Research Sub-Center, Yirgalem, Ethiopia

Email address:
meseret.deg2008@gmail.com

To cite this article:
Meseret Degefa Regassa. (2024). Over View of Coffee (Arabica Coffee) Breeding in Ethiopia. *International Journal of Genetics and Genomics*, *12*(1), 8-12. https://doi.org/10.11648/ijgg.20241201.12

Received: December 12, 2023; **Accepted**: December 29, 2023; **Published**: February 5, 2024

Abstract: Ethiopia, which is the origin and place of many varieties of Arabica coffee, is lucky in this regard. Although the genetic diversity of the coffee population provides a good opportunity for improvement, the lack of improved hybrids is a major problem. Arabica coffee (Coffea arabica L.) is the main coffee species in world coffee production, accounting for more than 60% of total production. 30% of Ethiopia's foreign exchange earnings come from Arabica coffee. Arabica coffee's unique aroma, taste and lack of caffeine make it a popular coffee variety in coffee producing and consuming countries. Since Ethiopia is the homeland of Arabica coffee, major genetic changes are expected in coffee genetic resources required for further development to meet the world's demand for Arabica coffee. The coffee plant is native to the Coffea and Rubiaceae genera. There are only two important and worldwide commercial species: Coffea arabica (Coffea arabica L.) and Coffea canephora Pierre. It is thought that the plant first appeared in Arabica coffee (Coffea arabica L.), whose genes are found in the southwestern region of Ethiopia. Greater genetic diversity of endogenous coffee varieties may lead to increased yield and reproductive characteristics. Therefore, the coffee program began in the 1970s, when coffee cherry virus (CBD) first appeared in Ethiopia. Breeding, selection and hybridization methods have been used since the beginning of breeding. Creating a simple understanding of Arabica coffee genetics and marketing 43 improved coffee varieties, including the 09 F1 hybrid, 6,793 entries were recorded and considered outstanding results. The article talks about specific achievements, challenges and hopes for the future.

Keywords: Coffee, Collection, Genetic Material, Hybridization, Hybrid, Selection

1. Introduction

The homeland of coffee plants is Coffea and Rubiaceae species [1]. According to early research, there are 90-100 types of coffee [2]. However, according to a recent study [3], 124 species of this genus have been found to date. Only two coffee species, Coffea arabica L. and Coffea canephora Pierre, are widespread and valuable worldwide. The mountainous region of Western Ethiopia is considered to be the place where the origin and genetics of Arabica coffee are concentrated [4, 5]. Arabica coffee can thrive in different agro-ecologies of Ethiopia, altitude, temperature, rainfall, moisture and soil type [6]. Coffee grown in these different conditions shows that there are many differences between people from different countries in terms of seed quality, performance and disease resistance, as well as other factors. The existence of this genetic diversity provides many opportunities for crop development to reach the desired level of interest [5]. Most of Ethiopia's foreign exchange earnings come from coffee, its most important crop. Additionally, coffee directly or indirectly affects the livelihoods of 15 million people [7, 8]. Coffee research in Ethiopia began in the early 1968s at the Jimma Agricultural Research Center (JARC) with the aim of using the genetic material available in the country [9]. Although a few species were initially collected as a starting point, a comprehensive coffee breeding program was established in Ethiopia in the 1970s, when coffee berry disease (CBD) first appeared. Since then, many improvements have been made in terms of higher yields, resistance to pests and diseases, and overall quality. Coffee cultivation programs have achieved good results using various development strategies [9-11] Therefore, the aim of this article is to investigate the development, progress, impacts and benefits of coffee programs in Ethiopia.

2. Ethiopian Arabica Coffee Breeding Techniques

To improve results and performance, coffee growing ideas and techniques similar to Arabica are used in many coffee growing countries around the world. However, the use of these methods may differ from country to country depending on genetic diversity, ecological conditions and current production problems. Ethiopian Arabica coffee breeding programs focus on increasing diversity by selecting those that are disease resistant, insect resistant, high yielding, high quality and adaptable to different agroecologies. Most of our countries embrace the selection of pure lines and intraspecific crossbreeding. Therefore, the main benefits affecting the country's coffee production and productivity have been recorded [9, 13-15].

3. Disease Resistance via Breeding

In response to the CBD incident in Ethiopia, an elaborate breeding program was initiated in the 1970s to create disease-resistant varieties. Ethiopia is the birthplace of Arabica coffee and the center of its genetic diversity; Therefore, the main goal of breeding is to create CBD-resistant varieties by selective breeding from the natural population as soon as possible. As a result, the emergency program was created and launched in 1972-1973. It involves giving birth to many babies at the same time. One successful project selected 696 parent trees with less than 5% CBD contamination in nature. By laboratory and laboratory testing of origin and descendant strains of the parent plant, 218 promising strains were discovered; of these, 13 CBD-resistant varieties were introduced in China for the first time in five years (1972-78) (Table 2). Given the devastating nature of the disease and that it affected all major coffee producing regions of the country, seed distribution and distribution to growers began as soon as possible and many new ones were initiated [16, 17]. The introduction of these strains has had a major impact on the country's coffee industry, and they continue to grow in diverse agro-ecologies without protection against disease.

4. Breeding for Arabica Coffee's General Improvement

The long-term breeding strategy was developed based on traditional breeding methods and initiated after the introduction of CBD-resistant varieties. The main aim of new breeding is to increase the overall economic and agricultural importance of Arabica coffee [9, 12, 13]. The main purpose of this strategy is to cure the disease, create varieties through selection and hybridization, and create basic information that will contribute to future births by conducting genetic research.

It is generally believed that easy access to intra- and interspecific genetic variation is necessary for crop improvement. Due to the knowledge gained during the implementation of the emergency program and the analysis of the genetic diversity of domestic coffee seeds, the collection and storage of genetic resources for post-breeding studies has become an important part of the breeding program.

Therefore, thanks to the long-term "National and International Coffee Gene Plasma Collection Program" and "Local Variety Development Strategy"[12] from 1966 to 2005, these varieties were developed in later stages of development and a total of 5820 varieties were obtained. Arabica coffee inclusions. plan [14]. However, ongoing plans to focus on coffee production areas excluding pre-harvest and farmers' demands to benefit from many local factors have led to the additional collection of 1000 varieties since 2005 [18]. A total of 6,793 species of coffee viruses and exotics have currently been collected and stored in field banks (Table 1).

While many of these crops have been evaluated for yield, pest and disease resistance/tolerance, performance and other reproductive traits, others are still under review. For this reason, many promising varieties are selected and used in breeding studies to create new varieties. The facility, which is the main source of the coffee factory, is now fully maintained, including a CBD-protected option collected in emergency situations. The existence of phenotypic variation among accessions preserved in gene banks has also been confirmed by characterization studies using morphological characters, indicating the potential of using hybrid vigor breeding in development programs [19–22]. Other studies outside Ethiopia using DNA-based molecular markers have also confirmed genetic diversity in Arabica coffee populations collected from forests, semi-forests, and orchards in many parts of the country [23-26]. There are few studies on the characterization and assembly of coffee genetics, so good strategies for rapid morphological, molecular and biochemical characterization are needed for future breeding purposes.

Table 1. *A list of the Arabica coffee germplasm collections kept at the JARC and EBI field gene bank.*

Type of collections	Year (GC)	Number of accessions
French mission collections and SN series	1966	73
Resistant selections CBD	1973-1975	696
Resistant selections CBD *	1981-1987	568
National coffee collections	1970- 1990	554
National coffee collections**	2004-2009	941
Sub total		2832
International coffee collection	1968- 1984	190
Local landrace coffee collections***	1994- 2021	3771
Total coffee genetic resource		6793

*:-selections after the discontinuation of the 1st crash-program **:- collected under the local landrace variety development program but planted outside their origin ***:- Collections under local landrace variety development program and planted at their place of origin.

4.1. Program for Greater Variety Development

The main aim of all coffee-producing countries is to develop varieties that can be used as resources to increase quality, yield, biotic and abiotic resistance [10, 12]. The coffee

program focuses on genetic research to increase yields by creating varieties that offer high yields, resistance/tolerance to pests and diseases, and improve quality upon release. CBD-resistant coffee varieties. For this reason, breeding methods consisting of pure line selection and intraspecific hybridization have been used since the beginning of the program. Therefore, the main consequences affecting the coffee industry have been recorded [9, 13-15]. Currently, JARC and its centers are collaborating with universities and research institutes in the region to carefully develop clear lines of "agro-ecology-based, demand-driven coffee technology" and multi-purpose construction projects. Generation and support".

4.2. Program for the Establishment of Pure Line Varieties

Pure coffee variety development in Ethiopia followed the breeding process until 1994 [9, 13, 14], including screening, various trials/modifications in many sites, contract ratification, many releases and releases from seeds. All varieties collected within the scope of the national and international coffee collection at every stage of cultivation are meticulously evaluated over the years. Consider best growing results such as yield, disease (CBD, CLR) and pest/tolerance, as well as quality traits. Variety development of pure lines is the main goal, starting with the introduction of varieties adapted to diverse (low to high altitude) agro-ecologies in all coffee producing regions regardless of their origin. This work has led to the release and distribution of 23 varieties, including CBD-resistant variants created in incidental breeding (Table 2), for production in low- and high-altitude regions of Ethiopia, where coffee is mainly produced [14, 27]. However, the coffee program focuses on the development of many areas for the already known worldwide coffee industry to produce flavored coffee. This was done in recognition of the long-term need to improve coffee varieties according to traditional growing methods, as well as the need for increased quality and traceability. As a result, the "Development Strategy for Local Development" was created [11].

Table 2. *Pure-line coffee varieties released from coffee breeding program in Ethiopia.*

Year of release	Number of varieties	Clean coffee yield (kg/ha)	Area of recommendation*
1978-1981	13	1220-1970	Low to high
1997	3	1660-1940	Low to medium
2002	2	2140-2540	Low to medium
2006	5	1540-2350	Medium to high
2010	11	1190 – 2120	Medium to high
Total	34		

As shown in Table 1, according to the purpose of this strategy, some Arabica coffee germplasm resources were collected from each region and then planted in research sub-centers established in the relevant areas for evaluation. Following extensive research and evaluation of crops, diseases and performance, 11 new plots of land were acquired in the Hararg, Siddam/Yirgacheffe and Wollega coffee producing areas in 2010 (Table 2) [28]. A range of future support options on other aggregate models on these sites are also being considered; Of these, approximately 40 options are currently in the final stages of validation in various experimental fields [18]. In the future, releasing offspring from these selections will be beneficial for the development of genetic diversity.

4.3. Development of Hybrid Coffee Varieties

The coffee hybridization initiative was launched in Ethiopia in 1978, immediately following the introduction of CBD-resistant cultivars. The major goals were to investigate coffee genetics in order to produce fundamental knowledge for later breeding tactics and create hybrid varieties with superior traits than the pure lines selected for release. In order to attain the necessary goals concurrently, various sets of trials including single crossings between parental lines chosen for desirable characteristics like yield, resistance to CBD and CLR, quality and vigor were started. Lack of cytoplasmic inheritance, presence of a significant amount of heterosis, importance of both additive and non-additive gene actions in regulating inheritance of CBD and the expression of yield and some yield related growth characters and importance of morphological variation are all factors that contribute to the susceptibility to coffee berry disease.

The first three hybrid varieties, combining high yield, medium endurance (CBD and CLR) and high productivity, were released in the middle of the top coffee-growing country in 1997 and 2002 after evaluation of selected coffee seeds. F1 hybrids have been identified through initial hybridization programs in different locations over the years [15]. Based on the results of genetic research and experiments aimed at improving coffee, three new hybrid varieties were released in 2016, recommended for cultivation in low and middle coffee-growing regions [18] (Table 3).

Table 3. *List of released varieties from hybrid variety development breeding program in Ethiopia.*

No.	Varieties released	Year of release	Yield(kg/ha)	Production area*
1	Ababuna	1997	2380	1500 – 1752
2	MelkoCH2	1997	2400	1500 – 1752
3	Gawe	2002	2610	1500 – 1752
4	EIAR50/CH	2016	2650	1000 – 1752
5	Melko-Ibsitu	2016	2490	1000 – 1752
6	TepiHC5	2016	2340	1000 – 1752
7	GeraCH-1	2018	2441	1750 – 2100
8	Awada CH1	2022	2168	1550– 1750
9	Rori	2022	2464	1550– 1750

Note: 1000-1752 and 1500-1752 represents low to medium and medium altitude areas of coffee producing regions of the country, respectively.

Similar hybrids are currently in the final stages of breeding for high altitude areas (high CBD areas). The project is still under development with a focus on quality improvement. As part of the local landrace breeding programme, superior parental lines were found and crossed to produce hybrid varieties for the Limu, Harerghe and Wolega coffee producing regions [18]. Initial data from hybridization studies formed the

basis for subsequent breeding attempts to produce hybrid coffee varieties in Ethiopia. According to the results obtained today, it is possible to increase the yield by breeding pure line and hybrid coffee varieties for different coffee varieties with coffee, agroecological and quality characteristics in Ethiopia [29-31].

5. Difficulties and Possibilities

Breeding programs include the reduction of soil suitable for the growth of Arabica coffee due to the change in various oscillations [32], abiotic stress, increase in temperature, changes in coffee bean dynamics, etc. It faces many serious problems such as: Due to continuous climate change, crops are vulnerable to pests and diseases, changes in rainfall and distribution, etc. is affected. [33].

6. Conclusion

The coffee program has achieved great results, including the production of 43 Arabica coffee varieties, including 09 F1 hybrids, which are now produced in various agro-ecosystems across the country. The introduction of these varieties increased coffee production in a country and reduced production costs associated with the purchase of drugs used to treat important fungal diseases that often affect crops. Although species conservation may not adequately represent current diversity, it will serve as a direct source of breeding material for future breeding programs. The development of a national coffee genetic material collection program is very important for the long-term sustainability of the program. Instead, existing molecular breeding methods, such as selection programs and the use of DNA markers to identify genetic crops, should be incorporated into breeding programs. In contrast, research on the diversity of biochemicals should be taken into account to identify molecules responsible for quality changes in coffee of foreign origin. Developing technology that can withstand these challenges will enable the coffee industry in Ethiopia and globally to thrive in the face of climate change.

ORCID

0000-0001-9572-886X

Conflicts of Interest

The authors declare no conflict of interest.

References

[1] Bridson D. M., Verdcourt B., (1988). Flora of tropical east fica - Rubiacae (part 2), Polhill RM. (eds), 227p.

[2] Wrigley, G. (1988). Coffee. Longman Scientific and Technical, England. 639pp.

[3] Davis AP. (2011). "Psilanthusmannii, the type species of Psilanthus, transferred to Coffea." Nordic Journal of Botany, 29: 471–472.

[4] Sylvain. P. G. (1958). "Ethiopian coffee-its significance for the world coffee problems." Economic Botany 12, 111-139.

[5] Berthaud J. and A. Charrier. (1988). Genetic resources of Coffea. In: R. J. Clarke and R. Macrae (Eds.), Coffee Agronomy, pp. 1-41. Elsevier Applied Science, London.

[6] MefinAmeha and BayettaBellachew (1987). "Genotype x environment interaction in coffee (Coffea Arabica L.)." In: Proc. Fourth international scientific colloquium on coffee (ASIC '87). Montreux. Pp 476-482.

[7] Petit, N. (2007). "Ethiopia's coffee sector: a bitter or better future?" Journal of Agrarian Change V: 7, 225-263.

[8] Jean-Pierre Labouisse, BayettaBellachew, SurendraKotecha and Benoit Bertrand. (2008). "Current status of coffee (Coffea arabica L.) genetic resources in Ethiopia: implications for conservation". Genet Resour Crop Evol. 55: 1079–1093.

[9] Bayetta Bellachew (2001). "Arabica coffee breeding for yield and resistance to coffee berry disease (Colletotrichumkahawaesp.nov.)". Ph. D thesis, Imperial College at Wye University of London.

[10] Van der Vossen HAM. (1985). Coffee Selection and Breeding. In: Clifford MN, Willson KC (Eds.) Coffee Botany, Biochemistry and Production of Beans and Beverage, Croom Helm, London.

[11] Bayetta, B. and Jean Pierre, L. (2006). "Arabica coffee (Coffea arabica L.) landrace variety development strategy in its center of origin and diversity". In: Proc. 21th International scientific colloquium on coffee 11-15, Montpelier, France.

[12] Van der Vossen, H. A. M. (2001). Agronomy I: Coffee breeding practices. Pp 184-189. In: Clark, R. J and Vitzthum. Coffee. Recent development black well science Ltd, uk.

[13] Fikadu Tefera, Bayetta Bellachew, Behailu Atero, Ashenafi Ayano and Tadesse Benti. (2008). Germplasm collection and maintenance of coffee (Coffea arabica L). Pp 45-49. In: Girma Adugna, Bayetta Belachew, Tesfaye Shimber, Endale Taye and Taye Kufa (eds.). Coffee Diversity and Knowledge. Proceedings of a National Workshop Four Decades of Coffee Research and Development in Ethiopia, 14-17 August 2007, Addis Ababa, Ethiopia.

[14] FekaduT Tefera, Melaku Adissu, Bayetta Belachew, Behailu Atero, Tadesse Benti, AshenafiAyano.(2008). Developing Improved Pureline Coffee Varieties for Different Coffee Growing Areas of Ethiopia. Pp 64-70. In: GirmaAdugna, BayettaBelachew, TesfayeShimber, EndaleTaye and TayeKufa (eds.). Coffee Diversity and Knowledge. Proceedings of a National Workshop Four Decades of Coffee Research and Development in Ethiopia, 14-17 August 2007, Addis Ababa, Ethiopia.

[15] Behailu Atero, Bayetta Bellachew, Fikadu Tefera, Melaku Addisu, Tadesse Benti and Ashenafi Ayano. (2008). Developing Coffee Hybrid Varieties. Pp 99-105. In: Girma Adugna, Bayetta Belachew, Tesfaye Shimber, Endale Taye and Taye Kufa (eds.). Coffee Diversity and Knowledge. Proceedings of a National Workshop Four Decades of Coffee Research and Development in Ethiopia, 14-17 August 2007, Addis Ababa, Ethiopia.

[16] Van der Graaff (1981). "Selection of Arabica coffee types resistant to coffee berry disease in Ethiopia". Doctoral thesis Mededelingen Land bouwhogeschool, Wageningen, the Netherlands.

[17] Bayetta, B., Behailu, A. and Fekadu, T (1999). "Breeding for resistance to coffee berry disease in arabica coffee: Progress since 1973". In proceeding of the workshop on control of coffee berry disease in Ethiopia, Addis Ababa, pp85-96. Ethiopian Agricultural Research Institute, Ethiopia.

[18] JARC, (2022). Jima Agricultural Research Center, coffee breeding progress report.

[19] Mesfin Kebede and Bayetta Belachew (2005). "Genetic Divergence of Harragie coffee (Coffea arabica L.). Germplasm accessions at pre- bearing stage". In: proc. 20th Int. Sci. Colloq. on coffee (ASIC), Montpellier, france.

[20] Seifu S., Singh H. and Bellachew B. (2004). "Diversity in the Ethiopian coffee (Coffea arabica L.) germplasm". In: proc. 20thInternationalConferenceon Coffee Science, Bangalore, India.

[21] Ermias Habte (2005). "Evaluation of Wellega coffee germplasm for yield, yield component and resistant to coffee berry disease at early bearing stage." MSc thesis, submitted to school of graduate studies of Alemaya University.

[22] Mesfin Kebede. (2008). Multivariate Analyses of Phenotypic Diversity in South and Southeast Ethiopian Coffee. In: GirmaAdugna, BayettaBelachew, TesfayeShimber, EndaleTaye and TayeKufa (eds.). Coffee Diversity and Knowledge. Proceedingsof a National Workshop Four Decades of Coffee Research and Development in Ethiopia, 14-17 August 2007, Addis Ababa, Ethiopia.

[23] Anthony F., Bertrand B., Quiros O., Wilches A., Lashermes P., Berthaud J. andCharrier A. (2001). "Genetic Diversity of wild coffee (Coffea arabica L.) using molecular markers". Euphytica 118: 53-65.

[24] Anthony F., Combes M. C., Astorga C., Bertrand B., Graziosi G. and Lashermes P. (2002). The origin of cultivated Coffea arabica L. varieties revealed by AFLP and SSR markers. Theor. Appl. Genet. 104: 894-900.

[25] Aga E. (2005). "Molecular genetic diversity study of forest coffee tree (Coffee arabica L.) populations in Ethiopia: Implications for conservation and breeding." Doctoral Thesis, Faculty of Landscape planning, Horticulture and Agricultural Science, Swedish University of Agricultural Sciences (SLU). 2005.

[26] Tesfaye K (2006). "Genetic diversity of wild Coffea arabica populations in Ethiopia as a contribution to conservation and use planning." PhD. diss. Univ. of Bonn, Ecology and Development Series No. 44.

[27] Bayetta, B., Behailu, A. and Gibramu, T. (1998). Description and production recommendations for new cultivars of arabica coffee. Research reports No. 34, IAR. Addis Abeba. 7pp.

[28] Chala J., Girma A., Demelash T., and Arega Z. (2012). "Development and Release of Coffee Berry Disease Resistant Varieties to Specialty Coffee Producing Regions in Ethiopia." In: Proc. 24th ASIC, International Scientific Conference on Coffee Science, San José, Costa Rica, PP 409.

[29] MesfinAmeha and BayettaBellachew. (1983). Heterosis in crosses of indigenous coffee selected for yield and resistance to coffee berry disease: II. First three years. Eth. J. Agr. Sci., V: 13–21.

[30] MesfinAmeha and BayettaBellachew (1982). "Resistance of the F1 to coffee berry disease in six parent diallel crosses in coffee."1984. P.107-117. In: Proc.1st Reg. workshop "coffee berry disease", Addis ababa.

[31] BayettaBellachew, Behailu Atero, FikaduTefera, AshenafiAyano and TadesseBenti. (2008) Genetic Diversity and Heterosis in Arabica Coffee. In: GirmaAdugna, BayettaBelachew, TesfayeShimber, EndaleTaye and TayeKufa (eds.). Coffee Diversity and Knowledge. Proceedings of a National Workshop Four Decades of Coffee Research and Development in Ethiopia, 14-17 August 2007, Addis Ababa, Ethiopia.

[32] Davis, Aaron P.; Tadesse Woldemariam Gole; Susana Baena; and Justin Moat (2012). The Impact of Climate Change on Indigenous Arabica Coffee (Coffea arabica): Predicting Future Trends and Identifying Priorities. http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0047981.

[33] Kimemia, J. K., (2010). "Effect of Global Warming on Coffee Production." Presented in Ugandan Coffee Traders Federation Breakfast Fellowship, in Kampala, Uganda.