10.21608/TAEC.2023.179945.1043 TAECKHOLMIA 43 (2023): 22-43

Computer-generated conventional keys and descriptions of some *Gossypium* species and cultivars (Malvaceae)

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Abstract

A data matrix was compiled to accommodate 32 characters of vegetative and floral morphology and stem anatomy of 18 cultivars of *Gossypium barbadense* L., one cultivar of *G. hirsutum* L., and three species representing the American, African, and Arabian wild species (*G. thurberi* Tod., *G. anomalum* Wawra & Peyr. and *G. stocksii* Mast., respectively). Of the 32 characters, 24 are phenetic, while eight are technological attributes defining the commercial quality of these cultivars and the potential value of the wild species. A conventional key to the 22 taxa and a description of every taxon based on the entire set of 32 characters were obtained from subjecting the data matrix to numerical analysis using the key-generating program package DELTA. The key is strictly comparative, easy to use, and leads to the full names of individual taxa. The data matrix is provided in the DELTA format. Additional wild and cultivated taxa from any part of the world can be included in the data matrix and appropriate keys and descriptions of them can be obtained.

Key Words Cotton cultivars; data matrix; DELTA; identification; lint technology

Introduction

The genus *Gossypium* L. (Malvaceae) comprises 54 species with accepted scientific names (The Plant List, 2012a), of which only four (*G. barbadense* L., *G. herbaceum* L., *G. hirsutum* L. and *G. arboreum* L.) are cultivated primarily as sources of the cotton fibers. Cotton is a crop with global economic importance. It is grown commercially for its fibres in more than 80 countries (Kalivas et al., 2011), with China as the world's leading cotton producer followed by India and the USA. India has the World's largest cotton area (Tripathi et al., 2011). Cotton is also one of the World's most important crops for producing oilseed (Zhang et al., 2007). In some rural communities in Egypt, the protein-rich remains of the cotton seeds crushed for

Received on 10/12/2022 and accepted on 19/05/2023

oil extraction are used as cattle feed and the dry shrubs are used as firewood. More recent studies by Adams et al. (2017a, 2017b & 2018) showed that cotton leaves are a rich source of pentane extractable hydrocarbons which can be used as biofuel.

The wild and cultivated *Gossypium* plants are usually perennial shrubs with stipulate 3-5-lobed palmate leaves. The number of leaf lobes and the depth of the sinuses between them is highly variable not only from species to species but often between individual plants of the same species or cultivar and sometimes on the same plant. The wide range of variation and anomalies in foliar structure include: (i) the two lateral lobes may be conspicuously unequal, (ii) one of the two lateral lobes may be absent, (iii) both lateral lobes may be wanting so that the leaf blade assumes a simple structure, and (iv) one or both of the two lateral lobes may have a much smaller attached lobes (Andres et al., 2016; Dao-fang et al., 2018). Andres et al. (2016) recognized four major shapes of leaf lobes and named them 'Normal', 'Sub-okra', 'Okra' and 'Super-okra' with narrow lobes and widening sinuses between them in the first three shapes and a simple narrowly lanceolate leaf blade in the fourth. Andres et al. (2016) regarded plants with abnormalities in leaf morphology as 'mutants' and showed that the changes in leaf lobe shape are genetically correlated with the plants' resistance to insects and boll rot, yield, and fibre quality. Flowers of *Gossypium* species and infra-specific taxa are invariably hermaphrodite, actinomorphic and each is subtended by an epicalyx of three persistent or deciduous bracts. The calyx consists of five short, united sepals with 5-toothed or truncate apex. The corolla consists of five free petals with anti-clockwise imbrication and a reddish-deep violet spot may be found at the base of each petal. Petal colour ranges from white, pale pink, yellow to different shades of red. Numerous united stamens form a narrow tube around the style; filaments and anthers assume different colours in different species ranging from white to yellow and red. The gynoecium consists of 3-5 united carpels and the ovary has an equal number of locules with numerous ovules per locule. The mature fruit (or boll) is a loculicidal capsule containing numerous seeds carrying epidermal fuzz and/or lint. According to Lang (1938), lint hairs originate when or soon after the cotton flower opens, while first fuzz hairs appear only after the lint population has been fully determined. Fuzz hairs are usually light brown, about 0.5 mm long and adhere strongly to the seed surface. In contrast, lint hairs are normally white, 30 mm long or more and easily detachable. These criteria for distinguishing between the two types of epidermal trichomes are commonly applied in studies of the inheritance of seed hairiness such as the 'naked' (or fuzz-free) seeds of *G. hirsutum* (Bardak and Bolek, 2016) and *Gossypium arboreum* (Erpelding, 2017). In various parts of the cotton plant, groups of cells form dark lysigenous glands containing toxic terpenoids such as gossypol which defend the plant against pests and pathogens (Janga et al., 2019).

The importance of wild and cultivated species of *Gossypium* to mankind cannot be over-emphasized: the former as sources of germplasm with useful traits which can be transferred to the latter to improve their qualities, and the latter as the major

source of revenue for cotton growers and workers in the textile industry. The wild *Gossypium* species, their multitude of cultivars and the innumerable hybrids produced continually with global economic importance deserve to have a means of rapid and accurate identification. The correct identity of wild and cultivated *Gossypium* taxa is of utmost importance to breeders and growers from the scientific and commercial standpoints. To date, attention was paid mostly to constructing keys for the identification of a few wild *Gossypium* species in local floras e.g. Andrews, (1952); Fryxell, (1976, 1992, & 1994); Fryxell and Hill, (2019); in addition to Verdcourt and Mwachala, (2009), while similar keys to the more economically useful cultivated varieties and hybrids are non-existent in most cotton producing countries. As an attempt to bridge this gap, we have set out to benefit from the versatility of some computer programs in generating keys and descriptions of a representative sample combining wild *Gossypium* species and cultivated varieties of American, African and Arabian origin.

Materials and Methods

Fresh specimens of 18 cultivars of *Gossypium barbadense*, one cultivar of *G. hirsutum*, and two species not in cultivation (*G. anomalum* and *G. thurberi*) were collected from the Research Stations of the Cotton Research Institute, Agricultural Research Centre in Giza and Bahteem, Egypt, to ensure the authenticity of their scientific names. Specimens of *G. stocksii* Mast. were collected in the desert of Dhofar region in the Sultanate of Oman, southern Arabia and identified with the help of the keys, descriptions and illustrations provided by Mandaville (1977), and Miller and Morris (1988); voucher material is kept in the Herbarium of King Faisal University (Al-Hofuf, the Eastern Province, Saudi Arabia). Identity of the N. American species *G. thurberi* was ascertained with the aid of the keys, descriptions and illustrations provided by Fryxell (1976, 1992 & 1994), and Fryxell and Hill (2015). For confirming the identity of the E. African species *G. anomalum*, the keys constructed by Andrews (1952) and Verdcourt and Mwachala (2009) were used. Confusion in the nomenclature of *G. thurberi* was resolved according to The World Flora online (2023) and the ITIS Report (2020). At least five healthy specimens of each taxon were collected in the flowering and fruiting stages and voucher material is kept in the Herbarium of the Faculty of Science, El-Arish University, North Sinai, Egypt.

A data matrix was compiled to include the names of the 22 species and cultivars and their phenetic (morphological and anatomical) characters. Variation in hairiness, the distribution of deep violet gossypol glands and calcium oxalate druses in the tissues of different organs was recorded for every taxon. Leaf Incision Factor (LIF) was designed to express variation in the depth of the sinus between the terminal leaf lobe and its two immediate lateral lobes (ab/bc in Figs. 1 & 2).

Free-hand permanent cross sections of the stem were cut and double-stained in 1% aqueous safranin and 1% light green in ethanol to reveal differences in stem anatomy of various taxa. The calyx was cut along one side of the tube and laid flat together with a part of one bract on a slide, cleared by warming in a few drops of 1% KOH to reveal the distribution of epidermal hairs, glands, and druses. Petal features were recorded directly from fresh material.

Fibre strength is expressed as the 'half fall' using a sledge cotton sorter (Ball's sorter) through which ½ gm of fibre was pushed from right to left on the surface of a bench covered with one-way plush so that the fibres are sorted into different length grades and those of each grade are collected and weighed. This procedure is repeated 30 times for each taxon and the lengths and weights of the 30 replica of each grade are plotted against each other to obtain a frequency curve from which the 'half fall' is calculated.

Fibre fitness and maturity were measured by two methods: (i) as hair weight in millitex (i.e. the weight in mg of 1000 m of fibre) according to the method of Lord (1961), and (ii) as the Micronaire index where air is forced at 7 pounds/in^2 through a sample of 3.24 gm of fibre and the resistance of the sample to air flow is scored. Fibre elongation was recorded as the average of measurements made from three samples of each taxon using a Steleometer calibrated at ⅛ in gauge according to the standard method developed by the American Society for Testing and Materials (ASTM, 2012). Lint colour was estimated using a Carl Zeiss Leucometer designed specifically to determine the differences in the degree of reflection between materials described roughly as white; the lint of *G. stocksii* is rust-coloured and the Leucometer is unsuitable for it. The seed index is the weight of 100 seeds in gm; the recorded value is the average of five sets of seeds for each taxon. Yarn strength was measured according to the standard method described by the American Society for Testing and Materials (ASTM, 2016). All technological tests were performed at the Cotton Technology Research Division, Cotton Research Institute, Agricultural Research Centre, Ministry of Agriculture and Land Reclamation, Giza at a controlled atmospheric of temperature 20°C ± 1.1°C and relative humidity of 65% ± 2%.

The data matrix combining the 25 phenetic and seven technological characters was subjected to numerical analysis under the key-generating computer program package DELTA (Dallwitz, 1993 onwards and 2010; Dallwitzet al., 1993 onwards; Dallwitz and Paine, 2005).

Results

1. Observations

The phenetic (1-24) and eight technological (25-32) characters recorded comparatively for the 22 taxa included in the present study are outlined defined in

Table (1). Variation in the number of leaf lobes was deliberately omitted because of its instability in plants of the same taxon. Leaf lobes are either narrowly lanceolate (length: width ratio 4 or more, Fig. 1), or broadly ovate (length: width ratio 2.5 or less, Fig. 2).

Neighbouring margins of leaf lobes are widely divergent (Fig. 1) or close to overlapping (Fig. 2). The three bracts of the epicalyx may be: (i) united at base or entirely free, (ii) broadly ovate with palmate venation and laciniate margins or narrowly lanceolate with parallel venation (lacking any cross veins) and entire margins, and (iii) with deep gossypol glands on their outer surface and calcium oxalate druses in their tissues or without glands and/or druses. Calyx teeth are either acute-acuminate or obtuse (Figs. 3-5), with or without glands on their outer surface and druses in their tissues, and the number of veins varies from taxon to another. Petal color may be white-pale rose, yellow or deep red, with or without a pale to dark violet spot at the base of each petal.

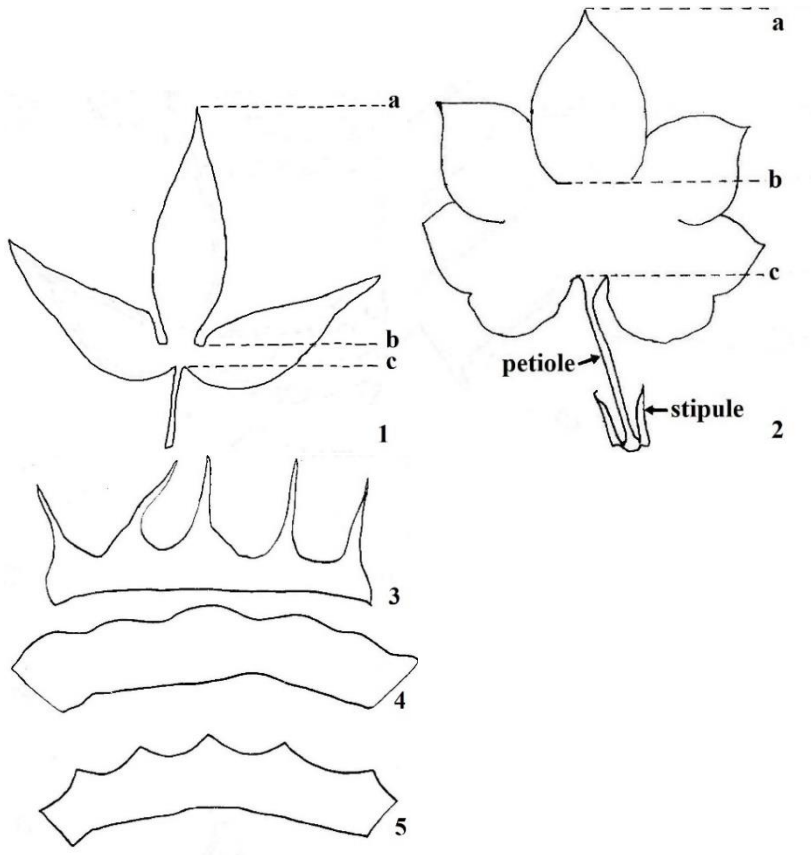
Fuzz is found either at the chalazal end of the seed or may cover its entire surface. When present, the lint is white in all taxa except in *G. stocksii* where it is rust colored.

Most details of stem anatomy are closely similar in the 22 *Gossypium* taxa. The only exception showing a clear aspect of variation in different taxa is the distribution of xylem vessels where they may be arranged in regular radial arms or distributed homogeneously in all parts of the secondary xylem. Character 2 in Table (1) is recorded for the *Gossypium* taxa for the first time, while the rest are in full agreement with the results of Webber (1938).

Computer-generated keys of *Gossypium* species

Table 1. List of 32 characters recorded comparatively for 18 cultivars of *Gossypium* barbadense, one cultivar of *G. hirsutum* and three wild *Gossypium* species and used to generate an automated conventional key to them.

#1. Stem/ 1. hairy/ 2. glabrous/ #2. Stem xylem vessels/ 1. in radial arms/ 2. homogeneously distributed/ #3. Petiole/ 1. hairy/ 2. glabrous/ #4. Leaf upper surface/ 1. hairy/ 2. glabrous/ #5. Leaf lower surface/ 1. hairy/ 2. glabrous/ #6. Margins of leaf lobes/ 1. widely divergent/ 2. close - overlapping/ #7. Leaf lobes length/width ratio/ 1. less than 2.5/ 2. at least 4/ #8. Leaf incision factor/ 1. 1.3–2.5/ 2. 3–4.5/ 3. 12 or more/ #9. Pedicel/ 1. hairy/ 2. glabrous/	#10. Pedicel length/ cm/ #11. Bracts/ 1. persistent/ 2. deciduous/ #12. Bracts/ 1. narrowly lanceolate/ 2. broadly ovate/ #13. Bracts/ 1. lacineate/ 2. entire/ #14. Bracts/ 1. united at base/ 2. free/ #15. Bract veins/ 1. 3–5/ 2. 10 or more/ #16. Bract venation/ 1. palmate/ 2. parallel/ #17. Bract cross veins/ 1. present/ 2. absent/ #18. Bract glands/ 1. present/ 2. absent/ #19. Bract druses/ 1. present/ 2. absent/	#20. Calyx/ 1. hairy/ 2. glabrous/ #21. Calyx teeth/ 1. acute-acuminate/ 2. obtuse-truncate/ #22. Calyx glands/ 1. present/ 2. absent/ #23. Dark spot at petal base/ 1. present/ 2. absent/ #24. Fuzz/ 1. on all seed surface/ 2. on chalazal end of seeds/ #25. Seed index/ #26. Half-fall/ #27. Hair weight in/ millitex/ #28. Micronaire index/ #29. Fiber elongation/ #30. Yarn strength/ #31. Lint/ 1. white/ 2. rust-coloured/ 3. absent/ #32. Lint whiteness/ %



Figs 1-5. Diagrammatic representation of variation in leaf and calyx morphology of the studied *Gossypium* taxa. **1**. Leaf with lanceolate and divergent lobes; **2.** Leaf with ovate and close or overlapping lobes. Distances between points a-c determine the degree of leaf incision; **3**. Calyx with 5 acuminate lobe apices; **4.** Calyx with 5 obtuse lobe apice**s; 5.** Calyx with 5 acute lobe apices.

2. The data matrix

The tabular form of the data matrix is transformed into the DELTA format whereby each character and its character-state are represented by the serial number assigned to it in (Table 1); a comma separates the number of every character and its state. Numeric values of characters 25-30 and 32 are given in the descriptions of individual species and cultivars.

\b\i{}*G. barbadense* \i0{}L. cv. Giza 30\b0{}/

1,2 2,1 3,1 4,1 5,1 6,1 7,1 8,1 9,2 10,1.1 11,2 12,2 13,1 14,2 15,2 16,1 17,118,1 19,1 20,1 21,2 22,1 23,1 24,2 25,10 26,41 27,147 28,3.4 29,7.5 30,1690 31,132,81.5

\b\i{}*G. barbadense* \i0{}L. cv. Giza 74\b0{}/

1,2 2,1 3,1 4,1 5,1 6,1 7,1 8,1 9,2 10,3.4 11,2 12,2 13,1 14,1 15,2 16,1 17,118,2 19,1 20,1 21,2 22,2 23,1 24,1 25,10.1 26,44 27,143 28,4.2 29,7.5 30,199031,1 32,78.5

\b\i{}*G. barbadense* \i0{}L. cv. Dandara (Giza 31)\b0{}/

1,2 2,1 3,1 4,1 5,1 6,1 7,1 8,1 9,2 10,11 11,2 12,2 13,1 14,1 15,2 16,1 17,118,1 19,1 20,2 21,1 22,1 23,2 24,2 25,10.8 26,41 27,138 28,3.7 29,8.2 30,199531,1 32,69.4

\b\i{}*G. barbadense* \i0{}L. cv. Giza 72\b0{}/

1,2 2,1 3,1 4,1 5,1 6,1 7,1 8,1 9,1 10,1 11,2 12,2 13,1 14,1 15,2 16,1 17,1 18,119,1 20,1 21,1 22,1 23,2 24,2 25,10.7 26,44 27,171 28,4.5 29,7.1 30,1770 31,1 32,68.3

\b\i{}*G. barbadense* \i0{}L. cv. Giza 66\b0{}/
1,2 2,1 3,2 4,2 5,1 6,2 7,1 8,1 9,2 10,7.4 11,2 12,2 13,1 14,1 15,2 16,1 17,118,1 19,1 20,1 21,2 22,1 23,2 24,2 25,10.4 26,41 27,164 28,4.4 29,7.7 30,182531,1 32,63.3

\b\i{}*G. barbadense* \i0{}L. cv. Menoufi (Giza 36)\b0{}/

1,2 2,1 3,1 4,1 5,1 6,2 7,1 8,2 9,1 10,9.9 11,2 12,2 13,1 14,1 15,2 16,1 17,118,1 19,1 20,1 21,2 22,2 23,1 24,2 25,10 26,46 27,124 28,3.4 29,7.5 30,2550 31,132,74.8

\b\i{}*G. barbadense* \i0{}L. cv. Giza 69\b0{}/

1,2 2,1 3,1 4,1 5,1 6,1 7,1 8,1 9,1 10,5.4 11,2 12,2 13,1 14,1 15,2 16,1 17,118,1 19,1 20,1 21,2 22,2 23,1 24,1 25,10.6 26,43 27,134 28,3.8 29,7.3 30,214031,1 32,81

\b\i{}*G. barbadense* \i0{}L. cv. Giza 67\b0{}/

1,2 2,1 3,1 4,1 5,1 6,1 7,1 8,2 9,2 10,6.7 11,2 12,2 13,1 14,1 15,2 16,1 17,118,1 19,2 20,1 21,2 22,2 23,2 24,2 25,11.8 26,43 27,160 28,4.1 29,7.7 30,204031,1 32,74.6

\b\i{}*G. barbadense* \i0{}L. cv. Giza 68\b0{}/

1,2 2,1 3,1 4,1 5,1 6,1 7,1 8,1 9,1 10,7.4 11,2 12,2 13,1 14,2 15,2 16,1 17,118,1 19,1 20,1 21,2 22,2 23,1 24,2 25,9.9 26,45 27,115 28,3.1 29,7.2 30,268031,1 32,73.2

\b\i{}*G. barbadense* \i0{}L. cv. Giza 45\b0{}/

1,2 2,1 3,1 4,1 5,1 6,2 7,1 8,1 9,2 10,1.1 11,2 12,2 13,1 14,1 15,2 16,1 17,118,2 19,2 20,1 21,2 22,2 23,2 24,2 25,9.8 26,49 27,107 28,3.1 29,7.5 30,295031,1 32,81.4

\b\i{}*G. barbadense* \i0{}L. cv. Giza 71\b0{}/

1,2 2,1 3,2 4,1 5,1 6,1 7,1 8,1 9,1 10,0.9 11,2 12,2 13,1 14,2 15,2 16,1 17,118,1 19,1 20,1 21,2 22,2 23,2 24,2 25,9.9 26,48 27,107 28,3.8 29,8 30,3160 31,132,74.6

\b\i{}*G. barbadense* \i0{}L. cv. Giza 70\b0{}/

1,2 2,1 3,1 4,1 5,1 6,1 7,1 8,1 9,1 10,5.1 11,2 12,2 13,1 14,1 15,2 16,1 17,118,2 19,1 20,1 21,2 22,1 23,1 24,1 25,9.9 26,48 27,131 28,3.8 29,6.8 30,281031,1 32,76.3

\b\i{}*G. barbadense* \i0{}L. cv. Karnak (Giza 29)\b0{}/

1,2 2,1 3,1 4,1 5,1 6,1 7,1 8,1 9,2 10,1.4 11,2 12,2 13,1 14,1 15,2 16,1 17,118,1 19,1 20,2 21,2 22,2 23,1 24,2 25,12.4 26,46 27,123 28,3.3 29,7.6 30,241031,1 32,74.3

\b\i{}*G. barbadense* \i0{}L. cv. Bahteem 190\b0{}/

1,2 2,1 3,1 4,1 5,1 6,1 7,1 8,1 9,2 10,0.8 11,2 12,2 13,1 14,1 15,2 16,1 17,118,1 19,2 20,1 21,2 22,1 23,1 24,2 25,13.7 26,46 27,142 28,3.6 29,8.7 30,231031,1 32,82

\b\i{}*G. barbadense* \i0{}L. cv. Giza 7\b0{}/

1,2 2,1 3,1 4,1 5,1 6,2 7,1 8,1 9,1 10,6.5 11,2 12,2 13,1 14,1 15,2 16,1 17,118,1 19,1 20,1 21,2 22,1 23,2 24,2 25,10.9 26,43 27,144 28,3.2 29,7.6 30,240031,1 32,69.3

\b\i{}*G. barbadense* \i0{}L. cv. Ashmouni (Giza 19)\b0{}/

1,2 2,1 3,1 4,1 5,1 6,1 7,1 8,1 9,2 10,1.3 11,2 12,2 13,1 14,1 15,2 16,1 17,118,1 19,1 20,2 21,2 22,1 23,1 24,2 25,10.3 26,40 27,173 28,4.4 29,7.4 30,163031,1 32,67.8

\b\i{}*G. barbadense* \i0{}L. cv. Giza 73\b0{}/

1,2 2,1 3,1 4,1 5,1 6,1 7,1 8,1 9,2 10,7.6 11,2 12,2 13,1 14,1 15,2 16,1 17,118,1 19,1 20,1 21,2 22,1 23,1 24,2 25,11.5 26,44 27,140 28,3.1 29,7.7 30,210031,1 32,73.6

\b\i{}*G. barbadense* \i0{}L. cv. Giza 75\b0{}/

1,2 2,1 3,1 4,1 5,1 6,2 7,1 8,1 9,2 10,1.3 11,2 12,2 13,1 14,1 15,2 16,1 17,118,1 19,1 20,1 21,2 22,1 23,2 24,1 25,10 26,43 27,152 28,3.8 29,6.1 30,2350 31,132,82.5

\b\i{}*G. hirsutum* \i0{}L. cv. Coker 100\b0{}/

1,2 2,1 3,1 4,1 5,1 6,2 7,1 8,1 9,1 10,1.3 11,2 12,2 13,1 14,1 15,2 16,1 17,118,1 19,1 20,1 21,2 22,2 23,2 24,2 25,11.2 26,42 27,151 28,3.9 29,5.2 30,204031,1 32,73.2

\b\i{}*G. thurberi* \i0{}Todaro\b0{}/

1,2 2,1 3,2 4,2 5,2 6,1 7,2 8,3 9,2 10,2.8 11,1 12,1 13,2 14,2 15,1 16,2 17,218,2 19,1 20,1 21,1 22,2 23,1 24,1 25,1.9 26,0 27,0 28,0 29,0 30,0 31,3 32,0

\b\i{}*G. anomalum* \i0{}Wawra&Peyr.\b0{}/

1,1 2,2 3,1 4,1 5,1 6,2 7,1 8,2 9,1 10,0.7 11,2 12,1 13,2 14,2 15,1 16,2 17,218,2 19,1 20,1 21,1 22,2 23,1 24,1 25,0.7 26,0 27,0 28,0 29,0 30,0 31,3 32,0

\b\i{}*G. stocksii* \i0{}Mast.\b0{}/

1,1 2,2 3,2 4,2 5,2 6,2 7,1 8,1 9,2 10,3.5 11,2 12,2 13,1 14,1 15,2 16,1 17,118,1 19,1 20,1 21,1 22,1 23,1 24,1 25,10.3 26,4 27,162 28,4.4 29,3.4 30,210331,2 32,0

3. The conventional key

The following is the unedited version of the conventional key to 22 *Gossypium* taxa based on the 32 characters listed in (Table 1). The prelude to the key indicates that only 14 of the recorded characters were sufficient to generate the key and that each of the 26 characters is given the same degree of reliability (importance) of 5.0:
Characters: 32 indata, 24 included, 14 in key.
Items: 22 in data, 22 included, 22 in key.
Parameters: Rbase = 1.40 Abase = 2.00 Reuse = 1.01 Varywt =.80
Characters included: 1–9, 11–24, 31
Character reliabilities: 1–32, 5.0

1. Calyx glands
   present……... 2
   Calyx glands absent……. 12

2(1). Dark spot at petal base
   present…….…… 3
   Dark spot at petal base absent……. 8

3(2). Fuzz on all seed
   surface…….…… 4
   Fuzz on chalazal end of seeds……. 5

4(3). Margins of leaf lobes widely divergent; pedicel hairy; calyx teeth obtuse-truncate;
   leaf lower surface hairy ……...……***G. barbadense* cv. Giza 70**
   Margins of leaf lobes close-overlapping; pedicel glabrous; calyx teeth acute-acuminate;
   leaf lower surface glabrous…….....…***G. stocksii***

5(3). Bracts druses
   present…… 6
   Bracts druses absent…….....……***G. barbadense*** cv. **Bahteem 190**

6(5). Bracts united at
   base…… 7
   Bracts free……..... ***G. barbadense*** cv. **Giza 30**

7(6). Calyx hairy…….***G. barbadense*** cv. **Giza 73**

Calyx glabrous……...***G. barbadense*** cv. **Ashmouni (Giza 19)**

8(2). Margins of leaf lobes widely divergent; calyx teeth acute-acuminate……...……. 9
Margins of leaf lobes close-overlapping; calyx teeth obtuse-truncate……..10

9(8). Pedicel hairy; calyx hairy…….***G. barbadense*** cv. **Giza 72**
Pedicel glabrous; calyx glabrous……..***G. barbadense*** cv. **Dandara (Giza 31)**

10(8). Petiole hairy; leaf upper surface hairy……...…... 11
Petiole glabrous; leaf upper surface glabrous……..……***G. barbadense*** cv. **Giza 66**

11(10). Pedicel hairy; fuzz on chalazal end of seeds…….***G. barbadense*** cv. **Giza 7**
Pedicel glabrous; fuzz on all seed surface…….……...***G. barbadense*** cv. **Giza 75**

12(1). Leaf incision factor 1.3-2.5……...…….13
Leaf incision factor 3-4.5……...19
Leaf incision factor 12 or more……...***G. thurberi***

13(12). Dark spot at petal base present……...…… 14
Dark spot at petal base absent…….. 17

14(13). Pedicel hairy…….. 15
Pedicel glabrous…… 16

15(14). Bracts united at base; fuzz on all seed surface…….……***G. barbadense*** cv. **Giza 69**
Bracts free; fuzz on chalazal end of seeds…….....…..***G. barbadense*** cv. **Giza 68**

16(14). Calyx hairy; fuzz on all seed surface; bracts glands absent……..***G. barbadense*** cv. **Giza 74**
Calyx glabrous; fuzz on chalazal end of seeds; bracts glands present…….…..……..***Gossypium barbadense*** cv. **Karnak (Giza 29)**

17(13). Margins of leaf lobes widely divergent; bracts free; petiole glabrous……..……***G. barbadense*** cv. **Giza 71**
Margins of leaf lobes close-overlapping; bracts united at base; petiole hairy…….....18

18(17). Pedicel hairy; bracts glands present; bracts druses present……..……. ***G. hirsutum*** cv. **Coker 100**
Pedicel glabrous; bracts glands absent; bracts druses absent……..……***G. barbadense*** cv. **Giza 45**

19(12). Margins of leaf lobes widely divergent; dark spot at petal base absent;
pedicel glabrous; bracts druses absent……***G. barbadense*** cv. **Giza 67**
Margins of leaf lobes close-overlapping; dark spot at petal base present; pedicel hairy; bracts druses present…….…… 20

20(19). Bracts united at base; bracts glands present; calyx teeth obtuse-truncate; fuzz on chalazal end of seeds …….…….
……***G. barbadense*** cv. **Menoufi (Giza 36)**
Bracts free; bracts glands absent; calyx teeth acute-acuminate; fuzz on all seed surface……..…***G. anomalum***

4. Descriptions

G. barbadense L. cv. **Giza 30**

Stem glabrous, xylem vessels in radial arms. Petiole hairy. Leaf upper surface hairy, lower surface hairy. Margins of leaf lobes widely divergent. Leaf lobes length/width ratio less than 2.5, incision factor 1.3–2.5. Pedicel glabrous, length 1.1 cm. Bracts deciduous, broadly ovate, lacineate, free, veins 10 or more, venation palmate, cross veins present, glands present, druses present. Calyx hairy, teeth obtuse-truncate, glands present. Dark spot at petal base present. Fuzz on chalazal end of seeds. Seed index 10. Half-fall 41. Hair weight in 147 millitex. Micronaire index 3.4. Fiber elongation 7.5. Yarn strength 1690. Lint white, whiteness 81.5 %.

G. barbadense L. cv. **Giza 74**

Stem glabrous, xylem vessels in radial arms. Petiole hairy. Leaf upper surface hairy, lower surface hairy. Margins of leaf lobes widely divergent. Leaf lobes length/width ratio less than 2.5, incision factor 1.3–2.5. Pedicel glabrous, length 3.4 cm. Bracts deciduous, broadly ovate, lacineate, united at base, veins 10 or more, venation palmate, cross veins present, glands absent, druses present. Calyx hairy, teeth obtuse-truncate, glands absent. Dark spot at petal base present. Fuzz on all seed

surface. Seed index 10.1. Half-fall 44. Hair weight in 143 millitex. Micronaire index 4.2. Fiber elongation 7.5. Yarn strength 1990. Lint white, whiteness 78.5 %.

G. barbadense L. cv. **Dandara (Giza 31)**

Stem glabrous, xylem vessels in radial arms. Petiole hairy. Leaf upper surface hairy, lower surface hairy. Margins of leaf lobes widely divergent. Leaf lobes length/width ratio less than 2.5, incision factor 1.3–2.5. Pedicel glabrous, length 11 cm. Bracts deciduous, broadly ovate, lacineate, united at base, veins 10 or more, venation palmate, cross veins present, glands present, druses present. Calyx glabrous, teeth acute-acuminate, glands present. Dark spot at petal base absent. Fuzz on chalazal end of seeds. Seed index 10.8. Half-fall 41. Hair weight in 138 millitex. Micronaire index 3.7. Fiber elongation 8.2. Yarn strength 1995. Lint white. Lint whiteness 69.4 %.

G. barbadense L. cv. **Giza 72**

Stem glabrous, xylem vessels in radial arms. Petiole hairy. Leaf upper surface hairy, lower surface hairy. Margins of leaf lobes widely divergent. Leaf lobes length/width ratio less than 2.5, incision factor 1.3–2.5. Pedicel hairy, length 1 cm. Bracts deciduous, broadly ovate, lacineate, united at base, veins 10 or more, venation palmate, cross veins present, glands present, druses present. Calyx hairy, teeth acute-acuminate, glands present. Dark spot at petal base absent. Fuzz on chalazal end of seeds. Seed index 10.7. Half-fall 44. Hair weight in 171 millitex. Micronaire index 4.5. Fiber elongation 7.1. Yarn strength 1770. Lint white. Lint whiteness 68.3 %.

G. barbadense L. cv. **Giza 66**

Stem glabrous, xylem vessels in radial arms. Petiole glabrous. Leaf upper surface glabrous, lower surface hairy. Margins of leaf lobes close-overlapping. Leaf lobes length/width ratio less than 2.5, incision factor 1.3–2.5. Pedicel glabrous, length 7.4 cm. Bracts deciduous, broadly ovate, lacineate, united at base, veins 10 or more, venation palmate, cross veins present, glands present, druses present. Calyx hairy, teeth obtuse-truncate, glands present. Dark spot at petal base absent. Fuzz on chalazal end of seeds. Seed index 10.4. Half-fall 41. Hair weight in 164 millitex. Micronaire index 4.4. Fiber elongation 7.7. Yarn strength 1825. Lint white. Lint whiteness 63.3 %.

G. barbadense L. cv. **Menoufi (Giza 36)**

Stem glabrous, xylem vessels in radial arms. Petiole hairy. Leaf upper surface hairy, lower surface hairy. Margins of leaf lobes close-overlapping. Leaf lobes length/width ratio less than 2.5, incision factor 3–4.5. Pedicel hairy, length 9.9 cm. Bracts deciduous, broadly ovate, lacineate, united at base, veins 10 or more, venation

palmate, cross veins present, glands present, druses present. Calyx hairy, teeth obtuse-truncate, glands absent. Dark spot at petal base present. Fuzz on chalazal end of seeds. Seed index 10. Half-fall 46. Hair weight in 124 millitex. Micronaire index 3.4. Fiber elongation 7.5. Yarn strength 2550. Lint white. Lint whiteness 74.8 %.

G. barbadense L. cv. **Giza 69**

Stem glabrous, xylem vessels in radial arms. Petiole hairy. Leaf upper surface hairy, lower surface hairy. Margins of leaf lobes widely divergent. Leaf lobes length/width ratio less than 2.5, incision factor 1.3–2.5. Pedicel hairy, length 5.4 cm. Bracts deciduous, broadly ovate, lacineate, united at base, veins 10 or more, venation palmate, cross veins present, glands present, druses present. Calyx hairy, teeth obtuse-truncate, glands absent. Dark spot at petal base present. Fuzz on all seed surface. Seed index 10.6. Half-fall 43. Hair weight in 134 millitex. Micronaire index 3.8. Fiber elongation 7.3. Yarn strength 2140. Lint white. Lint whiteness 81 %.

G. barbadense L. cv. **Giza 67**

Stem glabrous, xylem vessels in radial arms. Petiole hairy. Leaf upper surface hairy, lower surface hairy. Margins of leaf lobes widely divergent. Leaf lobes length/width ratio less than 2.5, incision factor 3–4.5. Pedicel glabrous, length 6.7 cm. Bracts deciduous, broadly ovate, lacineate, united at base, veins 10 or more, venation palmate, cross veins present, glands present, druses absent. Calyx hairy, teeth obtuse-truncate, glands absent. Dark spot at petal base absent. Fuzz on chalazal end of seeds. Seed index 11.8. Half-fall 43. Hair weight in 160 millitex. Micronaire index 4.1. Fiber elongation 7.7. Yarn strength 2040. Lint white. Lint whiteness 74.6 %.

Gossypium barbadense L. cv. **Giza 68**

Stem glabrous, xylem vessels in radial arms. Petiole hairy. Leaf upper surface hairy, lower surface hairy. Margins of leaf lobes widely divergent. Leaf lobes length/width ratio less than 2.5, incision factor 1.3–2.5. Pedicel hairy, length 7.4 cm. Bracts deciduous, broadly ovate, lacineate, free, veins 10 or more, venation palmate, cross veins present, glands present, druses present. Calyx hairy, teeth obtuse-truncate, glands absent. Dark spot at petal base present. Fuzz on chalazal end of seeds. Seed index 9.9. Half-fall 45. Hair weight in 115 millitex. Micronaire index 3.1. Fiber elongation 7.2. Yarn strength 2680. Lint white. Lint whiteness 73.2 %.

G. barbadense L. cv. **Giza 45**

Stem glabrous, xylem vessels in radial arms. Petiole hairy. Leaf upper surface hairy, lower surface hairy. Margins of leaf lobes close-overlapping. Leaf lobes length/width ratio less than 2.5, incision factor 1.3–2.5. Pedicel glabrous, length 1.1

cm. Bracts deciduous, broadly ovate, lacineate, united at base, veins 10 or more, venation palmate, cross veins present, glands absent, druses absent. Calyx hairy, teeth obtuse-truncate, glands absent. Dark spot at petal base absent. Fuzz on chalazal end of seeds. Seed index 9.8. Half-fall 49. Hair weight in 107 millitex. Micronaire index 3.1. Fiber elongation 7.5. Yarn strength 2950. Lint white. Lint whiteness 81.4 %.

G. barbadense L. cv. **Giza 71**

Stem glabrous, xylem vessels in radial arms. Petiole glabrous. Leaf upper surface hairy, lower surface hairy. Margins of leaf lobes widely divergent. Leaf lobes length/width ratio less than 2.5, incision factor 1.3–2.5. Pedicel hairy, length 0.9 cm. Bracts deciduous, broadly ovate, lacineate, free, veins 10 or more, venation palmate, cross veins present, glands present, druses present. Calyx hairy, teeth obtuse-truncate, glands absent. Dark spot at petal base absent. Fuzz on chalazal end of seeds. Seed index 9.9. Half-fall 48. Hair weight in 107 millitex. Micronaire index 3.8. Fiber elongation 8. Yarn strength 3160. Lint white. Lint whiteness 74.6 %.

G. barbadense L. cv. **Giza 70**

Stem glabrous, vessels in radial arms. Petiole hairy. Leaf upper surface hairy, lower surface hairy. Margins of leaf lobes widely divergent. Leaf lobes length/width ratio less than 2.5, incision factor 1.3–2.5. Pedicel hairy, length 5.1 cm. Bracts deciduous, broadly ovate, lacineate, united at base, veins 10 or more, venation palmate, cross veins present, glands absent, druses present. Calyx hairy, teeth obtuse-truncate, glands present. Dark spot at petal base present. Fuzz on all seed surface. Seed index 9.9. Half-fall 48. Hair weight in 131 millitex. Micronaire index 3.8. Fiber elongation 6.8. Yarn strength 2810. Lint white. Lint whiteness 76.3 %.

G. barbadense L. cv. **Karnak (Giza 29)**

Stem glabrous, xylem vessels in radial arms. Petiole hairy. Leaf upper surface hairy, lower surface hairy. Margins of leaf lobes widely divergent. Leaf lobes length/width ratio less than 2.5, incision factor 1.3–2.5. Pedicel glabrous, length 1.4 cm. Bracts deciduous, broadly ovate,lacineate, united at base, veins 10 or more, venation palmate, cross veins present, glands present, druses present. Calyx glabrous, teeth obtuse-truncate, glands absent. Dark spot at petal base present. Fuzz on chalazal end of seeds. Seed index 12.4. Half-fall 46. Hair weight in 123 millitex. Micronaire index 3.3. Fiber elongation 7.6. Yarn strength 2410. Lint white. Lint whiteness 74.3 %.

G. barbadense L. cv. **Bahteem 190**

Stem glabrous, xylem vessels in radial arms. Petiole hairy. Leaf upper surface hairy, lower surface hairy. Margins of leaf lobes widely divergent. Leaf lobes length/width ratio less than 2.5, incision factor 1.3–2.5. Pedicel glabrous., length 0.8 cm. Bracts deciduous, broadly ovate, lacineate, united at base, veins 10 or more, venation palmate, cross veins present, glands present, druses absent. Calyx hairy, teeth obtuse-truncate, glands present. Dark spot at petal base present. Fuzz on chalazal end of seeds. Seed index 13.7. Half-fall 46. Hair weight in 142 millitex. Micronaire index 3.6. Fiber elongation 8.7. Yarn strength 2310. Lint white. Lint whiteness 82 %.

G. barbadense L. cv. **Giza 7**

Stem glabrous, xylem vessels in radial arms. Petiole hairy. Leaf upper surface hairy, lower surface hairy. Margins of leaf lobes close-overlapping. Leaf lobes length/width ratio less than 2.5, incision factor 1.3–2.5. Pedicel hairy, length 6.5 cm. Bracts deciduous, broadly ovate, lacineate,united at base, veins 10 or more, venation palmate, cross veins present, glands present, druses present. Calyx hairy, teeth obtuse-truncate, glands present. Dark spot at petal base absent. Fuzz on chalazal end of seeds. Seed index 10.9. Half-fall 43. Hair weight in 144 millitex. Micronaire index 3.2. Fiber elongation 7.6. Yarn strength 2400. Lint white. Lint whiteness 69.3 %.

G. barbadense L. cv. **Ashmouni (Giza 19)**

Stem glabrous, xylem vessels in radial arms. Petiole hairy. Leaf upper surface hairy, lower surface hairy. Margins of leaf lobes widely divergent. Leaf lobes length/width ratio less than 2.5, incision factor 1.3–2.5. Pedicel glabrous, length 1.3 cm. Bracts deciduous, broadly ovate,lacineate, united at base, veins 10 or more, venation palmate, cross veins present, glands present, druses present. Calyx glabrous, teeth obtuse-truncate, glands present. Dark spot at petal base present. Fuzz on chalazal end of seeds. Seed index 10.3. Half-fall 40. Hair weight in 173 millitex. Micronaire index 4.4. Fiber elongation 7.4. Yarn strength 1630. Lint white. Lint whiteness 67.8 %.

G. barbadense L. cv. **Giza 73**

Stem glabrous, xylem vessels in radial arms. Petiole hairy. Leaf upper surface hairy, lower surface hairy. Margins of leaf lobes widely divergent. Leaf lobes length/width ratio less than 2.5, incision factor 1.3–2.5. Pedicel glabrous, length 7.6 cm. Bracts deciduous, broadly ovate, lacineate, united at base, veins 10 or more, venation palmate, cross veins present, glands present, druses present. Calyx hairy, teeth obtuse-truncate, glands present. Dark spot at petal base present. Fuzz on chalazal end of seeds. Seed index 11.5. Half-fall 44. Hair weight in 140 millitex.

Micronaire index 3.1. Fiber elongation 7.7. Yarn strength 2100. Lint white. Lint whiteness 73.6 %.

G. barbadense L. cv. **Giza 75**

Stem glabrous, xylem vessels in radial arms. Petiole hairy. Leaf upper surface hairy, lower surface hairy. Margins of leaf lobes close-overlapping. Leaf lobes length/width ratio less than 2.5, incision factor 1.3–2.5. Pedicel glabrous, length 1.3 cm. Bracts deciduous, broadly ovate, lacineate, united at base, veins 10 or more, venation palmate, cross veins present, glands present, druses present. Calyx hairy, teeth obtuse-truncate, glands present. Dark spot at petal base absent. Fuzz on all seed surface. Seed index 10. Half-fall 43. Hair weight in 152 millitex. Micronaire index 3.8. Fiber elongation 6.1. Yarn strength 2350. Lint white. Lint whiteness 82.5 %.

G. hirsutum L. cv. **Coker 100**

Stem glabrous, xylem vessels in radial arms. Petiole hairy. Leaf upper surface hairy, lower surface hairy. Margins of leaf lobes close-overlapping. Leaf lobes length/width ratio less than 2.5, incision factor 1.3–2.5. Pedicel hairy, length 1.3 cm. Bracts deciduous, broadly ovate, lacineate, united at base, veins 10 or more, venation palmate, cross veins present, glands present, druses present. Calyx hairy, teeth obtuse-truncate, glands absent. Dark spot at petal base absent. Fuzz on chalazal end of seeds. Seed index 11.2. Half-fall 42. Hair weight in 151 millitex. Micronaire index 3.9. Fiber elongation 5.2. Yarn strength 2040. Lint white. Lint whiteness 73.2 %.

G. thurberi Tod.

Stem glabrous, xylem vessels in radial arms. Petiole glabrous. Leaf upper surface glabrous, lower surface glabrous. Margins of leaf lobes widely divergent. Leaf lobes length/width ratio at least 4, incision factor 12 or more. Pedicel glabrous, length 2.8 cm. Bracts persistent, narrowly lanceolate, entire, free, veins 3–5, venation parallel, cross veins absent, glands absent, druses present. Calyx hairy, teeth acute-acuminate, glands absent. Dark spot at petal base present. Fuzz on all seed surface. Seed index 1.9. Half-fall 0. Hair weight in 0 millitex. Micronaire index 0. Fiber elongation 0. Yarn strength 0. Lint absent. Lint whiteness 0 %.

G. anomalum Wawra & Peyr.

Stem hairy, xylem vessels homogeneously distributed. Petiole hairy. Leaf upper surface hairy, lower surface hairy. Margins of leaf lobes close-overlapping. Leaf lobes length/width ratio less than 2.5, incision factor 3–4.5. Pedicel hairy, length 0.7 cm. Bracts deciduous, narrowly lanceolate, entire, free, veins 3–5, venation parallel, cross veins absent, glands absent, druses present. Calyx hairy. Calyx teeth acute-acuminate. Calyx glands absent. Dark spot at petal base present. Fuzz on all seed

surface. Seed index 0.7. Half-fall 0. Hair weight in 0 millitex. Micronaire index 0. Fiber elongation 0. Yarn strength 0. Lint absent. Lint whiteness 0 %.

G. stocksii Mast.

Stem hairy, xylem vessels homogeneously distributed. Petiole glabrous. Leaf upper surface glabrous, lower surface glabrous. Margins of leaf lobes close-overlapping. Leaf lobes length/width ratio less than 2.5, incision factor 1.3–2.5. Pedicel glabrous, length 3.5 cm. Bracts deciduous, broadly ovate, lacineate, united at base, veins 10 or more, venation palmate, cross veins present, glands present, druses present. Calyx hairy, teeth acute-acuminate, glands present. Dark spot at petal base present. Fuzz on all seed surface. Seed index 10.3. Half-fall 4. Hair weight in 162 millitex. Micronaire index 4.4. Fiber elongation 3.4. Yarn strength 2103. Lint rust-coloured. Lint whiteness 0 %.

Discussion

The key presented in this study is applied to the identification of only 18 cultivars of *Gossypium barbadense*, one cultivar of *G. hirsutum*, and the three wild species *G. anomalum*, *G. thurberi* and *G. stocksii*. However, the method of computer-generated keys is so flexible that the data matrix on which this key was based is easily expandable to accommodate any additional taxa and/or characters to produce updated and more comprehensive keys for the cottons of any part of the world, together with detailed description of the added taxa.

The prelude to the key shows that only 14 of the 32 recorded characters were sufficient to generate the required key. This is a clear indication that the initial version of the data matrix subjected to numerical analysis under the program package DELTA included a surplus of 18 confirmatory characters. In fact, confirmatory characters are always more than 18. For instance, the user of this key is able to identify a specimen of *G. barbadense* cv. Bahteem 190 by the states of only the four characters highlighted in the following excerpt of the key:

Calyx glands present……..…… 2
Calyx glands absent…….…..…….. 12

2(1). Dark spot at petal base present……..…… 3
Dark spot at petal base absent……...……. 8

3(2). Fuzz on all seed surface……...…….. 4
Fuzz on chalazal end of seeds……...……. 5

4(3). Margins of leaf lobes widely divergent; pedicel hairy; calyx teeth obtuse-truncate; leaf lower surface hairy ……..…***G. barbadense*** cv. **Giza 70**
Margins of leaf lobes close-overlapping; pedicel glabrous; calyx teeth acute-acuminate; leaf lower surface glabrous…..……. ***G. stocksii***

5(3). Bract druses present……6
Bract druses absent……..… ……***G. barbadense*** **cv. Bahteem 190**

The maximum number of characters required to identify a *Gossypium* taxon in this key is seven (for *G. stocksii* Mast. and *G. barbadense* L. cv. Giza 70). The remaining characters in the detailed description of any taxon can be used to confirm its identity.

It is noticeable that the list of 32 recorded characters included 22, two and eight qualitative, multi-state and quantitative characters, respectively (Table 1). The program package DELTA provides a means of assigning different degrees of importance (or "reliability") to different characters ranging from 1 to 10, with gradual sequential preference for qualitative, multi-state and quantitative characters. In the present study, we opted for treating all characters equally with the default reliability value 5 (see prelude to key). Since only 14 of the qualitative characters completed the assignment of key generation, eight qualitative, two multi-state and all eight quantitative characters did not feature in the key to taxa. The eight quantitative characters cover all the recorded technological attributes of the species and cultivars. Disappearance of the technological properties of Gossypium taxa in the key does not mean that they are wasted because they remain an integral part of the detailed description of every taxon, where they can be easily extracted and serve the all-important function of confirming its identity.

The accurate identity of a cotton cultivar is an essential factor in fixing its market price. To this extent, computer-generated keys of the type provided in the present study would then be pivotal in the pricing of cotton cultivars worldwide. The present study is intended as an example to be utilized in the accurate identification of species and cultivars of not only wild and cultivated cottons but those of other crops as well.

Computer-generated keys of *Gossypium* species

In the quest for cotton plants with improved productivity and lint quality, hybridization of wild and cultivated species and cultivars of different genome groups is a daily occurrence in all cotton growing countries. The compilation of data matrices similar to the one used in the present study to encompass the phenetic and technological characteristics of the new hybrids is a necessity because such matrices are not only the basis for building identification keys for their identification but are also an indelible record of the characters and pedigree of these hybrids.

Acknowledgements

We wish to thank Dr. Ahmad El-Naeem (College of Agricultural Sciences and Foods, King Faisal University, Al-Hofuf, The Eastern Province, Saudi Arabia) for providing specimens of *Gossypium stocksii* which he collected in Dhofar, Oman.

References

Adams R.P., TeBeest A.K., Frelichowski J., Hinze L.L., Percy R.G., Ulloa M. and Burke J. (**2017a**). Survey of Cotton (*Gossypium* sp.) for non-polar, extractable hydrocarbons for use as petrochemical feedstocks. *Phytologia* 99 (1): 54-61.

Adams R.P., TeBeest A.K., Ulloa M., Witt T., Burke J., Frelichowski J. and Hinze L.L. (2017b). Comparison of hydrocarbon yields in cotton from field grown vs. greenhouse grown plants. *Phytologia* 99 (3): 200-207.

Adams R.P., Ulloa M., Witt T. and Burke J. (2018). Comparison of hydrocarbon yields in four cotton accessions: regular vs. limited (induced dryland) irrigation. *Phytologia* 100 (1): 6-11.

Andres R.J., Bowman D.T., Jones D.C. and Kuraparthy V. (**2016**). Major leaf shapes of cotton: genetics and agronomic effects in crop production. *Journal of Cotton Science* 20: 330-340.

Andrews F.W. (1952). *The Flowering Plants of the Anglo-Egyptian Sudan, Vol. 2. Sterculiaceae-Dipsacaceae.* T. Buncle & Co. Ltd., Arbroath, Scotland, pp. 17-18.

ASTM (2012). Standard test method for breaking strength and elongation of cotton fibers (flat bundle method). American Society for Testing and Materials. D-1445/D-1445M. Available from: http:// www.ASTM.org (accessed: 18.3.2021).

ASTM (2016). Standard test method for breaking strength of yarn in skein form. American Society for Testing and Materials. D-1578-93. Available from: http:// www.ASTM.org (accessed: 18.3.2021).

Bardak A. and Bolek Y. (2016). Inheritance of fuzz and lint fiber initiation of cotton (*Gossypium hirsutum* L.). *Turkish Journal of Agriculture and Forestry* 40: 606-612.

Dallwitz M.J. (1993 onwards). Applications and documentation of the DELTA system. Available from: http://delta-intkey.com (accessed: 15.9.2021).

Dallwitz M.J. (2010). Overview of the DELTA system. Available from: http://delta-intkey.com/www/overview.htm (accessed: 15.9.2021).

Dallwitz M.J. and Paine T.A. (2005). Definition of the DELTA format. Available from: http://delta-intkey.com/standard.htm (accessed: 15.9.2021).

Dallwitz M.J., Paine T.A. and Zurcher E.J. (1993 onwards). User's guide to the DELTA system: a general system for processing taxonomic descriptions, 4th edition. Available from: http://delta-intkey.com (accessed: 15.9.2021).

Dao-fang H., Xiang Z., Cheng-zhen L., Tao Z., Abid, M.A., Yong-ping C., Jin-ling H. and Rui Z. (2018). Genetic variation in *LBL1* contributes to depth of leaf blades lobes between cotton subspecies, *Gossypium barbadense* and *Gossypium hirsutum*. *Journal of Integrative Agriculture* 17 (11): 2394-2404.

Erpelding J.E. (2017). Inheritance of the ovule fuzzless trait for *Gossypium arboretum* germplasm line PI 529708. *International Journal of Plant Breeding and Genetics*11: 25-30.

Fryxell P.A. (1976). A nomenclator of *Gossypium*. The botanical names of cotton. *Technical Bulletin of the USDA* 1491: 73.

Fryxell P.A. (1992). A revised taxonomic interpretation of *Gossypium* L. (Malvaceae). *Rheedea* 2: 108-165.

Fryxell P.A. (1994). Malvaceae. *Journal of the Arizona-Nevada Academy of Sciences* 27(2): 222-236.

Fryxell P.A. and Hill S.R. (2015). 24. *Gossypium* Linnaeus. *Flora of North America, Vol. 6 Magnoliophyta: Cucurbitaceae-Droseraceae*. Oxford University Press, New York, USA, 468 pp.

ITIS report (2020). Integrated Taxonomic Information System Report: Gossypium thurberi Todaro, Taxonomic serial number 502819. Last modified 17th January, 2020. - https://www.itis.gov/servlet/SingleRpt/SingleRpt?search_topic=TSN&search_value=502819#null (accessed 26.2.2021).

Janga M.R., Pandeya D., Campbell L.M., Konganti K., Villafuerte S.T., Pukhaber L., Pepper A., Stipanovic R.D., Scheffler J.A. and Pathorse K.S. (2019). Genes regulating gland development in the cotton plant. *Plant Biotechnology Journal* 17(6): 1142-1153.

Kalivas K., Xanthopoulos F., Kehagia O. and Tsaftaris A.S. (2011). Agronomic characterization, genetic diversity and association analysis of cotton cultivars using simple sequence repeat molecular markers. *Genetic and Molecular Research* 10 (1): 208-217.

Lang A.G. (1938). The origin of lint and fuzz hairs of cotton. *Journal of Agricultural Research* 56 (7): 507-521.

Lord E. (1961). *Manual of Cotton Spinning, Vol. 2, Part 1*. Butterworth & Co. Ltd., New York.

Mandaville, J.P. (1977). Systematic list of plant species. In: Shaw Reade S.N., Sale J.B., Gallagher M.D. & Daly R.H. (Eds.). *The Scientific Results of the Oman Flora and Fauna Survey 1975 (Dhofar)*. A Journal of Oman Studies, Special Report No. 2. Ministry of Information and Culture, Sultanate of Oman, pp. 79-86.

Miller A.G. and Morris M. (1988). *The Plants of Dhofar (The southern region of Oman; traditional, economic and medicinal uses)*. The Office of the Advisor for Conservation of the Environment, Sultanate of Oman, 361 pp.

Tripathy K.K., Warrier R., Ahuja V. and Govila O.P. (2011). *Biology of Gossypium spp. (cotton). Series of Crop Specific Biology Documents*. Ministry of Environment and Forests and Ministry of Science and Technology, Government of India, 41 pp.

Verdcourt B. and Mwachala G.M. (2009). Malvaceae. In: Beentje H.J. and Ghazanfar S.A. (Eds.) *Flora of Tropical East Africa*. Royal Botanic Gardens, Kew, UK, 175 pp.

Webber I.E. (1938). Anatomy of the leaf and stem of *Gossypium*. *Journal of Agricultural Research* 57(4): 269-286.

World Flora online (2023). *Gossypium thurberi* Tod. Available from: www.worldfloraonline.org/taxon/wfo-0000708114 (accessed: 22.4.2023).

Zhang Y.X., Lin Z.X., Li W., Tu L.L., Chun N.Y. and Long Z.X. (2007). Studies of new EST-SSRs derived from *Gossypium barbadense*. *Chinese Science Bulletin* 52: 2522-2531.