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Three Decades of Cotton Improvement Research and Progresses in Ethiopia

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Abstract

Scientific research on cotton in Ethiopia started in 1964, following various earlier attempts. The major objectives of the cotton research have been to develop and promote high-yielding cotton cultivars with superior fiber quality, along with improved production management packages. Thus, the purpose of this paper is to present the cotton breeding progresses made over the past three decades. Introduction of germplasm and hybridization of selected parental lines have been considered as the priority approaches to enhance cotton production in the country. The introduced germplasm have been utilized directly in variety trials, and as parental lines for hybridization. Subsequently, crossing and evaluation of segregating populations (F_2-F_6) are being done every year. The germplasm enhancement, subsequent variety evaluation and verification programs over the last six decades resulted in releases of 44 improved new cotton varieties in which 32 cotton varieties were released or registered in last three decades. In research station trials, the productivity of these varieties in irrigated areas has increased from 2.43 ton ha^{-1} (Ionia) to 5.4 ton ha^{-1} (Arkebe) in seed cotton yield. Another important trait namely, ginning outturn ranged from 29.0% (VBCH 1527) to 46.5% (Arkebe). Besides conventional research achievement, two single gene (Bt) varieties and one triple genes (Bt-Gt) of cotton variety (ACH3) registered during 2018 and 2025 cropping season, respectively, following standard institutional procedures and the biosafety law of the country under close supervision of the Ethiopian Environmental Protection Authority.

Keywords: Cotton, Breeding and Genetics, Genetic resource, Fiber quality, Lint yield

Introduction

Cotton belongs to the genus *Gossypium* in the family Malvaceae and produces the single most important textile fiber, accounting for 35% of the world's total annual fiber demand because of yarn made from cotton fiber is soft, absorbent, cool, comfortable and durable(Constable *et al*, 2017). The *Gossypium* genus comprises 45 diploid species (2n = 2x = 26) and seven tetraploid species (2n = 4x = 52), which exhibit a wide range of morphological variations. These variations include different plant architectures ranging from wild perennial small trees and shrubs to cultivated herbaceous annuals, with variable leaf shapes and different fiber characteristics (Fang *et al*., 2017). However, only four cotton species are grown commercially because they produce fibers long enough to be spun into yarn for textiles. These are; G. *hirsutum* (Upland cotton); G. *barbadense* (Pima or Egyptian cotton); G. *arboreum* (Desi cotton) and G. *herbaceum* (Arabian cotton). *Gossypium hirsutum* is by far the most widely grown with over 90% of world production because of its higher yields and greater adaptability. *Gossypium barbadense* follows with 6%, while G. *arboreum* and G. *herbaceum* each contribute less than 2% (Constable *et al*, 2017).

Cotton, the primary product is fiber, is the most widely utilized natural fiber and a crucial commercial product in the global textile industry. It is a universal term for a small number of indeterminate perennials of the Gossypium genus that produce long fibers on its seed coat, grown in up to 100 countries as an important annual crop with significant economic value in agriculture and industry (NCCRS, 2015; Sleper and Poehlman. 2006). It is believed that Ethiopia is one of the centers of origin for several cultivated crops including cotton. In Ethiopia, there is a huge source of cotton genetic diversity for cultivated as well as wild relatives, some of which are conserved at Ethiopian Biodiversity Institute (EBI). Besides, Ethiopia has a unique distinction of being the only country in the horn of Africa to possess a long tradition in the cultivation, processing and utilization of cotton. Ethiopia is also unique in cultivating three of the total four cultivable *Gossypium* species, namely, G. *herbaceum*, G. *arboreum* and G. *hirsutum*. *Gossypium hirsutum* cotton represents 98% of the annual cotton production and favored for its wide range of adaptability and higher yield potential (Merdasa *et al.*, 2022; Donis *et al*., 2023).

Cotton not only provides fiber for the textile industry, but also plays a role as animal feed and a raw material for the oil industries due to its oil and protein-rich seeds. One of the most important byproduct of cotton production is the cotton seed, which is an important source of edible oil, cotton seed cake and animal feed used in animal fattening sector (Pendzhiev, 2023). The research conducted at Werer Agricultural Research Center has led to the development and release of numerous improved cotton technologies to meet the growing demand for cotton production. Initially, the focus was on increasing cotton yield to cater to the expanding textile mills, resulting in the successful development of varieties with remarkable seed cotton yields under research conditions. Over the past six decades, 44 improved varieties with impressive yield performances have been identified and recommended/released to cotton producers. However, despite these achievements the available technology still not impact the end user due to lack of effective agricultural extension services and well-organized seed system on cotton. The fundamental concern of this paper is to review progresses and achievements over the last three decades of cotton breeding and genetics research in Ethiopia, shade light on challenges and opportunities, future direction, and needs for further breeding efforts.

Production and Productivity of Cotton

Cotton, locally known as *tit* (Amharic), *tut* (Afar) or *Jirbii* (Afaan Oromoo), has been under cultivated since ancient times. According to International Cotton Advisory committee, the global land coverage, lint productivity and lint production of cotton is averaged about 32,895.25ha, 769.5kg/ha, 25,314,271.59 ton from 2018/19 to 2022/23 cropping seasons, respectively. The leading cotton producing countries during this period were India, China, USA, Brazil and Pakistan, accounting for 76.76% of global production. Specifically, these countries held shares of 23.27%, 22.99%, 15.15%, 10.59% and 4.76%, respectively. In Africa, the leading cotton producers were Benin, Mali, Côte d'Ivoire and Burkina Faso, contributing 0.97% to global cotton production during the same period. The world average cotton lint yield in 2023 is 768 kg/ha, whereas Ethiopia's lint yield is slightly lower to 726 kg/ha (ICAC, 2023). In contrast, the productivity in some countries like China, Brazil, Australia, Turkiye, and Mexico stands among the highest in the world, and is more than double as compared to the global average (Figure 1).

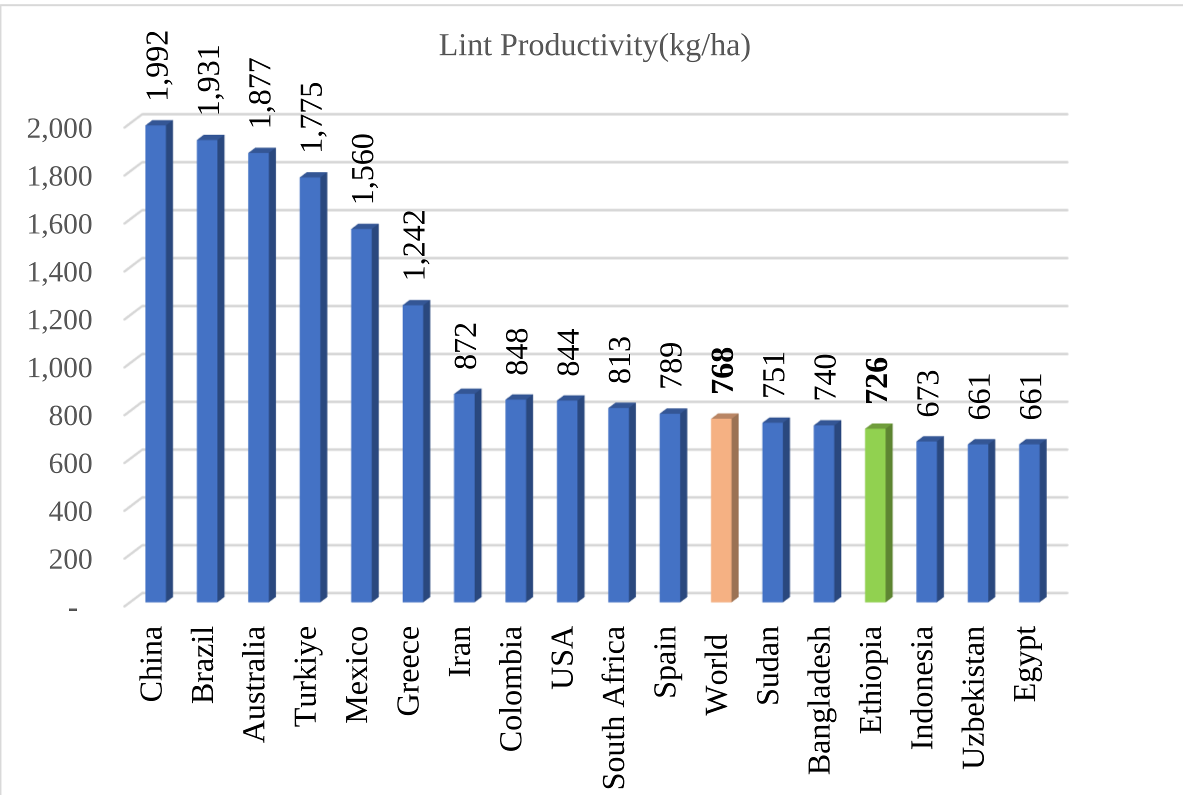

Figure 1. Cotton Lint productivity in World (ICAC, 2023)

Ethiopia's share of global cotton production only 0.24%. Over the past decades, the total annual cotton production of the crop in Ethiopia has increased from 20,000 tons to 60,000 tons, with productivity rising from 236 kg/ha to 745 kg/ha (Figure 2). However, production areas of cotton was decreased from 136,000 hectares in 2011/12 to 83,000 hectares in 2021/22 as a result of marginalization of cotton production areas largely due to the expansion of sugarcane plantations. On area basis across the regions, cotton is mainly grown in the Amhara (33.9 %), Benishangul-Gumuz (15.8%), Afar (13.7%), former SNNP (13.4%), Tigray (11.1%), Gambella (10.6%) and Oromia(1.5%) in which lint productivity at irrigated areas(Afar and South Ethiopia regional state) is almost two folded to the rainfed areas(Amhara, Benishangul-Gumuz, Gambella and Tigray regional state). In general, about 98.5% of the cotton production is concentrated in six regions i.e. Amhara, Benishangul-Gumuz, Afar, former SNNP, Tigray and Gambella (ETIDI, 2022). Additionally, 22% of state-owned irrigated farms, 45% of private farms, and 33% of smallholders grow cotton primarily as a rain-fed crop(Endale *et al*, 2023).

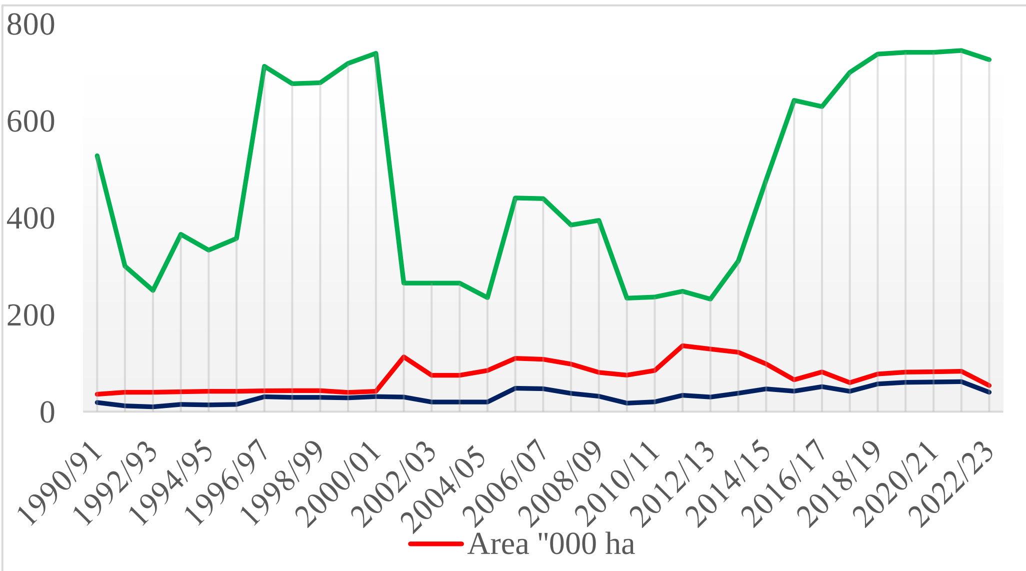

Figure 2. Three decades of Cotton production and Productivity in Ethiopia (ICAC, 2023)

History of Cotton Breeding in Ethiopia

Before scientific cotton improvement research in Ethiopia was started by Institute of Agricultural Research at Werer Agricultural Research Center, there was different effort on cotton research for decades. The first attempt was from 1901 to 1910 by the Italians in which before the modern upland type cotton cultivars were introduced to Ethiopia by the Italians colonists. All cultivars of the cultivated cottons in Ethiopia were old world's cultivars, mainly G. *herbaceum and* G. *arboreum*. At that time, cotton production in Ethiopia was not more than a home-yard grown crop by subsistence farmers for home use and to meet their family needs. The second attempt was 1928 by Germans at Upper Awash using Egyptian cotton (*Gossypium* *barbadense* L.) for seven year research effort without any success. Then after the third attempt during the second Italian occupation of Ethiopia, the Italians proved the possibility of large-scale cotton production in Ethiopia and research on cotton resumed in 1964 at the then Malka-Werer Agricultural Research Station (now Werer Agricultural Research Center-WARC) by the research department of the then Ministry of Agriculture through the assistance of Food and Agricultural Organization of the United Nations (FAO).

Since the inception of research in the mid-1960, efforts have been made to improve cotton production and productivity from time to time. Initial research merely focused on conducting variety testing to increase yield and identify appropriate agronomic and crop protection practices. A more detailed research plan was launched in 1970, with the different research conducted at Werer Agricultural Research Center, including crossing, selection from foreign introductions, variety trials, cultural practices and soil fertility trials. Emphasis was placed on the development of new disease resistant varieties by replacing obsolete varieties to improve commercial cotton production. These activities included identification of suitable cotton varieties for high yield, and disease resistance for both rain fed and irrigated production areas. Later from 1966 to 1988, cotton research was carried out under Field Crops Department of the Ethiopian Agricultural Research Institute. In 1989, the cotton crop was elevated to commodity-based and team-led multidisciplinary approach coordinated by Werer Agricultural Research Center (WARC). In 2016, the national rain-fed cotton research was transferred and coordinated by Asosa Agricultural Research Center (AsARC). At present, cotton research is structured into a program-based namely National Cotton and other Industrial Crops Research Program under Crop Research Directorate of EIAR. This national program, coordinated by WARC, consists of three projects: Irrigated Cotton Research, Rain-fed Cotton Research, and Biofuel Research.

Breeding Approaches and Strategies

Research strategies

- Introduction and adoption of improved varieties from abroad
- Introduction of cotton germplasms of medium, long and extra-long staple cotton
- Hybridization among the divergent parents and selection of segregating lines based on pedigree selection method
- Adaptation trial of existing improved varieties in new potential areas
- Popularization and transfer of the existing improved varieties to the users
- Pre-basic seed multiplication of improved cotton varieties
- Development of varieties having fiber qualities that fulfil the requirements of international markets
- Development of varieties resistance to diseases and insect pests
- Variety development for stressed areas (varieties resistant to drought, salinity, high temperature)
- Development of cotton varieties suitable for mechanical harvesting

Cotton Breeding Achievement

Genetic Resource and Source of Variation

Ethiopia is considered one of the primary centers of origin and diversity for *Gossypium herbaceum* cotton. For over five decades, the national cotton improvement program has been dedicated to enhancing various germplasm through diverse breeding strategies. The primary source of breeding materials is mainly introduction of germplasm and advanced lines from different countries like Pakistan, Mexico, Uganda, USA, Israel, Ivory Coast, Turkiye, Mali, and India. The other sources are targeted hybridization efforts with the aim of improving fiber quality, seed cotton yield, ginning outturn and adaptability. In addition to these, collection and utilization of landraces from the local sources were also used as part of the germplasm enhancement program (Bedane and Arkebe, 2019). At WARC, there are currently 650 cotton accessions, which are rejuvenated every two years for conservation purposes. Of these accessions, 258 are populations of segregating generation of intra specific and interspecific crosses, and 193 are collections from different cotton growing areas. In content of species; 579 are *Gossypium hirsutum*, 36 are G*ossypium barbadense* and 35 are interspecific crosses between these two species.

Varieties Replacement on Cotton Production in Ethiopia

Since the beginning of the cotton improvement program at WARC, varieties have been replaced six times. The first replacement was from 1966 to 1969`s when some newly introduced African and American upland cottons replaced the short staple Old World cottons. The second replacement occurred from 1974 to 1976 when `Acala` 1517/ 70, an introduced cotton from New Mexico replaced the bacterial blight susceptible American upland varieties. The third replacement happened from 1989 to 1990 when the introduced earlier Acala variety and deteriorated African cottons replaced by new introductions of Delta and Pine Land varieties, along with some home bred varieties. The fourth replacement took place from 1990 to 2007, when short season Stoneville cottons were extended to North Omo areas, while West African mid maturing cottons with high ginning outturn cotton recommended for general production in rain fed areas.

From 2015, replacement occurred by Turkiye variety namely, Cluadia, known for its good ginning outturn and fiber quality, was introduced to both irrigated and rain-fed areas. Finally, following the obtaining of a special permit, a process outlined in the Biosafety Law within the Ethiopian Biosafety framework for research purpose, the Ethiopian Institute of Agricultural Research (EIAR) has introduced and registered two Bt cotton hybrids (single gene) sourced from India during 2018 cropping season and failed to supply cottonseed to end user due to poor access to seed. Subsequently, the illegal GMO product rapidly spread to cotton producers in both rainfed and irrigated regions. However, the future replacement of cotton varieties faces dilemma between introduced GMO cotton varieties and recently released conventional varieties, despite the growing preference for GMO product is high for commercial farms.

Cotton Breeding Research/Varietal Development

The commencement of cotton breeding activities led to the development and release of numerous improved varieties that offer stable and high yields, desirable fiber qualities, high ginning outturn, resistance to sucking pest and tolerance to salinity. Importantly, registration of transgenic cotton varieties resistant to African bollworm and herbicide tolerant. Among 44 varieties, 32 were released in the last three decades through collection, introduction and hybridization followed by pedigree selection (Table 1) for the merits of seed cotton yield, ginning outturn and fiber quality traits.

Moreover, significant progress has been made, with seed cotton yield improving from 3890 to 5433 kg/ha over three decades cotton breeding effort (Table 1). In the past one half decade alone, high number of varieties (24) were released, surpassing the number of developed varieties in the previous five decades. Among these, nine varieties were specifically released for irrigated cotton production, resulting from extensive selection and hybridization efforts followed by pedigree selection at the WARC.

Breeding for Seed Cotton Yield Varieties

Over the past several decades, the focus of cotton breeding in Ethiopia has been on improving seed cotton yield. However, more recently, efforts have expanded to include fiber quality and fiber yield attributes such as ginning outturn to meet both national and international fiber qualities standards. Among 32 varieties released in the past three decades, about 27(87.09%) were released for their seed cotton yield, with acceptable fiber qualities. These varieties were developed through introduction and hybridization followed by pedigree selection and achieving ranging from 2430 kg/ha (VBCH 1527) to 5433 kg/ha (Arkebe). Under research level production for seed cotton yield has increased by 3003 kg/ha over last three decades of breeding effort (Table 1).

On the other hand, the yield after processing (ginning) seed cotton namely lint yield and which depends on the ginning outturn ranged from 700 kg/ha (VBCH 1203) to 2539 kg/ha (Arkebe). Furthermore, the ginning outturn values ranged from 34.6% (A-333-57) to 46.5% (Arkebe), compared to Ethiopia’s standard of 37% (Table 1). On the other hand, the current average cotton productivity at farmers field stands at 726 kg/ha (ICAC, 2023), which is below world average of 771 kg/ha, though research has demonstrated average potential lint yields of 2539 kg/ha under improved package application. Furthermore, significant advancements including development of cotton varieties with a lint yield percentage of 46.5% (Arkebe) have been recorded.

Table 1. Description of cotton varieties released over the last three decades in Ethiopia

S/N	Name	Year of Release	SCY kg/ha	GOT (%)	LY (kg/ha)	FL(mm)	M	FS(g/tex)
1	Bulk-202	1989	3340	41.0	1370	28.1	3.5	78.3
2	Deltapine-90	1989	3860	37.61	1340	27.7	3.7	77.3
3	Cucurova-1518	1994	4170	38.9	1620	26.9	3.8	74.6
4	Cu-Okra	1994	3760	38.9	1460	26.1	4.0	75.7
5	Carolina queen	1994	4180	39.6	1660	27.2	3.8	77.6
6	Sille-91	1997	3860	39.4	1520	27.9	3.6	72.7
7	Stam59A	2007	3340	42.0	1400	29.8	4.3	32.5
8	Ionia	2008	2890	38.7	1120	30.0	4.2	31.4
9	YD-206	2011	4100	37.3	1500	34.8	3.6	36.5
10	YD-223	2011	4000	37.3	1500	34.1	3.5	36.6
11	YD-211	2011	4100	35.7	1500	34.7	3.3	36.6
12	YD-670	2013	4000	37.1	1500	32.0	3.5	34.8
13	YD-195	2013	3400	39.2	1300	31.7	3.5	35.2
14	VBCH 1203	2013	2400	31.1	700	34.4	3.5	35.4
15	VBCH 1527	2013	2600	27.7	700	36.5	2.9	36.6
16	STG-14	2014	3880	42.7	1660	30.0	4.2	31.7
17	Candia	2014	4060	44.1	1790	29.0	4.1	30.2
18	Claudia	2014	3840	45.7	1750	30.9	4.4	32.4
19	Gloria	2014	4260	43.0	1830	29.4	4.1	31.9
20	Sisikuk-02	2015	4070	44.8	1820	28.8	4.3	25.9
21	Werer-50	2015	4300	39.0	1680	27.7	3.9	29.5
22	Weyto-07	2015	4620	38.2	1760	26.1	3.9	29.5
23	JKCH 1947(Bt)	2018	3060	39.4	1200	27.8	4.1	27.8
24	JKCH 1050(Bt)	2018	3050	39.2	1200	28.4	3.9	28.6
25	Werer-12	2019	4430	36.3	1610	28.4	4.2	26.0
26	Malkasadi	2019	4680	38.4	1800	29.1	4.5	30.9
27	WARC-LS1	2019	2500	37.3	940	33.9	3.7	38.7
28	WARC-LS2	2019	2460	37.9	930	32.9	3.6	38.4
29	Werer-13	2020	4890	38.2	1810	28.7	4.4	27.5
30	Sille-13	2020	4760	40.2	1920	27.8	4.7	28.8
31	Arkebe	2024	5433	46.5	2539	28.1	4.3	26.1
32	ACH3(Bt-Gt)	2025	4372	36.6	1601	29.3	4.6	27.91

Keynote:- *The unit of fiber strength for varieties from 1-6 serial number is Ib/sq.inch), SCY= Seed Cotton Yield, GOT= Ginning Outturn, LY= Lint Yield, FL= Fiber Length, M= Micronaire and FS= Fiber Strength*

Breeding for Hybrids Varieties

Research on cotton hybrids were started in the United States, but hybrid cotton was first used on large scale in India and then in China. Hybrid cotton currently occupies up to 96% of the cotton area in India and about 80% in China. In these countries, hand-pollination and the use of male-sterile lines are the two major methods for hybrid seed production. In particular, F_1 hybrid cotton seeds are more expensive than other types of cotton seeds due to cost of labor-intensive production process. In Ethiopia, seven introduced hybrids from India; namely YD-206, YD-223, YD-21, YD-670, YD-195, VBCH 1203 and VBCH 1527 were recommended for production. However, these hybrids were not entered to production. Consequently, there has been no commercial hybrid cotton production in Ethiopia.

Breeding Fiber Quality Traits

The most important cotton fiber quality traits are upper half mean length, fiber strength, fiber elongation, micronaire and uniformity index. Fiber quality traits varied depend on variety, shortened growing season and available enough carbohydrates. Cotton breeding research efforts have led to the release of two varieties, WARC-LS1 and WARC-LS2, for the merit of fiber qualities by sacrificing seed cotton yield. These two varieties are G. *barbadense* species and they have shown average qualities with upper half mean length of 32.9 and 33.9 mm, micronaire values of 3.6 and 3.7, and fiber strength of 38.4 and 38.7 g/tex., respectively.

Breeding for Transgenic Cotton Varieties

Bollworms are a major constraints for cotton production in Ethiopia, particularly in the Rift Valley, causing yield losses of 30-50 percent. To solve this great challenge in cotton production, Cry1AC gene Bt-cotton hybrid varieties, JKCH 1947 and JKCH 1050, were introduced by JK Agri. Genetics, an Indian company. Subsequently confined field trial was carried out in 2017 and approved for commercial release in 2018 for irrigated and rain-fed conditions. The company was also granted permission from the Ethiopian government to supply the seeds in the country. The aforementioned varieties, JKCH 1947 and JKCH 1050 produce seed cotton yield of 3060 kg/ha and 3050 kg/ha; ginning percentages of 39.4% and 39.2%, respectively. Despite resistant to bollworm, the Bt-cotton hybrid varieties showed low performance as compared with newly released conventional varieties. In respect to fiber quality traits, JKCH 1947 has fiber length, micronaire, and strength of 27.8 mm, 4.1, and 27.8 g/tex, while JKCH 1050 has values of 28.4 mm, 3.9, and 28.6 g/tex, respectively.

On the other hand, four GMO cotton hybrids varieties (ACH1, ACH2, ACH3 and ACH4) with traits for herbicide tolerance and resistance to African bollworm had introduced by the Ethiopian Institute of Agricultural Research (EIAR) and Bio and Emerging Technology Institute (BETin) in collaborating with Black Stone PLC. Multi-location CFT was conducted out for NPTs (national performance trials) across four cotton growing locations along efficacy test and herbicide pre-verification study under irrigated areas. And the two best-performing of Bt-Gt cotton varieties, ACH2 and ACH3, have been put through six locations for Variety Verification Trail (VVT) under irrigated cotton producing areas during 2024 cropping season. Among tested varieties, ACH3 hybrid cotton variety resistant to African bollworm and tolerant to glyphosate registered in Ethiopia during 2025 cropping season with performance of 4372 kg/ha for seed cotton yield and 29.3 mm for fiber length.

Genetic Diversity Study in Cotton Germplasm

Studying genetic diversity is the initial step in any effective crop improvement program, as it helps identify crop plants with valuable variations for the traits of interest. This study is conducted using various techniques based on morphological, physiological, and DNA characteristics, known as genetic markers. Molecular genetic diversity analysis employs molecular markers, which are specific genomic loci detectable through probes or specific primers. In Ethiopia the application of molecular markers in cotton research is relatively recent and limited. Among the various types of molecular markers, SSR markers have been used to study molecular genetic diversity in some improved *G. hirsutum* L. species cotton varieties, *G. barbadense* L. species genotypes, and interspecific (*G. hirsutum* x *G. barbadense*) hybrid cotton germplasm (Donis Gurmessa, 2019; Donis Gurmessa *et al*., 2024).

Challenges, Opportunities and Future Research Directions

Challenges

In the history of the country, the area coverage of cotton cultivation remained less than 4% out of available suitable land. This is in part contributed by poor extension system for technology dissemination and a limited availability of quality inputs including improved seeds. As discussed earlier considerable achievements are registered so far but the access of farmers to technologies has remained inadequate. There is no cotton seed multiplying and distributing unit or organisation and proper seed supplying system, leaving WARC as the sole supplier of improved cotton seeds. This has made very challenging to fulfill the seed demand of all the producers throughout the country. The initiative to multiply and outreach improved cotton technology effort must be started to narrow the seed demand supply gap and ensuring long-term sustainability.

Plant germplasms serves as a raw genetic material that is basic to genetic alteration of crops in order to improve for human needs (Haussmann *et al*., 2004; Upadhyaya *et al.*, 2014). The early cotton research was active in introducing foreign genetic materials to increase the number of germplasm. Later the hybridization of available germplasm started. Recently local accessions have been collected from cotton growing areas of Afar, South Ethiopia, Amhara and Tigray region. However, the available cotton germplasm resource are very limited and there is still much more left to be done on introduction, collection, hybridization and selection. The world has been very much quick to harness the potential of modern science, encourage silent innovations in technology generation, and provide an enabling policy environment and investment support. Many cotton producing countries of the world employed strong integration of conventional cotton breeding approaches with modern tools and methods of biotechnology, including tissue culture, molecular markers, genomics, and related fields. Cotton research in Ethiopia has never benefited from such modern science.

Attempts to address the limited number of improved cotton varieties to revive the sector during the 1990s not yielded satisfactory result, but in the last six years considerable number of improved varieties has been developed. However, there is still a sense of the sector lags behind its full potential. Constraints facing cotton research are numerous. Key constraints include a lack of fiber quality testing facilities, cold storage for keeping germplasm, shortage of well-trained research staff, lack of linkage with international cotton organizations, inadequate budget allocated from government treasury to purchase the necessary services and equipment. Additional key challenges include

- Reliance on conventional breeding methods and lack of molecular breeding strategies like Marker Assisted Breeding(MAB), which are used in other crops in Ethiopia
- Limited number of germplasm having narrow genetic base
- Absence of simultaneously high yielding and high fiber quality varieties
- Limited research on the development of varieties for abiotic stresses(drought, frost and salinity) and biotic stresses including insects pests and diseases
- Lack of well-organized seed system for conventional varieties and Transgenic varieties

Opportunities

The Agricultural development led industrialization (ADLI) policy by the Ethiopia Government development policy, encourages research on industrial commodity crops such as cotton. This policy aligns with national development goals, including food security/self-sufficiency, export promotion, import substitution and raw material production for local industries and this form the basis of the cotton research in the country. Other cotton research opportunities includes,

- Suitable agro ecology: Ethiopia's diverse agro-ecological zones are conducive to cotton production
- Economic incentives: Reducing the import of cotton lint, which incurs significant costs, can boost local production
- Progress in Breeding**:** Notable advancements have been made in conventional breeding at Werer Agricultural Research Center (WARC).
- Growing Textile Industry**:** The expansion of textile industries in Ethiopia presents a market opportunity for increased cotton production.

Future Research Directions

In Ethiopia, at present, cotton varieties under production falls in medium and medium long staple types, which not fulfills all the requirement of the domestic industry. Breeders are making efforts to develop extra-long staple cotton varieties. Since the start of large-scale commercial farming in Ethiopia in the 1970s, a great stride has been made in area expansion and cotton production in the country. As a result, cotton production showed rapid advance from manual cultivation and production to semi-mechanized farming. Cotton harvesting, however, remains unchanged and still practiced by hand picking. Nowadays it is not uncommon to see the fully matured cotton crop to remain for an extended period of time exposed to the sun, dust, and weathering and many other varying environmental factors and this may continue for some time to come. Some private investors are suffering from acute shortage of labor during peak harvest periods. To address this issue, they are requesting for improved and or potential promising varieties that are suited to mechanical harvesting.

Soil salinity and water scarcity is the major issue not only in Ethiopia but also in the world. The research on salinity and drought resistant/tolerant and low water requirement varieties need to be developed for efficient utilization of irrigation water. Transgenic cotton has been proved not only in controlling the insect pests particularly of bollworms but also is environmentally friendly, reducing pesticide use and reduce labour requirement to control weed. As a result, there is a need for intensive research to develop local transgenic cotton varieties for commercial cultivation in the country. Future research should also address the balance between Bt-cotton and conventional cotton varieties, considering the potential benefits and impacts for medium scale and commercial cotton farming system. In addition, most cotton producer use illegal cottonseed for more five years due shortage transgenic seed supply in Ethiopia. Therefore, launching F_1 hybrid cottonseed production for transgenic cotton varieties is mandatory to fulfill the demand of commercial cotton producer in the country's. Other concern in Bt production is the development of resistance in insects and pests that has reduced effectiveness of the genes. To manage resistance to Bt cotton, employ a refuge strategy, pyramided Bt Cotton and other mechanism to tackle the problem of resistance development.

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