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Impact of Species Differences on Cotton Fiber Characteristics and Dye-ability

Waleed M. B.Yehia, Hanaa A. Zaghlol and Shereen O. Bahlool *,
Cotton Research Institute - Agricultural Research Center, 12619, Giza ,Egypt

Abstract
Gossypium barbadense and *Gossypium hirsutum* account for the vast majority of international cotton acreage. Therefore, the aim of this study is to compare the fiber quality of these cotton genotypes native to the Egyptian region with other cotton species grown worldwide to improve the understanding of cotton fiber quality and its applicability in different contexts of the textile industries. We conducted a comparative analytical study for a total of 14 cotton samples, 6 of G. barbadense (Egyptian cotton) and 8 of G. Hirsutum (Upland cotton). Fiber quality analyses of all cotton fiber samples were performed using the Uster high volume instrument (HVI) to determine fiber characteristics such as fiber length, uniformity, strength, elongation, fineness, maturity, color, and trash. Also, fiber was chemically analyzed to determine the difference in chemical constituents such as ; α-cellulose %, reducing sugar %, wax %, moisture %, ash % of fibers, and seed oil content % of the seeds among the *Gossypium hirsutum* and *Gossypium barbadense* understudied samples. The dye ability of various cotton genotypes using orange reactive dye was measured, and all color measurements were analyzed.

The data on fiber quality properties were analyzed. The results of fiber quality properties showed that characteristics of *Gossypium barbadense* have high quality compared to *Gossypium hirsutum.* Although G. *barbadense* cotton genotypes were superior to *G. Hirsutum* genotypes in the majority of fibers characteristics, both had good affinity to the reactive dye. Studying the differences between cotton fibers from *Gossypium hirsutum* and *Gossypium barbadense* is extremely important across scientific, industrial, and agricultural domains. The novelty lies in bridging fundamental science as genomics and biochemistry to the applied innnovations across various fields, such as agriculture, textiles and sustainability.

Keywords: Gossypium sp. ; Egyptian Cotton; Upland cotton; Fiber properties; Mechanical properties; Chemical composition; Reactive dyes

1. Introduction

Cotton is considered as one of the most important natural fibers in the world, which played a crucial role in the textile industry for centuries. It is an important crop that influences the economics of countries across the globe, as it is considered the most environmentally friendly natural fiber. But increasing competition from man-made fibers such as polyester and nylon has put additional impetus for the improvement of cotton fiber quality. (Zheng et al., 2023) [1]

Cotton is a member of the family Malvaceae, which includes the mallows. The Gossypium genus is one of great species diversity and range, consisting of 52 distinct species distributed globally (Fryxell, 1992) [2] (Wendel and Cronn, 2003) [3] (Y. Wang et al., 2023) [4].

The Gossypium genus presents a remarkable example of plant domestication by humans, where four geographically isolated and unique species were domesticated for the production of natural fiber. Archaeological evidence of cultivation for the Asiatic/African species G. *herbaceum* and G. *arboreum* can be traced back to almost 4,700 years ago. Archaeologists have stated that G. *hirsutum* dates back to 4000 to 5000 years ago. The primary gene pool of G. *hirsutum* can generally be considered the cultivated form of Upland. While G. *barbadense* was originally domesticated between 4000 and 5000 years ago, Westengen et al., 2005, G. *hirsutum* in the northern Yucatan peninsula around the same time [5]

Almost exclusively, except for those species grown under cultivation, members of these species occur in the tropics or sub-tropics and exist as perennials. This unique genus has an interesting evolutionary history, reflected in its diversity both in morphology and cytology. Of the species comprising this diverse genus, most are diploid (2n = 26), and have the genome group designations A-G, and K [5] Species from the A genome group include G. *arboreum* and G. *herbaceum*, both of which are native to the African and Asian continents and were independently domesticated by early agriculturalists. These species have a considerable history of cultivation, although today they are not grown on a large industrial scale. They are the only examples of cultivated diploid species of the *Gossypium* genus. The D genome group includes 13 New World diploid species, such as G. *raimondii*, which is believed to be one of the precursors of our nowadays cultivated species. The other diploid groups include several species, such as D- and K-groups, which contain 12 and 13 species respectively - to those with very few, as is the case for the F-group which contains only one species, G. *longycalyx* of East Africa (Wendel and Cronn, 2003).[5] Hybridization initiated a polyploidy event that gave rise to what is now our AD-genome, allotetraploid cotton species, including the widely cultivated G. *hirsutum* and G. *barbadense* is the most prominent, but there are also the non-cultivated species such as: G. *tomentosum*, G. *darwinii*, G. *mustelinum*, G. *ekmanianum*, and G. *stephensii*.[5]

There are two cultivated species, G. *barbadense* and G. *hirsutum*, which exhibit a diverse array of morphological variations that reflects the wild-to-domesticated form. [6] *Gossypium hirsutum* is prevalent across central and northern South

*Corresponding author e-mail: dr_shereen_bahlool@yahoo.com.; (Shereen O. Bahlool).
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America, the Caribbean, and extends to reaches the Pacific. *Gossypium hirsutum* is thought to have a more northern distribution compared to G. *barbadense*. G. *hirsutum* is referred to as Upland cotton; G. *barbadense*, commonly termed Pima or Egyptian, or extra-long staple (ELS) cotton. 11.2 million acres of planted cotton in 9 states in the American states in 2021. (USDA-NASS, 2022)[6, 7].

Gossypium barbadense L., commonly known as Sea Island, Pima, Egyptian, long staple cotton is characterized by its exceptional fiber quality. Cardoso et al. (2023) reported that new genotypes of G. *barbadense* L. were derived from Sea Island cotton and improved to produce Egyptian and Pima cotton. Therefore, due to its excellent fiber quality with softness, long, strong, and fine fibers, G. *barbadense* represents an alternative option for the improvement of fiber quality alleles into upland cotton *Gossypium hirsutum*. (Campbell et al., 2018 and Cardoso et al. 2023). [8, 9]

In recent decades, man-made fibers such as polyester have taken significant textile market share from natural fibers such as cotton. In 1990, cotton and other natural fibers accounted for over 60% of the global textile production market and in 2000 it was down to 45%. In 2010, natural fibers accounted for 36% of world fiber consumption, with cotton accounting for 32.9% of the total consumption (FAO-ICAC, 2013). This rapid decline in cotton market share can be tied to recent advances in man-made fiber technologies as well as the historically high price of the raw cotton fiber and the processing costs associated with the natural product vs. man-made synthetic fibers. For cotton to remain competitive with man-made fibers, it is important that the cotton breeding community improve the fiber quality genetic potential of the cotton crop.[5]

Cotton fiber's characteristics determine their value for spinning into yarns from which to make textiles include some characteristics such as length, strength and fiber diameter. These parameters, as well as the chemical composition and the physical nature or three-dimensional shapes of the fibers, all contribute to the selection of a fiber as a suitable source for spinning into yarn. They also influence the characteristics of the yarn, the textile produced from the yarn, and the costs associated with processing the fiber into yarns.[5]

Fiber length is important for producing thin and strong yarns, whereas strong fibers are required to withstand the rigors of mechanical processing and also help to create a strong yarn. Uniformity of length is also important for the efficient production of yarn at an industrial scale. After being spun to create yarn, the yarns are woven to produce textiles or twisted together to produce string. Yarns produced from long strong fibers are used in the production of higher end products such as fine dress shirts or high-thread-count sheets, whereas shorter fibers are used to produce coarse yarns used in towels and denim jeans. [5] Delhom et al., 2024 has reviewed the characterizing cotton fiber such as tensile strength and elongation from manual to modern high-speed automated testing. Also studied the Factors such as genetics and the environment, and the influence of these on textile processing and fiber quality.[10]

The chemical and physical composition of fibers influences their spinning characteristics as well as their dyeing and finishing qualities. For instance, cotton fiber is 99.5% cellulose, a polysaccharide linear chain of hundreds to thousands of glucose molecules. Primarily composed of α-cellulose, the crystallinity of the cellulose as well as the non-cellulosic components affects dye uptake. The chains of cellulose are deposited to constitute the secondary cell wall. Immature fibers have a lesser degree of this secondary cell wall deposition, thereby making immature cotton fiber weaker than a fully mature fiber and poorer dye uptake. Karademir et al.(2010) studied the relationship between yield, fiber length and other fiber related traits in advanced cotton strains, derived from a cotton breeding program. The correlation analysis revealed significant negative correlations between fiber length and cotton lint/seed cotton yield, and ginning percentage. Conversely, it demonstrated significant positive correlations between fiber length and fiber strength. [11] However, it has been shown to have a negative correlation with yield (Azhar, et al., 2004&2008; Shen, et al., 2007). Along with this negative correlation with yield, it is against a grower's best interest to grow a variety with good fiber quality if it will not yield competitively. [12-14]

Zhang et al, 2014, provide a comprehensive analysis of hybridization between Upland and Pima cotton essential for breeding. They also stated that Upland cotton yield and fiber quality can be improved by breeding between Upland and Pima [15]

Cotton fiber quality is determined through several properties, such as fiber length, uniformity, strength, elongation, fineness, maturity, trash, color and chemical composition. Cotton fiber properties are crucial for the production of high-quality textile products and satisfy the demands of the global market. A comprehensive and detailed study to fundamental fiber properties allows the assessment of fiber quality to produce high-quality fiber and then improve fabric quality. A comparative analysis used to determine the quality of cotton fibers from two different species, *Gossypium Hirsutum* and *Gossypium barbadense*. Identifying cotton genotypes with high fiber quality can significantly contribute to the final quality of textile products. Furthermore, an accurate characterization of fiber quality properties can provide valuable information to cotton processors and textile manufacturers, helping in decision-making on the optimal use of different fiber types. Species-Specific Traits: For example, *Gossypium barbadense* (Egyptian cotton) produces extra-long staple fibers prized for luxury textiles, while *Gossypium hirsutum* (upland cotton) is high-yielding and widely adapted. Studying these differences helps farmers choose species/varieties suited to local climates, soil, and market demands.

Studying cotton species and varieties drives economic growth by: Enhancing agricultural productivity, unlocking premium markets through superior fiber quality, reducing costs via sustainable practices, and strengthening trade competitiveness.
So, it is a demand for a scientific research related to the genetic breeding of cotton with an emphasis on its fiber quality.

2. Experimental

2.1. Materials

All cotton materials were collected during the summer of season 2023. These varieties were planted in Giza Agricultural Research station. The sampling of cotton accessions was carried out using the non-probability subjective sample selection method. A total of fourteen samples of *Gossypium* sp., 6 samples of *Gossypium Barbadense* and 8 samples of *Gossypium Hirsutum*. All listed in table 1

Table 1 Samples understudy genotypes of *Gossypium* sp.

Gossypium Barbadense			***Gossypium Hirsutum***		
Egyptian Cotton Variety	**Origin/ Pedigree**	**Release Year**	**Upland Cotton Variety**	**Origin/ Pedigree**	**Release Year**
Giza 92	G84x(G74xG68)	2009	**Deltapine 245**	DP 2379-4/Domor BG	1997
Giza 93	G77xPima S6	2010	**Deltapine 1909xF**	Unknown	-
Giza 94	G86x 10229	2015	**Wilson 1**	Unknown	-
Giza 96	G84x (G70xG51A) xS62	2016	**Wilson 2**	Unknown	-
Giza 97	(((G89xR101)xG86)xG94))	2020	**Tamcot 788**	CA398/P1874	1984
Giza 98	G83x G80x G89x S107	2022	**Tamcot Sphinx**	MAR-CDP37HPIH-1-1-86/Sel. PM 145	1995
			Tamcot Luxor	CA BUCAHuGS-1-88/CABUCAG8US-1-88	2004
			Tamcot Pyramid	Tamcot Sphinx/CD3HGCBU8S-1-91	2004

Egyptian varieties produced by modern breeding methods and artificial hybridization from 1920 until now [16]
All cotton fibers testing must be performed in an environmentally controlled room in standard conditioning and testing occurs in accordance with ASTM D1776 (2005) using 21 ± 1 C and 65 ± 2% relative humidity.[17] It should be noted that due to the sensitive nature of cotton fibers, these conditions are more constrained in textile testing. [10]

2.2. Chemicals and auxiliaries

All chemicals used in this study were of analytical grade. Glauber's salt, Sodium Carbonate, Sodium hydroxide, hydrogen peroxide, sodium silicate, Ethyl alcohol, Phenol, Sulfuric Acid, Acitic acid, chloroform and Triton X100 as a wetting agent, were all of commercial grade, while detergent was supplied by Merck Co, Egypt.

2.3. Dyestuff

Reactive orange ME-2RN from the Azo dye class was used for this research. The chemical structure represented in Fig.1

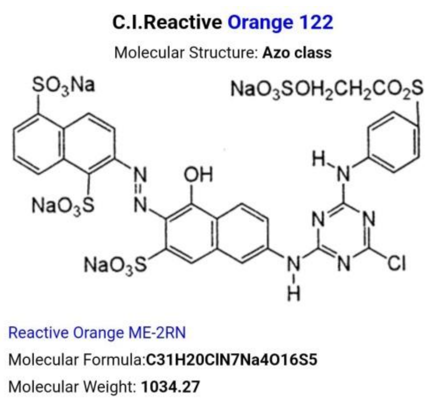


Fig. 1. Molecular structure of reactive orange dye

2.4. Pretreatments

Conventionally, scouring is done in a hot aqueous solution of 3% NaOH to remove hydrophobic components from the raw cotton fibers at temperature 95-100°C for 60 minutes, after scouring rinse twice with hot and cold water. [18] Conventional bleaching was done using H_2O_2 depending on weight of the cotton fiber samples. The scoured samples were bleached for 60 min at boiling according to Bahlool, et al. 2020 [18]
The alkaline pretreatment of cotton lint was carried out using sodium hydroxide to isolate alpha cellulose. 10 g. cotton lint was treated with 400 ml NaOH (17.5%) at 80c for 30 min, then filtered and rinsed with distilled water until reaching pH7. Then bleaching using 100ml of H_2O_2 (30%) at room temp. for 15 min. then the bleached cellulose rinsed several timrs with distelled water. Then samples were oven-dried until constant weight is achieved. [19]

2.5. Dyeing

Both *Gossypium barbadense* and *Gossypium Hirsutum* cotton fibers samples were dyed with 4% concentration of Orange reactive dye in bath contain 60g/l gluber salt and sodium carbonate 15g/l to adjust pH =11 at 60ºC.using L.R 1:20 , by conventional dyeing techniques for 60 min. according to Bahlool (2019) as shown in Fig.2. After dyeing, soaping was performed with 2 g/L non-ionic detergent at 90ºC for 10 minutes and finally the samples were dried. [20]

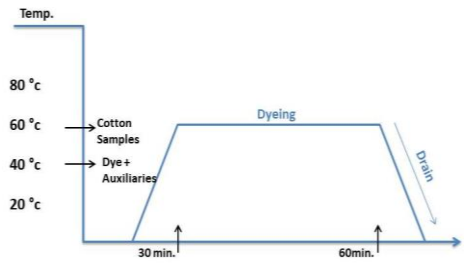


Fig. 2 Diagram of Reactive dyeing processes

2.6. Evaluation Tests

All cotton samples were pre-conditioned for 24 hours, at a standard tropical atmospheric condition of 65 ± 2% RH and 27 ± 2 °C temperatures for 24 hours, according to ISO: 6359-1971 standard method before testing using cotton testing instruments at Cotton Research Institute, Agricultural Research Center (ARC), Giza, Egypt.

Fiber quality analyzes of all cotton fiber samples were performed using the Uster high volume instrument (HVI) M-1000 equipment under controlled conditions. The fiber properties determined using HVI included staple length (SL, mm), length uniformity index (UI, %), Micronaire index (MIC, unit), fiber strength (STR, g tex−1), fiber elongation (FE, %), and maturity coefficient (Mc, unit). Staple length (mm) was measured as the upper half mean length (UHML). The uniformity index (%) is the ratio of the fiber mean length divided by the UHML. according to (ASTM: D4605-1986). [21]

Fibers were chemically analyzed to determine the difference in chemical constituents between the *Gossypium Hirsutum* and *Gossypium barbadense* under studied samples. Such as, α-cellulose (%) by treating cotton lint with hot alkali then was bleaching to remove any residual traces of lignin and hemicellulose providing fibrous of alpha cellulose according to ASTM-D165-07. Reducing sugar content (%) determined using Soxhlet extraction according to Dubois 1956, the reducing sugar content (%) was determined using the standard curve previously prepared. Wax content (%) was determined according to Conrad 1944, Moisture regain % using oven drying method, Ash (%) determined using ASTM-D3516-89 (reapproved 2000) and Cotton seed oil content (%) was determined using hexane as a solvent in Soxhlet extraction method according to AOAC2005.

The dye-ability of *Gossypium Hirsutum* and *Gossypium barbadense* cotton fibers samples was determined after reactive dyeing and measured the dye uptake and all color measurements such as; a*, b*, L* and shade depth k/s., redness (+) – greenness (-), yellowness (+) – blueness (-), lightness and the color depth values, respectively

Color measurements a*, b*, and L* were determined using cotton classifying system CCS-V5. Color strength K/S of the dyed samples was measured using Perkin Elmer spectrophotometer, using the reflectance data in a visible spectrum between 400 and 700nm wavelengths with 20nm interval under an illuminate D65/10◦ standard observer. The color strength was expressed as K/S using Kubelka-Munk equation is as follows:

$K/S = (1-R)^2/ 2R$. [20].

Color fastness to washing, light, and perspiration were assessed using a grey scale. Fastness tests were done according to ISO:105-C06,ISO:105-B02 , ISO:105-E04 methods respectively.

2.7. Statistical Analysis

Complete randomized design with three replicates was used in this study, Moreover, for all data collected cotton fibers properties were compared using paired student t-test / ANOVA with the WinPepi statistical software package. P values less than 0.05 were considered significant.

3. Results and Discussion

3.1. Physical and mechanical properties of Gossypium barbadense and Gossypium Hirsutum Cotton

The fiber quality properties of the 14 cotton genotypes, *Gossypium barbadense* -Egyptian cotton and *Gossypium Hirsutum* -Upland cotton, were analysed, using HVI instrument to measure fiber length (UHML), fiber strength (FS), elongation (ELO.), color, trash content, and micronaire. HVI determines fineness and maturity together through micronaire (MIC) reading. All of which is very important to the textile industry for determining the quality of cotton. The results are summarized in Table 2.

Table 2 Fiber physical and mechanical properties of *Gossypium barbadense* and *Gossypium Hirsutum* Cottons

Genotype		Mic.	Mat. I.	UHML mm	UI %	St. g/Tex	Elo. %	Rd	b+	cnt. trash	trash Area %
Giza 92	**Mean**	3.72	0.9	34	86.93	47.13	5.17	76.83	8.43	41.33	0.38
	SD	0.19	0.01	0.1	0.47	0.25	0.21	0.57	0.49	2.52	0.04
Giza 93	**Mean**	3.37	0.88	36.57	88.87	45.2	5.27	69.07	11.6	46.67	0.71
	SD	0.25	0.01	0.06	0.15	0.87	0.12	0.93	0.2	16.26	0.06
Giza 94	**Mean**	4.2	0.9	34	87.73	42.17	6.3	77.27	8.73	37	0.37
	SD	0.1	0.01	0.1	0.38	1.4	0.2	1.01	0.35	3.61	0.13
Giza 96	**Mean**	3.9	0.86	36.33	87.73	45.73	5.18	72.6	9.53	39.67	0.53
	SD	0.1	0.01	0.32	0.31	0.8	0.16	1.77	0.21	5.13	0.13
Giza 97	**Mean**	4.33	0.9	33.87	87.54	42.63	6.23	75.93	8.8	32.33	0.31
	SD	0.15	0.01	0.15	0.44	1.46	0.21	0.47	0.1	7.23	0.04
Giza 98	**Mean**	4.47	0.87	30.37	87.57	36.07	6.93	67.23	12.07	30	0.37
	SD	0.25	0.01	0.76	0.57	0.76	0.15	0.76	0.15	2.65	0.04
Deltapine245	**Mean**	3.93	0.86	26.51	83.1	26.53	5.23	80.6	10.17	24.33	0.16
	SD	0.01	0.01	0.08	0.9	0.25	0.15	0.6	0.12	3.21	0.07
Deltapine1909xf	**Mean**	4.34	0.87	27.27	84.3	27.7	5.13	79.6	9.73	11	0.11
	SD	0.14	0.01	0.16	0.36	0.17	0.06	0.2	0.12	1	0.01
Wilson 1	**Mean**	4.25	0.87	27.32	86.37	27.6	5.2	79.6	10.4	20	0.23
	SD	0.03	0.01	0.15	0.15	0.17	0.1	0.17	0.2	1.73	0.04
Wilson 2	**Mean**	3.95	0.87	28.18	86.43	30.1	4.4	78.17	10.37	9.33	0.08
	SD	0.04	0.01	0.06	0.31	0	0.2	0.15	0.15	1.53	0.02
Tamcot788	**Mean**	4.21	0.86	27.39	84.47	28.33	5.13	80.9	10.2	29	0.25
	SD	0.04	0.02	0.37	0.42	0.25	0.12	0.36	0.1	2	0.03
Tamcot sphinx	**Mean**	4.08	0.86	26.85	83.87	26.1	5.37	77.77	10.2	24.67	0.18
	SD	0.02	0.01	0.01	0.31	0.1	0.15	0.35	0.1	0.58	0.01
Tamcot luxor	**Mean**	4.33	0.87	28.11	86.1	28.57	5.03	78.4	10.1	12	0.17
	SD	0.4	0.02	0.01	0.1	0.21	0.06	0.2	0.1	1	0.01
Tamcot pyramid	**Mean**	3.91	0.86	27.51	84.77	26.17	4.67	78.7	10.23	11.67	0.13
	SD	0.06	0.01	0.12	0.06	0.21	0.12	0.17	0.06	0.58	0.01
P value		**< 0.001***	**< 0.001***	**< 0.001***	**< 0.001***	**< 0.001***	**< 0.001***	**< 0.001***	**< 0.001***	**< 0.001***	**< 0.001***

Abbreviations: Mic. =Micronaire value, Mat.=Maturity fiber index, UHML=Upper half mean (mm), UI = Uniformity Index , St. = Fiber Strength (g/tex), Elo. = fiber elongation (%), Rd= , +b = , Trash ct. = trash content, Trash Area %

The genetic determined fiber perimeter, also the developmental maturity of the fiber, has influence on fineness of the fibers, as well as, the interaction between genetic structure and environment. Whereas, fiber maturity is the percentage of the development of the fiber's secondary wall which has thickened over the fiber growth. The value of this index must be greater than 0.80-0.86. Since good fiber maturity is essential to guarantee adequate spinning and dyeing performance (Wang and Memon, 2020). Immature fibers cause poor performance during dye uptake, decreased fiber strength and increased breakage during processing, defects in the fabric and waste during textile and yarn manufacture. Immature fibers also cause neps, which are little knots of entangled fibers that develop in yarns and can be considered as fabric defects. Fiber with very high maturity and overly thick secondary cell wall deposition will result in fibers that do not collapse in on themselves when the fiber cells dry out, thus creating a fiber that is circular in cross section that does not spin well, Fibers with optimum maturity have sufficiently thick secondary cell walls, have strong fibers that still collapse after drying, and are spun to create strong yarns [5]

In this study, all 14 samples of Gossypium sp. , 6 samples of *Gossypium Barbadense* (Egyptian cotton) and 8 samples of *Gossypium Hirsutum* have good fiber maturity. *Gossypium Hirsutum* cotton fibers had an intermediate MIC. But, Giza 93 from *Gossypium barbadense* cotton fibers have the lowest MIC of 3.3, that indicates a fine fiber related to the fibers maturity.

Cotton fiber fineness affects the dye-ability of the fiber, that very fine fineness fibers are undesirable for the textile industry as they impair the adhesion of the dye to the fiber thread during dyeing. Cotton fibers measurement include determination of parameters characterizing the fineness, maturity, fiber strength and elongation as well as the fiber length and its uniformity presented in Table 2.

The length of an individual cotton fiber is very important and has long been considered as one of the most important aspects of fiber quality for yarn strength and quality. Fiber length is positively correlated with yarn tenacity and yarn elongation. Additionally, the length of the fiber determines the fineness of the yarn capable of being produced.

Fiber length is measured in several different ways: upper-half mean length (UHML), which is the mean length of the longest 50% of fibers in the sample, and the Uniformity Index (UI), which is the ratio of the mean length (ML) compared to the UHML, which gives some idea of the fiber length distribution. Fiber length uniformity is the ratio between the average length of total fibers and is an important characteristic for textile manufacturing. Furthermore, it is an indicator used in selecting cotton genotypes in cotton breeding programs.

The HVI device has the capability of measuring fiber length (UHML), determination of parameters characterizing the fiber length and its uniformity is shown in Table 2. These cotton have medium long fiber lengths (26-28mm) for *GossypiumHirsutum* cotton fibers (Upland cotton) while it was long (29-34mm) and extra long fiber lengths (>34mm) for *Gossypium barbadense* cotton fibers (Egyptian cotton).

The Uniformity Index (UI), of *Gossypium sp*. of various genotypes was determined. *Gossypium Hirsutum* cotton fibers were classified at a high >83% uniformity value. While *Gossypium barbadense* cotton fibers have the highest uniformity value of >85%, which demonstrates the superiority of this cotton genotype in comparison to other cotton fiber.

Fibers which had lower UI, indicating that fiber length was slightly more variable in these genotypes than the others in the trial. It is important to note, however, that all the UI values seen here are within the premium range given to growers. So, while the differences are significant, they are not agronomically meaningful since they are all at a premium level for UI, which gives further evidence that these genotypes produce fibers that are desirable for spinners.[5]

Fiber Strength is the ability of fiber to withstand a load until it breaks. Fiber Strength (g tex^{-1}) of cotton samples is an essential quality characteristic for the durability of the fabric and for determining the performance of a material in textile processing. . Fibers with a higher strength values (>28 g tex^{-1}) are generally preferable. The strength of fibers has a large effect on the yarn that will be produced and the textile that it will be used in, and how well the fiber handles the harsh mechanical rigors of processing. [10]

Estimation of fiber strength is conducted using HVI analysis. *Gossypium barbadense* cotton fibers have a very high strength (>36 g tex^{-1}), and Giza 92 has the highest fiber strength (up to 47 g tex^{-1}), which demonstrates the superiority of this cotton genotype in comparison to others. While, for *Gossypium Hirsutum* cotton fibers were classified as the average strong fibers (26-30 g tex^{-1}).

Fiber elongation refers to the amount a fiber stretches before break. Measurement of this characteristic is achieved using HVI analysis or by Stelometer, that fiber elongation is a vital parameter in cotton quality. As cotton fiber elongation capacity is an important factor in the quality and flexibility of the fabric. Furthermore, Faulkner et al. (2012) found that cotton fibers from cultivars which have similar fiber length and strength but differ in elongation values represented different work-to-break values. While fiber strength is an important aspect of spinning performance, fiber ELO is shown in this study to be of increased importance to yarn production and spinning efficiency.[23]

Gossypium barbadense cotton fibers have a very high elongation (>5) and Giza 98 has the highest fiber elongation (up to 7 %) which demonstrates the superiority of this cotton genotype in this characteristic. While, *Gossypium Hirsutum* cotton fibers were classified as average elongation.

Although foreign matter and trash content are not fiber quality parameters intrinsic to the cotton fiber themselves, it can be considered a fiber quality parameter of a cultivar, a region, or an individual bale. Foreign matter and trash content are very important to textile manufacturers, and as such should be treated as an important aspect of cotton fiber quality.[24] Common contaminants include leaf, bark and stem particles, burs, seeds, seed fragments, motes, grass, sand, oil and dust. The majority of these contaminants are removed during the ginning process. However, not all of it can be affectively or efficiently removed entirely by mechanical cleaning. *Gossypium Hirsutum* cotton fibers have lower trash content compared to *Gossypium barbadense* cotton fibers, which could be due to the ginning processing. Results presented in Table 2 show that the cotton fiber physical and mechanical properties were all significantly different when compared among the various cotton genotypes of different spices.

3.2. Chemical composition of Gossypium barbadense and Gossypium Hirsutum Cotton

The chemical composition of *Gossypium barbadense* cotton, and *Gossypium Hirsutum* cotton represented in Table 3. The chemical analysis allowed the identification of these cotton genotypes collected from different *Gossypium sp*.; *G. barbadense* with high-quality standards and fiber properties highly valued in the textile industry.

Cotton lint was pretreated with sodium hydroxide in order to remove wax and impurities, and then bleached using hydrogen peroxide to remove any residual traces of lignin and hemicellulose fibrous alpha cellulose. The percent yield of α-cellulose is represented in Table 3.

Table 3 Chemical composition of *Gossypium barbadense* and *Gossypium Hirsutum* Cottons

Genotype		α- Cell. %	R. Sugar %	Wax %	Moist. %	Ash %	Seed oil%
Giza 92	**Mean**	93.42	0.16	0.6	6.9	0.9912	22.47
	SD	0.63	0.01	0.02	0.1	0.0003	0.15
Giza 93	**Mean**	92.18	0.173	0.77	6.43	0.9867	23.47
	SD	0.35	0.006	0.026	0.06	0.0002	0.45
Giza 94	**Mean**	91.46	0.213	0.977	6.37	0.9892	22.13
	SD	0.83	0.012	0.112	0.15	0.0001	0.15
Giza 96	**Mean**	91.96	0.167	0.753	6.87	0.9903	21.13
	SD	0.29	0.015	0.015	0.15	0.0002	0.15
Giza 97	**Mean**	90.98	0.19	0.84	6.13	0.9903	22.82
	SD	0.48	0.01	0.066	0.12	0.0003	0.05
Giza 98	**Mean**	89.93	0.197	0.743	6.63	0.991	21.3
	SD	0.51	0.006	0.038	0.15	0.0003	0.17
Deltapime245	**Mean**	86.5	0.217	0.853	6.03	0.9879	20.75
	SD	0.2	0.012	0.025	0.06	0.0002	0.21
Deltapime1909xf	**Mean**	87.83	0.213	0.69	6.1	0.9874	21.95
	SD	0.15	0.015	0.036	0.1	0.0005	0.06
Wilson 1	**Mean**	87.9	0.21	1.23	5.97	0.9874	21.02
	SD	0.36	0.01	0.036	0.15	0.0004	0.07
Wilson 2	**Mean**	89.05	0.257	0.993	6.23	0.989	21.38
	SD	0.4	0.006	0.08	0.21	0.001	0.06
Tamcot788	**Mean**	88	0.237	1.093	5.92	0.9881	20.45
	SD	0.2	0.015	0.197	0.13	0.0002	0.05
Tamcot sphinx	**Mean**	86.63	0.203	0.86	6.03	0.988	18.82
	SD	0.4	0.006	0.017	0.06	0.0001	0.13
Tamcot luxor	**Mean**	88.28	0.22	0.523	6.23	0.9921	19.66
	SD	0.7	0.01	0.025	0.25	0.006	0.1
Tamcot pyramid	**Mean**	86.58	0.23	1.193	6.03	0.9888	17.65
	SD	0.63	0.01	0.21	0.15	0.0011	0.14
P value		**< 0.001***	**0.006***	**< 0.001***	**0.002***	**0.009***	**< 0.001***

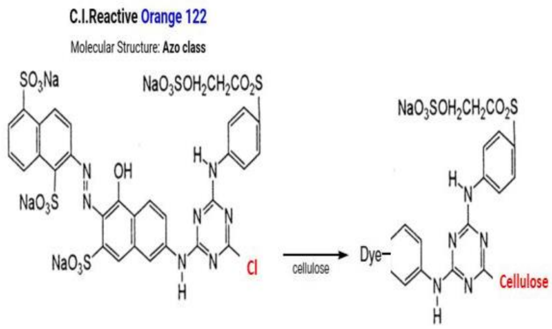
Abbreviations: α- Cell. = alpha cellulose, R. Sugar = Reducing sugar, Wax = wax%, Moist. = Moisture%, Ash = Ash %, seed oil = cotton seed oil-content%

The results presented in Table 3 show that the fiber chemical properties were all significantly different when compared among the 14 cotton genotypes with the greatest variability in the α-cellulose, wax and oil cotton seed content percentages. In general, the results presented here showed that the *Gossypium barbadense sp.* is considered as a promising option to being used as high-quality fiber progeny in cotton genetic improvement programs aimed at improving fiber-quality cotton characteristics.

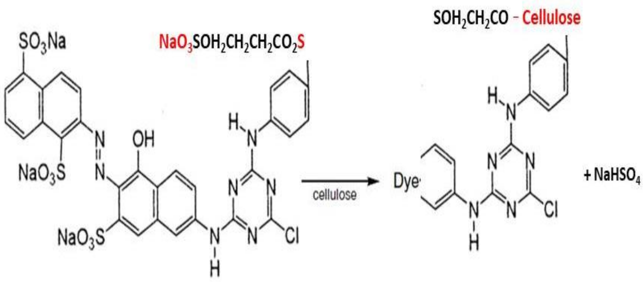
3.3. Color measurements of dyed fibers

The dye-ability of *Gossypium barbadense* and *Gossypium Hirsutum* cotton fibers samples was determined after reactive dyeing .

Cellulosic fibers combine with the dye molecule by hydrogen bonding as well as Vander walls forces. Reactive dyes contain electrophilic groups (e.g., chlorotriazine, vinyl sulfone) that react with nucleophilic oxygen in cellulose under alkaline conditions. The dye's reactive group has a labile chlorine atom. Cellulose-O⁻ attacks the electrophilic carbon bonded to chlorine in the dye molecule. Chlorine is displaced as a leaving group (Cl^-), forming a covalent ether bond (Cellulose-O-Dye). Reactive dyes form covalent bonds with cellulose fiber by nucleophilic substitution and addition reactions as shown in Scheme 1 and 2.

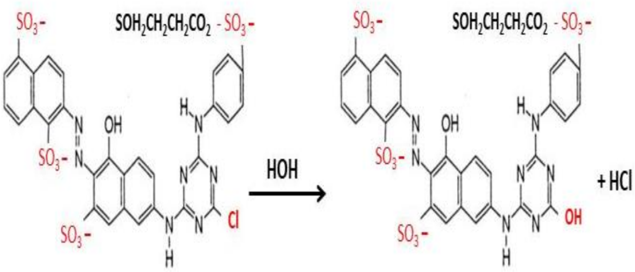


Scheme 1: Reactive orange dye molecules bonded with cellulose by substitution reaction



Scheme 2: Reactive orange dye molecules bonded with cellulose by addition reaction

Also, this reactive dye type is highly reactive and also hydrolyzed when react with water. Reactive dye which has Solubilizing group: such as Sulfonate ($-SO_3^-$) ensures water solubility and the reaction mechanism is as shown in Scheme 3.



Scheme 3: Hydrolysis of Reactive dye in water bath

These chemical reactions as well as several chemical bonds explain the high fastness properties of the dye. Measures of the dye uptake and all color measurements such as; a*, b*, L* and shade depth k/s., are presented in Table 4. The dye-ability of *Gossypium barbadense* and *Gossypium Hirsutum* cotton fibers samples has a good affinity to the reactive dye used.

Table 4 Color measurements of *Gossypium barbadense* and *Gossypium Hirsutum* Cottons dyed with reactive dye

Genotype		K/S	L	a	b
Giza 92	**Mean**	4.33	70.33	26.57	44.67
	SD	0.15	0.51	1.05	0.23
Giza 93	**Mean**	4.93	67.73	29	47.97
	SD	0.15	1.27	0.46	0.8
Giza 94	**Mean**	4.23	70.8	26.9	46.87
	SD	0.25	0.98	0.4	0.76
Giza 96	**Mean**	4.58	69.5	26.4	46.1
	SD	0.1	0.35	0.1	0.36
Giza 97	**Mean**	4.25	68.87	26.13	46.33
	SD	0.05	1.07	0.31	0.38
Giza 98	**Mean**	5	70.47	29.07	48.07
	SD	0.1	0.71	0.95	0.67
Deltapime245	**Mean**	4.22	68.67	28.63	46.33
	SD	0.08	1.05	0.95	1.46
Deltapime1909xf	**Mean**	4.33	71.53	28.43	46.43
	SD	0.15	1.11	1.29	0.55
Wilson 1	**Mean**	4.5	67.93	27.73	47.73
	SD	0.26	1.25	0.76	0.45
Wilson 2	**Mean**	4.72	67.7	26.3	47.83
	SD	0.1	0.5	1.08	1
Tamcot788	**Mean**	4.15	70.23	27.57	47.43
	SD	0.05	0.84	0.45	0.32
Tamcot sphinx	**Mean**	4.15	70.3	28.07	46.47
	SD	0.13	0.1	0.68	0.4
Tamcot luxor	**Mean**	4.3	69.1	29.43	45.97
	SD	0.2	0.53	0.31	0.72
Tamcot pyramid	**Mean**	4.13	69.93	27.97	46.73
	SD	0.12	0.38	0.75	0.9

Abbreviations; a*= redness (+) – greenness (-), b* yellowness (+) – blueness (-), L* = lightness, and K/S= shade depth values

3.4. Color fastness.

Reactive orange dye exhibits moderate to excellent color fastness properties when applied to cotton fibers from different genotypes. It shows a very good light fastness with rating of 4/5. Dyed fibers have excellent wash fastness with a range of about 5, while, dyed fibers exhibit moderate to good color fastness against perspiration ranging from 3 to 5. These results are in agreement with Bakr Abdel-Wahab et al., 2020 [27]

3.5. Gossypium. barbadense vs Gossypium. hirsutum

There are a number of differences between the varieties of G. *barbadense* and G. *hirsutum*. The fiber perimeter is almost greater for *G. hirsutum* than for *G. barbadense*.

As represented in Figure 3. *G. Hirsutum* cotton fibers had an intermediate MIC of 3.9-4.3, and Giza 93 from *G. barbadense* cotton fibers had the lowest MIC of 3.3. Where, Low MIC indicates a fine fiber related to the fiber's maturity. Immature fiber which has low MIC values (less than 3.5) causes neps and weakness of the yarn, as well as reduced dye-uptake due to limited cellulose deposition. Also, high MIC cotton, which is usually considered to be >5.0, generally does not spin well and cannot be used to produce high-quality yarns.[25,26]

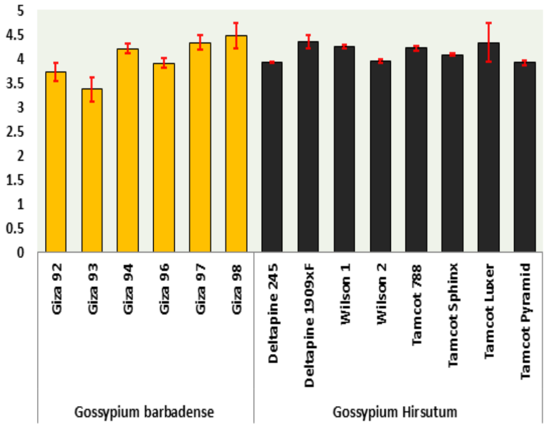


Fig. 3 Micronaire of *Gossypium barbadense* vs. *Gossypium Hirsutum* Cotton

The fiber length is mostly smaller for *G. hirsutum* than for *G. barbadense*. The number of convolutions per unit of length is greater for *G. hirsutum* than for *G. barbadense*. The bundle strength and the elongation of the raw fibers are lower for G. *hirsutum* than for G. *barbadense*. It could be noted that these differences continue to exist after treatment.

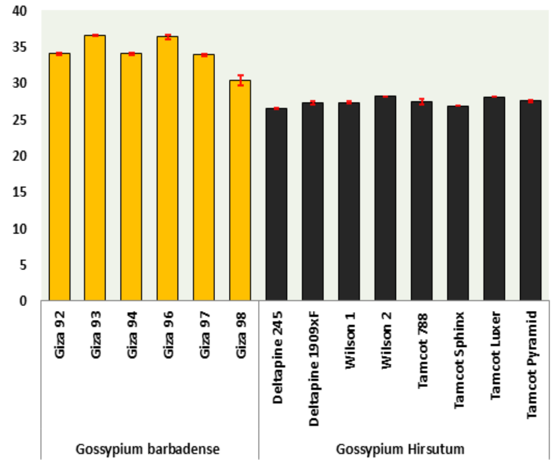


Fig.4 Upper half mean length (UHML) of *Gossypium barbadense* vs. *Gossypium Hirsutum* Cotton

Fiber strength estimation of the cotton genotypes represented in Figure 5 showed that *G. barbadense* cotton fibers have a very high strength, which demonstrates the superiority of this cotton genotype in comparison to others. While, for *G. Hirsutum* cotton fibers were classified as the average strong fibers.

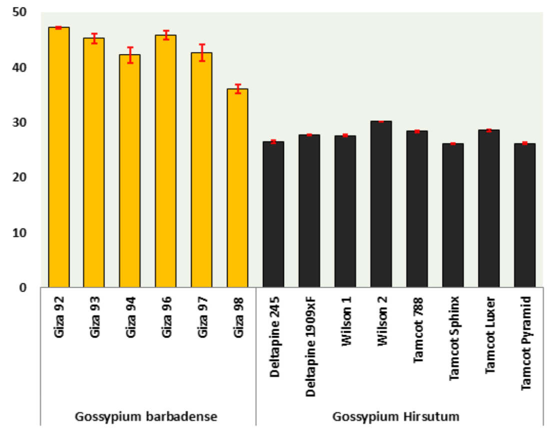


Fig.5 Fiber strength of *Gossypium barbadense* vs. *Gossypium Hirsutum* Cotton

Cotton fibers differ in elongation percentage represented in figure 6 showed that G. *barbadense* cotton fibers have a very high elongation in comparison to G. *Hirsutum* cotton fibers, which are classified as average low elongation. That demonstrates the superiority of G. *barbadense* cotton genotype in this characteristic.

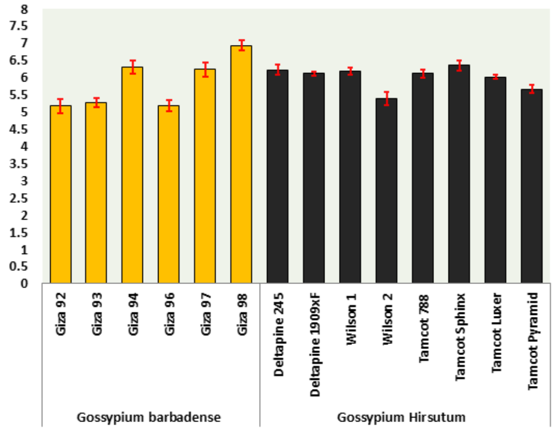


Fig.6 Elongation of *Gossypium barbadense* vs. *Gossypium Hirsutum* Cotton

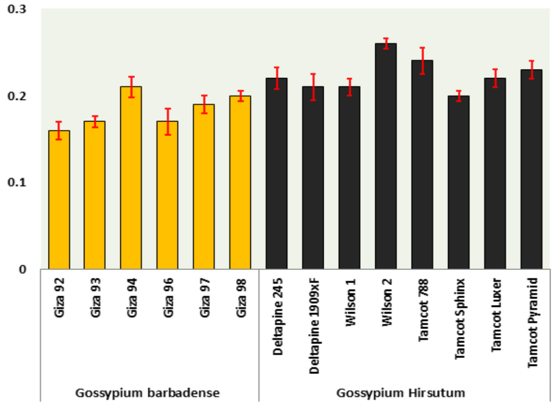


Fig.7 Reducing sugar % of *Gossypium barbadense* vs. *Gossypium Hirsutum* Cotton

The honeydew (insect sugars) are primarily cotton aphids, Aphis gossypii, and silver leaf whiteflies, which cause complex concentrated carbohydrates on the surface of cotton fibers and cause cotton stickiness that is hindering the spinning process [25]. Therefore, the determination of reducing sugar in cotton composition is one of the most important chemical analyzes of cotton. The results are shown in Figure 7 that compared the reducing sugar % of *Gossypium Hirsutum* vs. *Gossypium barbadense* Cotton. It is interesting to note that the values of total reducing sugar% for all the genotypes were in normal range and considered as not sticky cotton.

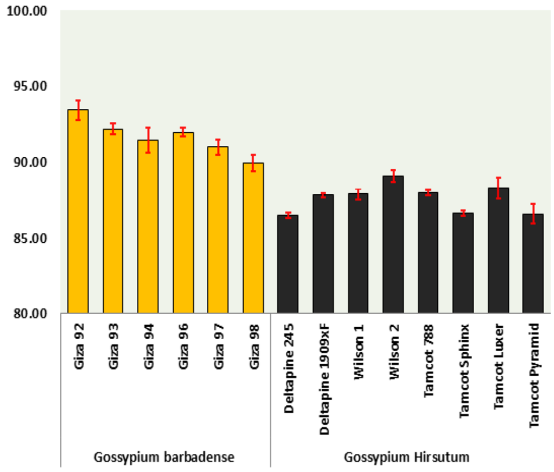


Fig.8 α – cellulose % of *Gossypium barbadense* vs *Gossypium Hirsutum* Cotton

Cotton is an important natural source of cellulose, the structure of cotton α-cellulose has been stated that its building unit is glucose. Alpha-cellulose is empirically defined as the fraction that can be filtered out of a mixture consisting of the fibrous material and sodium hydroxide solution, after the fibers have previously been swollen with sodium hydroxide. The α-cellulose content of 14 genotypes is presented in Figure 8.

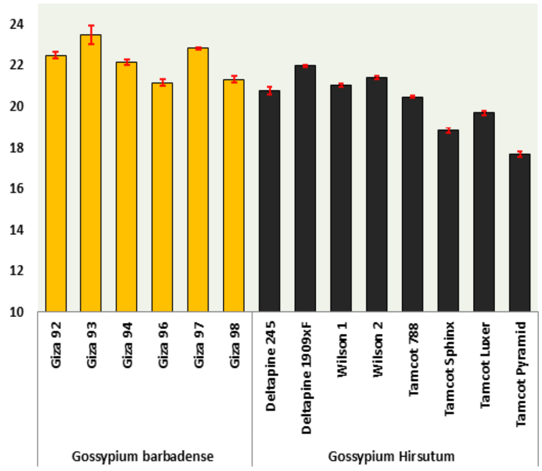


Fig.9 Oil cotton-seed content % of *Gossypium barbadense* vs *Gossypium Hirsutum* Cotton

The effect of genotypes on oil cotton-seed content was highly significant, as illustrated in Figure 9. Whereas genotype Giza 93 recorded the highest value (23.4%) followed by Giza 97 and Giza 92 was recorded (22.5) while genotype Tamcot pyramid recorded the lowest value (17.6).

4. Conclusions

In the present study, we measured the physical, mechanical and chemical properties of a total of 14 cotton samples of G. *barbadense* and G. *hirsutum*. Analysis of fiber quality, such as fiber length, uniformity, strength, elongation, fineness, maturity, color, and trash, and chemical analyzes, such as α-cellulose, reducing sugar, wax , moisture, ash, and cotton seed oil content were all performed for all genotypes. Moreover, we performed a comparison between *Gossypium hirsutum* and *Gossypium barbadense* concerning also the dye-ability of these cotton genotypes using orange reactive dye, and all color measurements were analyzed.

Differences between genotypes were significant for the majority of the evaluated physical, mechanical and chemical properties. Although G. *barbadense* cotton genotypes were superior to *G. Hirsutum* genotypes in the majority of fibers characteristics, both had good affinity to the reactive dye.

The results of this study are of great importance to the international scientific community, regional farmers, and the textile industry because studying these differences has profound economic implications for agriculture, textile industries, trade, and sustainability. And it is critical to maximizing long-term benefits for farmers, industries, and economies.

By decoding the differences between *hirsutum* and *barbadense* genotypes, we can allocate the suitable cotton varieties for resource-scarce regions and develop strategies to protect biodiversity, and enhance global trade. This interdisciplinary research positions cotton not just as a commodity crop but as a driver of sustainable development and technological advancement.

5. Conflicts of interest

There are no conflicts to declare.

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