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Cotton Germplasm Collection of Uzbekistan

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ABSTRACT

Cultivated cotton (*Gossypium* spp.) is the main source of natural fiber and oilseed as well as one of the most important crops for bioenergy production. Although cotton is native to the tropics and subtropics, it is naturally cultivated in more than 80 countries. The Uzbekistan cotton germplasm collection is one of the largest among worldwide collections, representing accessions and species not only with wide geographic and ecological niches but also with large amplitude of morphobiological and genetic diversity. More than 40 A- to G and K-genomes of wild *Gossypium* species as well as ~7,500 cotton accessions are preserved in the Institute of Genetics and Plant Experimental Biology at the Academy of Sciences of Uzbekistan (IGPEB). There are a number of lines and cultivars with useful agronomic traits (early maturing, long fiber, high yield, disease tolerant, etc.) that have been developed using Uzbek cotton germplasm resources. A history of the collection development, maintenance, management and problems of *ex situ* conservation as well as utilization of germplasm resources are reviewed in this paper.

Keywords: breeding, cotton germplasm, cultivar, *G. barbadense*, *G. hirsutum*, *Gossypium* L., Pima, Upland, variety

Abbreviations: ELS, Extra Long Staple cotton; **HVI**, High Volume Instrumentation; **IGPEB**, Institute of Genetics and Plant Experimental Biology; **IPGRI**, International Plant Genetic Resources Institute, **MIC**, Micronaire; **UHML**, Upper Half Mean Length; **USDA-ARS**, United States Department of Agriculture – Agricultural Research Service. Letter in the some cultivar names denotes: **AN**, Academy of Sciences; **C**, Cotton Breeding Institute; **F**, Fergana experimental station; **I**, Iolatan experimental station. Fiber type describes the textile property of the cotton fiber and designated with 1, 2, 3, 4, 5, 6, 7. Fiber types 1-3 are considered the finest cotton fiber while types 4 and 5 are middle quality fibers. Fiber types 6 and 7 are considered not useful in textile industry.

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INTRODUCTION

The cultivated *Gossypium* spp. (cotton) represents the single most important, natural fiber crop in the world. The value of cotton during 2005-2007 ranged from US $27–29 billion worldwide (National Cotton Council; Campbell *et al.* 2010). This average world-wide value of cotton was equivalent to ~20% of the total 2007 gross domestic product of the Philippines (US $144 billion, World Bank, Campbell *et al.* 2010).

In Uzbekistan, cotton is one of the main economic resource. It produces annually 3.5 to 4 million tons of raw cotton fiber and exports cotton fiber valued at ~$0.9 to 1.2 billion. According to the World Bank, from 2005-2007, an average of 5.5 million bales were produced on a yearly basis. The Uzbek cotton crop is produced primarily for the export market and represented 22% of all Uzbek exports from 2001-2003. In addition to its lint, the oil and protein portion of the cottonseed also represents significant economic value where cottonseed oil and protein are used in a variety of ways, including animal feed and industrial lubricants (Abdurakhmonov 2007; Campbell *et al.* 2010).

The genus *Gossypium* includes approximately 46 diploid and 5 allotetraploid species (Percival *et al.* 1999) that are largely spread in tropical and subtropical regions of the world. Diploid cottons, referred as Old World cottons, are classified into eight (A-G to K) cytogenetically defined genome groups that have African/Asian, American, and Australian origin (Endrizzi *et al.* 1985). Two of these Old World cottons from Asian origin, *Gossypium arboreum* and

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Invited Review

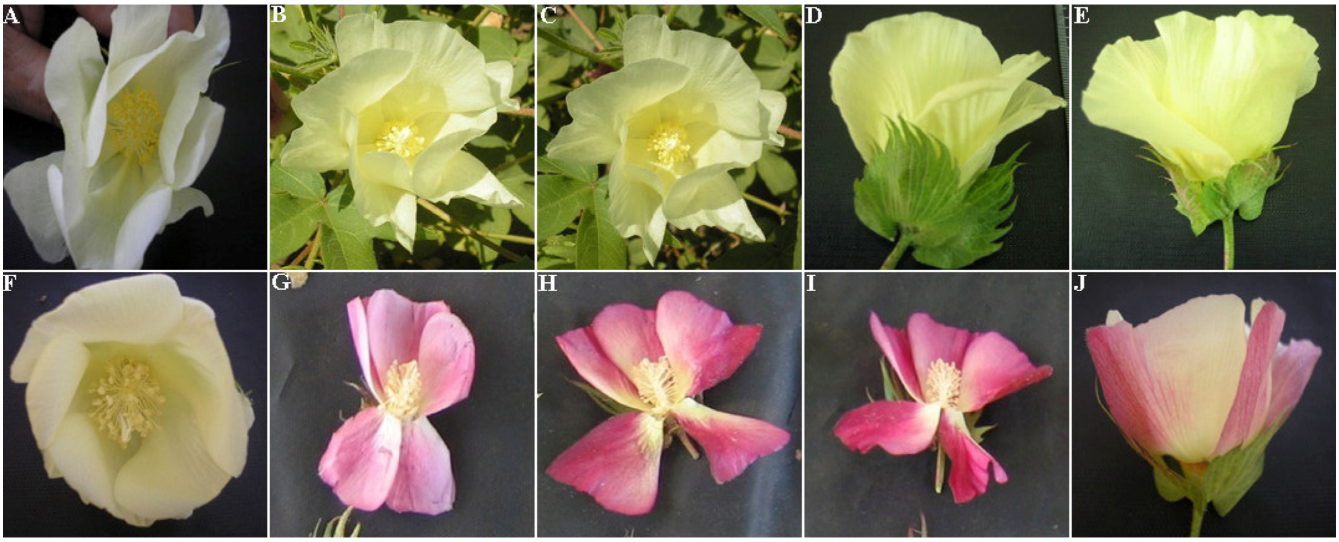

Fig. 1 Diversity on flower color observed in *G. hirsutum* germplasm. (**A**) White-yellow; (**B, C**) light yellow; (**D, E**) yellow; (**F**) cream color; (**G**) lavender; (**H, I**) pink; (**J**) bicolor. Source: Abdurakhmonov (2007).

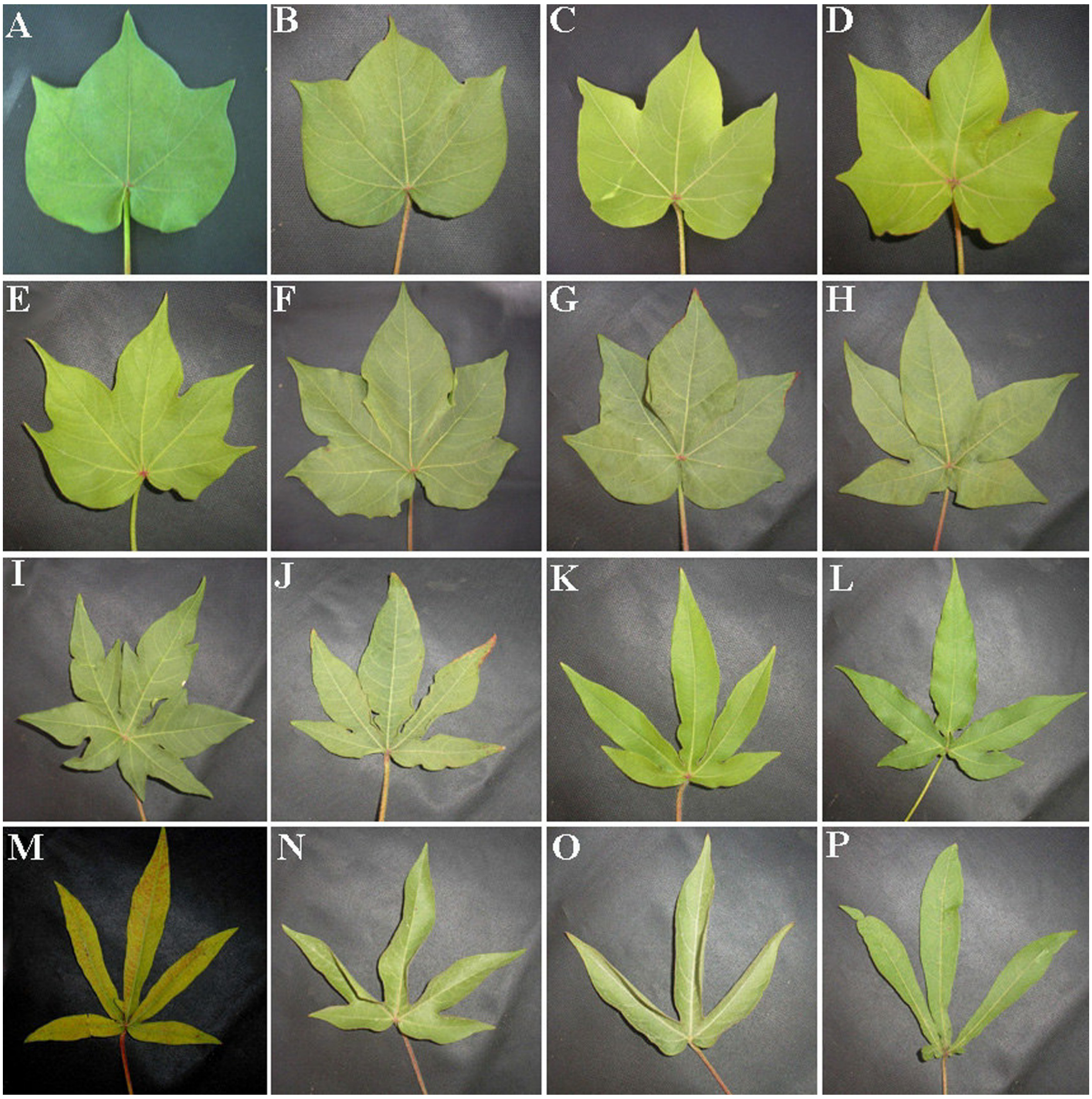

Fig. 2 Diversity on leaf plate shape observed in *G. hirsutum* germplasm. (**A-C**) variations of 3-lobbed leaf plates; (**D**) 5-lobbed leaf plate; (**E-H**) variations of palmate type leaves; (**I-L**) variations of semi-digitate and digitate type leaves; (**M-P**) variations of okra and super okra type leaves (**P**). Source: Abdurakhmonov (2007).

G. herbaceum, with a spinnable seed fiber, were originally cultivated in Asian continent. Hybridization between A-genome (Asian cottons) and D-genome (American cottons) diploids and subsequent polyploidization about 1.5 million years ago created the five AD allotetraploid lineages that are indigenous to America and Hawaii (Phillips 1963; Wendel and Albert 1992; Adams *et al.* 2004). These New World allotetraploid cottons include the commercially important species, *G. hirsutum* and *G. barbadense*, which are widely cultivated worldwide (Abdurakhmonov 2007; Campbell *et al.* 2010).

G. hirsutum (referred to as also Acala, Moco, Cambodia, or Upland cotton) is the most widely cultivated (90%) and industrial cotton among all *Gossypium* species (Abdurakhmonov *et al.* 2012). *G. hirsutum* is spread throughout Central America and Caribbean. According to archaeobotanical findings, *G. hirsutum* probably was domesticated originally within the Southern end of Mesoamerican gene pool (Wendel 1995; Brubaker *et al.* 1999). Two centers of genetic diversity exist within *G. hirsutum*: Southern Mexico-Guatemala and Caribbean (Brubaker *et al.* 1999); Mexico-Guatemala gene pool is considered site of original domestication and primary center of diversity. *G. hirsutum* exhibits diverse types of morphological forms, including wild, primitive to domesticated accessions and a number of wild landraces such as *yucatanense*, *richmondi*, *punctatum*, *latifolium*, *palmeri*, *morilli*, *purpurascens* and their accessions as well as a number of domesticated variety accessions from 80 different cotton growing countries worldwide (Abdurakhmonov 2007; Abdurakhmonov *et al.* 2012).

The wide distribution as well as the greatest genetic diversity of *G. barbadense* included mostly West of Andes, South America, southern Mesoamerica and the Caribbean basin (Fryxell 1979; Percy and Wendel 1990). *G. barbadense*, accounting for about 9% of world cotton production, was originally cultivated in coastal islands and lowland of the USA that became known as Sea Island cotton. Sea Island cottons, then, were introduced into Nile Valley of Egypt and widely grown as Egyptian cotton to produce long staple fine fibers (Abdalla *et al.* 2001). The other three AD tetraploid species of cotton, *G. mustelinum* with specific distribution in the Northeast Brazil (Wendel *et al.* 1994), *G. darwinii* endemic to Galapagos Islands (Wendel and Percy 1990), and *G. tomentosum* Nutall *ex* Seemann endemic to Hawaiian Islands (DeJoode and Wendel 1992; Hawkins *et al.* 2005), are truly wild species (Westengen *et al.* 2005).

Thus, the *Gossypium* genus, encompassing wide geographic and ecological niches, has a large amplitude of morphobiological and genetic diversity (e.g. **Figs. 1, 2**) that conserved *in situ* at centers for cotton origin (Ulloa *et al.* 2006) and preserved *ex situ* within worldwide cotton germplasm collections and materials of breeding programs. These resources are very important for breeding of superior fiber quality, resistance to insects and pathogens and tolerance to abiotic stresses (Abdurakhmonov 2007; Abdurakhmonov *et al.* 2012).

WORLDWIDE COTTON GERMPLASM COLLECTIONS

There are the main cotton germplasm collections preserved *ex situ* in the US, France, China, India, Russia, Uzbekistan, Brazil, and Australia. Representing the major cotton germplasm resources, these eight countries have a germplasm storage and conservation program in place (Abdurakhmonov 2007; Campbell *et al.* 2010; Abdurakhmonov *et al.* 2012).

World cotton germplasm collections were highlighted in several documents by Abdurakhmonov (2007), Chen *et al.* (2007), Stelly *et al.* (2007), Ibragimov *et al.* (2008), Campbell *et al.* (2010), and Abdurakhmonov *et al.* (2012). The contents and distribution of cotton germplasm accessions across the eight collections is well described and covered by Campbell *et al.* (2010), where one should easily note that Uzbekistan cotton germplasm is one of the largest among other collections worldwide. Therefore, here, we briefly revisited the description of our cotton germplasm collection in Uzbekistan, providing additional information on a history of the development of Uzbek Upland and Pima cotton cultivars.

UZBEKISTAN COTTON COLLECTION HISTORY

Uzbek scientists Drs. F. M. Mauer and A. Abdullaev stated the idea of utilization of wild cotton species as a source of valuable biologic and agronomic traits more than 60 years ago. This persuaded Uzbekistan scientists for detail study of worldwide cotton biodiversity with creation of enriched germplasm collections, which became possible after introduction of wild cottons to Uzbekistan and development of *ex situ* and *in situ* collections. In 1920-1930, Drs. N. I. Vavilov and F. M. Mauer represented pioneer efforts to initiate the development of cotton collection in the Former Soviet Union (FSU), and Dr. A. Abdullaev's group at the Academy of Sciences of Uzbekistan continued this endeavor. Collection of cotton plant materials performed in two directions. The first direction was a continuous selection of cultivated cotton varieties. The second direction was the collection of wild cotton species and wild/exotic relatives of cultivated cottons from the centers of origin. There were several expeditions to the centers of origin initiated by Dr. N. I. Vavilov, P. M. Jukovsky, Dr. F. M. Mauer (1920-1930s) and Dr. D. V. Ter-Avanesyan (1950s) to Central Asia, Afghanistan, China, India, Turkey, Iran, Korea and Japan followed by Dr. A. Abdullaev (1974, 1984, 1988-89 and 1997-98) to Mexico, Peru, China, India and Sri-Lanka, Australia and Pakistan.

These scientific expeditions to Asian counties enriched Uzbekistan collection with Old World (Afro-Asian and Indian) diploid cottons (*G. herbaceum* and *G. arboreum*), whereas expeditions to Mexico and Peru resulted in enrichment of the collection with a number of wild, exotic and cultivated tetraploid and diploid cottons. For example, Dr. A. Abdullaev collected in Peru 23 unique samples of *G. barbadense* mostly arborescent, and perennial cottons; 115 wild varieties and 200 samples of cultivated and primitive Upland cottons (*G. hirsutum*) as well as most of the wild D-genome diploid species (11 out of 13) from Mexican states (including islands). Since 2000s there has not been an additional expedition due to lack of financial support; however, the Uzbek cotton germplasm collection have been enriched by collaborative efforts of germplasm exchange worldwide. Expeditions and germplasm exchange with other collections facilitated the enrichment of the IGPEB cotton germplasm collection with a wide geographic coverage represented by 4 continents, ~33 geographic regions, and ~103 countries (**Tables 1, 2; Fig. 3**).

GERMPLASM CONTENT

In total, as reported by Campbell *et al.* (2010), there are over 20,000 cotton germplasm accessions available in Uzbekistan including isogenic, inbred lines, recombinant inbred lines (RIL), elite AD allotetraploid varieties (*G. hirsutum* and *G. barbadense*), monosomic and translocation lines (Abdukarimov *et al.* 2003) along with wild, primitive and extant representatives of the A- to G and K-genome species. The majority of *G. hirsutum* wild and cultivar accessions (~12,000) are preserved at the Cotton Breeding Institute of the Ministry of Agriculture and Water Resources of Uzbekistan (Ibragimov *et al.* 2008).

Approximately 7,500 cotton accessions are preserved within the IGPEB cotton germplasm collection that represent more than 40 A- to G and K-genome wild *Gossypium* species (also vegetatively maintained at the germplasm Unit greenhouse). These accessions consist of ~4,500 *G. hirsutum* accessions, 971 *G. barbadense* accessions, 857 *G. herbaceum* and 547 *G. arboreum* accessions (Abdurakhmonov 2007), 200 photoperiod-converted mutants of photoperiodic allotetraploid species (Djaniqulov 2002; Abdurakhmonov *et al.* 2007), and a number of intra- and interspecific hybrids (Rizaeva 1996; Abdurakhmonov 2007).

Additionally, approximately 771 genetic stocks of *G. hirsutum* consisting of fiber mutants, RIL populations, near isogenic lines (NILs), and cytogenetic stocks are maintained at the National University of Uzbekistan at Tashkent

(Musaev *et al.* 2000; Sanamyan and Rakhmatulina 2003; Abdurakhmonov 2007). The Upland (*G. hirsutum* L.) and Pima (*G. barbadense* L.) germplasm groups represent the majority of the preserved accessions in the Uzbek cotton germplasm collection and have not been yet described in detail in any of germplasm review papers referenced herein. We highlight the brief history and development of Uzbek Upland and Pima cultivars in below sections.

UZBEK *G. HIRSUTUM* GERMPLASM

In the Old Word, domestication and cultivation of cotton occurred in parallel, but independently from the New World. There are historical evidences of cotton cultivation on the territory of Central Asia (Turkestan) since VI-V centuries B.C. Environmental conditions and soil composition in Central Asia and Azerbaijan are favorable for cotton plants. The main cotton species cultivated in Central Asia, so called "Asian guza" (*G. herbaceum* spp. *euherbaceum*), was introduced to this region from Africa through Iran (Ter-Avanesyan 1973). In XVI-XVII century, in Central Asia, cotton was grown on small areas and exported to Russia. After introduction and adaptation to environmental conditions these cultivated diploid cottons in Central Asia formed diverse forms. Some of them, for example, "guza" from Khiva had fine and silky fibers compared to the one from Tashkent. Nevertheless, all types of "guza" had short fiber (17-25 mm), very low-yield and small bolls which did

Table 1 Geographic composition of Uzbek cotton germplasm collection maintained in IGPEB.

Continent	Number	Region	Number	Country	Number
Australia	127	Australia	127	New South Wales	5
				Unknown	122
Asia	2577	Middle East	25	Palestine	1
				Syria	24
		Eastern Asia	180	Western China	10
				China	137
				Korean peninsula	10
				Japan	23
		Transcaucasia	134	Azerbaijan	118
				Armenia	9
				Georgia	7
		Western Asia	103	Iran	64
				Turkey	39
		Northern Asia	2	Russia	2
		Central Asia	1677	Kazakhstan	8
				Kirgizstan	17
				Tajikistan	39
				Turkmenistan	225
				Uzbekistan	1368
				Unknown	20
		Southeast Asia	12	Burma	6
				Vietnam	2
				Sumatra	2
				Thailand	1
				Philippines	1
		Southwest Asia	96	Afghanistan	71
				Yemen	5
				Iraq	20
		South Asia	348	Bangladesh	1
				India	221
				Pakistan	126
America	2183	South America	1972	Mexico	393
				USA	1579
		Pacific archipelago	1	Galapagos islands	1
		Central America	2	Guatemala	1
				Costa Rica	1
		South America	185	Argentine	48
				Bolivia	7
				Brazil	25
				Venezuela	1
				Columbia	6
				Patagonia	2
				Peru	52
				Chile	1
				Ecuador	41
				unknown	2
		unknown	23	unknown	23
Africa	470	Eastern Africa	74	Madagascar	6
				Tanzania	35
				Uganda	32
				unknown	1
		Western Africa	50	Burkina Faso	2
				Cameroon	4
				Cote d'Ivore	1
				Mali	8
				Nigeria	12
				Senegal	21
				Sierra Leone	1
				unknown	1
		Northern Africa	43	Algeria	41
				Sahara	2
		Southwest Africa	63	Morocco	63

Table 1 (Cont.)

Continent	Number	Region	Number	Country	Number
Africa		Southeast Africa	162	Egypt	116
				Somali	3
				Sudan	34
				Eritrea	2
				Ethiopia	7
		Central Africa	30	Burundi	3
				Guinea	8
				Congo	3
				Panama	1
				Chad	3
				Tanganyika	7
				France Equatorial Africa	5
		Southeast Africa	1	unknown	1
		South Africa	31	Swaziland	1
				Zambia	4
				Zimbabwe	2
				SAR	20
				Unknown	4
		unknown	16	unknown	16
West-India	24	West India	24	Antilles	1
				Small Antilles	1
				Cuba	9
				Trinidad and Tobago	8
				unknown	5
Malay Archipelago	3	Malay Archipelago	3	Java	2
				Central Java	1
Europe	304	Eastern Europe	147	Latvia	1
				Northern Caucasia	2
				Ukraine	58
				Czech Republic	74
				Yugoslavia	12
		Western Europe	19	Great Britain	1
				Germany	4
				Netherlands	3
				France	11
		Northwest Europe	1	Denmark	1
		Central Europe	13	Austria	1
				Hungary	12
		Southwest Europe	7	Portugal	4
				Spain	3
		Southeast Europe	104	Albania	1
				Bulgaria	80
				Bosnia	1
				Greece	11
				Macedonia	1
				Portugal	4
				Romania	6
				Serbia-Montenegro	2
				Cyprus	2
		South Europe	3	Italy	3
		North Caucasia	9	Dagestan	9
		Middle East	1	Malta	1
Unknown	391	unknown	391	unknown	387

Table 2 Composition of Uzbek cotton germplasm by continent.*

Continent	Amount
Australia	127
Asia	2577
America	2183
Africa	470
West-India	24
Europe	304
Malay Archipelago	3
unknown	391

Data was obtained from Cotton Germplasm Unit (IGPEB) catalogue.

not fully open.

After merging of Central Asia with Russia, the areas occupied by cotton significantly were increased; however, the low-yield varieties of *G. herbaceum* did not satisfy not only merchants but also farmers. Therefore, local authorities in 1870-1880s, widely initiated a program for introduction of American Upland cottons to Central Asia. The first experiments and evaluations of Upland cotton in Turkestan started by A. I. Wilkins in 1884. Later, he published a guide on cultivation and successful distribution of Upland cottons in Turkestan (Wilkins 1899). A successful increasing of cotton growing area in Central Asia was stimulated by following factors: 1) a high price on American Upland cotton fiber; 2) the development of railways from the Russian cities to the Turkestan cities; 3) import of ginning and cotton fiber processing instruments that facilitated the preparation of cotton fiber for the export; 4) the development of state regulations to restrict import of cotton fiber from America to Russia. This resulted in development of new local cotton cultivars. Because of random distribution and mixing of seeds from different cultivar populations (‘King’,

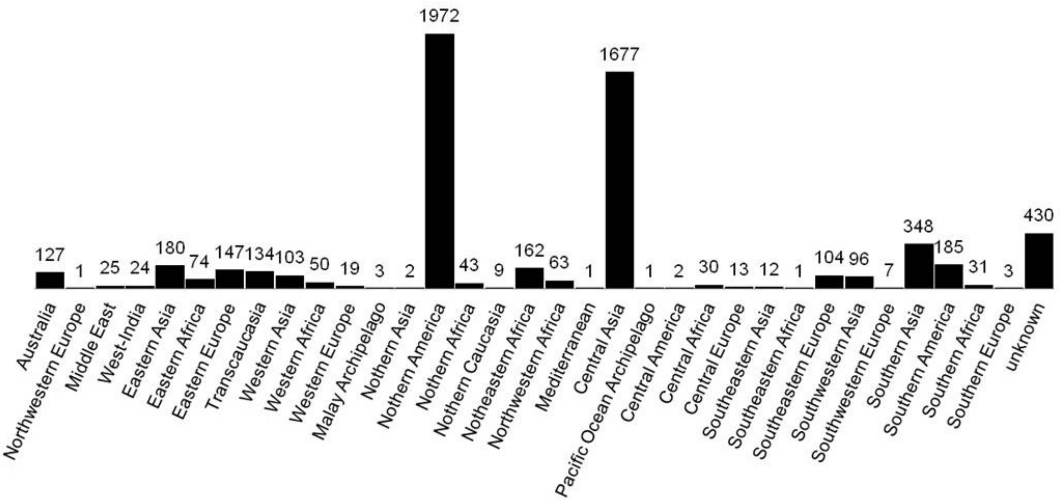

Fig. 3 Content of Uzbek cotton germplasm by place of origin. Source: from the Uzbek Cotton Germplasm catalogue.

Table 3 The most popular varieties of *G. hirsutum* germplasm developed in Uzbekistan.*

Varieties group	Year of cultivation	Cultivar name
Old-time	1913-1940s	Navrotskiy, Triumph of Navrotskiy, Pakhtakor-36-M-2, Bolshevik-2034, Kolhoznik-8517, Batir 508, C-450, C-460, Shreder-1306, Dekhkan-169, Ak-Djura-182
New	1940-1970s	108-F, 137-F, 138-F, 144-F, 148-F, 149-F, 149-F, C-450-555, C-1472, C1581, C-1470, C4727
Present-time	1970s-present	AN-Bayaut-2, C-6524, C6532, Namangan-77, 175-F, Sharaf-75, Khorazm-126, Tashkent-1, Tashkent-6, Bukhara-6, Omad, Bukhara-102, Andijan-35, Okdaryo-6, Yulduz, Fergana-3
Prospective	2000s-present	C-6541, Chimbay-5018, UzFA-703, Andijan-36, Andijan-37, Namangan-34, Kelajak, AN-419

*Data was obtained from Cotton Germplasm Unit (IGPEB) catalogue

'Triumph', 'Russell's' and others) in different regions of Central Asia, newly developed local cultivar populations of Upland cotton were called as "factory mixtures" (type *euhirsutum*). The most popular factory mixtures were: 'Merv', 'Bayram-Ali', 'Chardjou', 'Bukhara', 'Fergana', 'Tashkent', 'Samarkand', 'Khiva', 'Turkestan', 'Chimkent', 'Chimbay', 'Mugan', 'Shirvan', 'Gyandji', 'Armenian-Nakhichevan'.

In different regions, diverse "mixtures" were formed; for example, in Southern Turkestan (Turkmenistan and Bukhara), a highly productive, but late-maturing "factory mixtures" were formed, whereas in Northern Turkestan (Chimkent, Turkestan and Chimbay), there were early-maturing, but low fiber yield "mixtures". This cultivars or "mixtures" also differed by fiber length (25-30 mm), fiber yield (28-31%), Micronaire, fiber strength and other traits, depending on the origin of "mixture".

The replacement of "Asian guza" by American Upland cottons was sporadic and very slow; for example, *G. herbaceum* varieties cultivated in Bukhara, Khiva, Armenia and Azerbaijan until 1928. The real breeding experiments with Upland cottons were started in 1908-1913. At that period, a number of experimental stations were founded in Tashkent, Andijan, Fergana and Samarkand region. The cultivars developed at these stations started to be widely cultivated. At the first steps of breeding process, 'old-time' varieties were developed by simple analytical selection (selection of the best individual plant). The most popular old-time cultivars were: 'Navrotskiy' (fiber yield 33-35%, fiber length 27-28 mm), 'Triumph of Navrotskiy', 'Ak-Jura-182' and 'Dehkhan-169', etc. (**Table 3**). Since that time, "factory mixes" started to be replaced by newly developed cultivars and finally eliminated from cultivation in 1933. More productive varieties such as '36-M-2' ('Pakhtakor'), '2034' ('Bolshevik'), '8517' ('Kolhoznik'), '508' ('Batir'), 'C-450', 'C-460', '1306' ('Shreder'), 'Dekhkan-169', 'Ak-Djura-182' were released in 1937. At that time, all these varieties were grown on 1 million hectare area. The main cultivar was 'Shreder' (736.000 ha), which exceeded 'Navrotskiy' by more than 15% on raw cotton yield, lint percentage (37-35%) and fiber length (31-32 mm).

In the territory of former Soviet Union, the Upland cottons formed 3 groups depending on their environmental and geographic distribution: Central Asian, Trans-Caucasian and Caucasia-Ukrainian. The Central Asian group divided into 3 subgroups: Southern, Middle and Northern (**Table 4**). The Southern subgroup represented by late and moderate maturity (130-160 days), *Verticillium* wilt and heat resistance cultivars with large cotton bolls (7-10 g), which required high temperatures and short day-light (13-14.5 h). The most popular old-time cultivars of the Southern subgroup were 'Navrotskiy' developed from population of 'Russels' cultivar in 1913 and 'Triumph of Navrotskiy' developed from 'Triumph' cultivar in 1915. One of the successful and widely cultivated modern cultivars of Southern subgroup was '108-F'. It is important to note that most of cultivars at that time were developed using some imported American varieties such as: 'Russels', 'Triumph', 'King', 'Acala 0278', 'Kook', 'Delphos', 'Lone Star', etc. Each subgroup was divided to several regions according to environmental conditions and soil composition. Thus, only specific cotton cultivars suitable to defined environmental conditions were developed and cultivated in each region. Middle subgroup represented by moderately early-maturing (120-140 days) cultivars, slightly heat resistant and less susceptible to day-light (13.5-15 h) with middle and large cotton bolls. Old-time varieties of this subgroup were susceptible to *Verticillium* wilt. Northern subgroup represents early-maturing (110-130), heat susceptible and long day-light (14-15.5 h) varieties. More detail description of cotton varieties of each subgroup summarized in **Table 4**.

Cultivar '108-F', developed by L. Rumshevich in 1940, was among varieties cultivated during the 1950-1960s in Uzbekistan. In 1960, '108-F' was widely cultivated not only in Uzbekistan (on ~74% of cotton growing area) but also in Tajikistan, Kirgizstan, Turkmenistan, Kazakhstan and Azerbaijan (Galicinsky *et al.* 1962). Vegetation period of '108-F' varied from 130-140 to 155-165 days depending on cultivation area (Southern and Northern part of Uzbekistan, respectively). An average fiber yield was 34.4-38.5%, raw cotton weight was 7 g, cotton yield was 3.72 metric tons per hectare. The '108-F' was cultivated by some farmers until

Table 4 Geographic groups of *G. hirsutum* variety germplasm.*

Group (geographic/environmental)	Subgroup	Common characters
Central-Asian	Southern	Late to moderate maturing (130-160 days) Verticillium wilt resistance - high Short day-light (13-14.5 h) Weight of 1000 seeds – 130-150 g Raw cotton weight 7- ≥10 g Plant height 90-120 cm HS 5-8 Fiber length 27-35 mm Fiber yield 31-38%
	Middle	Moderate maturing (120-140 days) Verticillium wilt resistance - moderate to high Day light 14-15 h Weight of 1000 seeds – 110-130 g Raw cotton weight 5-6 g Plant height 80-110 cm HS 4-6 Fiber length 25-34 mm Fiber yield 32-39%
	Northern	Early maturing (110-130) Verticillium wilt resistance - low to high Long day light – 14-15.5 h Weight of 1000 seeds – 90-110 g Raw cotton weight 3.5-≥4.5 g HS 3-5 Plant height 70-100 cm Fiber length 26-32 mm Fiber yield 32.5-37%
Trans-Caucasian	Eastern lowlands	Moderate maturing (130-150 days) Verticillium wilt and/or bacteriosis resistance – moderate to high Day light 13.5-15 h Weight of 1000 seeds 110-130 g Raw cotton weight 5-≥6 g HS 4-6 Plant height 80-110 cm Fiber length 29-32 mm Fiber yield 31-38%
	Western foothills	Early maturing (115-130 days) Verticillium wilt and/or bacteriosis resistance – high Day light 13.5-15 h Weight of 1000 seeds 90-110 g Raw cotton weight 4-≥5 g HS 3-5 Plant height 70-100 cm Fiber length 27-32 mm Fiber yield 34-40%
Caucasia-Ukrainian	North-Caucasian	Early/Moderate maturing (110-137 days) Verticillium wilt and/or bacteriosis resistance – moderate Day light 14-15.5 h Raw cotton weight 3.7-4.6 g Fiber length 27-31 mm Fiber yield 32-33%
	Ukrainian	Early/Moderate maturing (129-138 days) Verticillium wilt resistance – low Bacteriosis resistance – moderate to high Raw cotton weight 3.8-4.5 g Day light 14-16 h Fiber length 27-31 mm Fiber yield 32-34%

*Data was obtained from Cotton Germplasm Unit (IGPEB) catalogue

mid 1990's. In the beginning of 70's '108-F' was substituted by cultivar 'C-4727' that was developed by individual selection among the best progeny of crossings '137-F' (developed from old variety 'Bolshevik 2034') and 'C-1470'.

The 'C-4727' was more productive, early maturing (120-125 days), had high fiber yield (38%), but more susceptible to wilt disease compared to '108-F'. The best overall characteristics of 'C-4727' were demonstrated in Tashkent and Samarkand environments. The spread of wilt disease at many farms in 1960s -1970s forced scientists and breeders to develop wilt resistant cultivars such as 'Tashkent-1' (followed by 'Tashkent-2' and 'Tashkent-3'). The efforts on hybridization of Tashkent varieties and wild germplasm led to release an early-maturing cultivar 'AN-Bayovut-2' in 1983. In turn, the utilization of germplasm resources resulted in development of the newest, most popular, early-maturing, high-yield, and superior fiber quality as well as pests and diseases resistant *G. hirsutum* varieties such as 'Tashkent-6', 'Namangan-77' and 'Okdaryo-6' (early maturing), 'C-6524', 'Bukhara-6', 'Bukhara-102', 'Omad' and 'Andijan-35' (high yield, resistant to pests and diseases, high fiber quality). The most popular old-time, new, present-time and prospective Uzbek cotton varieties are listed in **Table 3**. Fiber quality characteristics of pre-

Table 5 Fiber quality parameters of some modern Uzbek germplasm varieties.*

Uzbek Cotton Fiber Quality								
Varieties	**MIC**	**STAPLE**	**UHML**	**STR**	**UI**	**RD**	**b**	**SFI**
	unit	**mm**	**inch*100**	**g/tex**	**%**	**%**	**%**	**%**
Akdarya-6	4.5	35.9	112.9	30.9	82.9	78.4	9.0	6.6
AN-Bayaut 2	4.6	35.2	110.6	30.3	82.6	78.9	8.7	7.8
Andijan 35	4.5	35.0	110.0	30.9	82.6	77.3	8.8	8.1
Bukhara 102	4.5	35.9	112.6	31.8	82.9	80.1	8.9	4.7
Bukhara 6	4.4	36.0	112.9	32.3	83.0	80.0	9.0	4.7
Bukhara 8	4.5	36.0	113.2	32.2	83.2	79.8	9.0	4.7
C-4727	4.7	34.8	109.4	30.7	82.5	78.8	8.7	3.6
C-6524	4.4	35.7	112.0	32.3	83.1	77.5	8.6	6.3
Denau	4.7	35.0	110.0	30.5	83.3	78.3	9.2	3.9
Ibrat	4.6	35.8	112.3	31.6	82.8	80.8	8.6	4.3
Khorezm-127	4.6	35.7	112.0	31.1	82.8	80.7	8.2	4.5
Mehnat	4.5	35.6	111.7	30.6	82.7	80.7	8.3	4.6
Namangan	4.4	35.2	110.7	30.8	82.9	79.2	8.8	5.0
Omad	4.6	36.1	113.4	31.0	82.8	78.2	9.0	4.9
Termez-31 (*G. barbadense*)	4.3	41.6	123.0	37.7	84.9	71.7	10.4	

*Data was kindly provided by Dr. A. Narimanov, head of the cotton variety testing department, State variety testing committee of Uzbekistan

sently cultivated popular Uzbek varieties are summarized in **Table 5**.

Continuous genetic and breeding experiments with wild and cultivated cotton germplasm led to development of a number of prospective varieties. These prospective cotton varieties have been extensively evaluated in different eco-geographic areas of Uzbekistan. For example, cultivar 'UzFA-703', developed in IGPEB, is salt and drought resistant, early-maturing (112-117 days) and has 34.5-35.5 mm of fiber length, fiber yield up to 39% and cotton yield ~4.3 t/ha. The results of evaluations of the most prospective varieties in comparison with standard cultivars are presented in **Table 6**. In 2010 prospective varieties occupied 9% of total cotton planting area in Uzbekistan (Najimov 2010).

UZBEK *G. BARBADENSE* GERMPLASM

The entire germplasm of cultivated *Gossypium barbadense* presented on the territory of former Soviet Union belongs to two groups – Central Asian (Turan) and Azerbaijanian. These groups formed under historical agroclimate prerequisites. Both groups represent cultivars and lines with wide range of morphobiological and agricultural traits. Most cotton germplasm of Azerbaijanian group is resistant to viruses and bacteriosis, but require high level of humidity, whereas most cotton germplasm of Central Asian group is resistant to high temperature and *Fusarium* wilt (Mauer 1954).

Pima cotton was introduced to Central Asia (Tashkent region and Fergana), Georgia (Kutaisi) and Azerbaijan (Geokchay) in 1860-1870s. For example, in Tashkent region different cultivars of Sea Island cotton (*G. barbadense var. maritima*) were introduced and studied (Ter-Avanesyan 1973). Unfortunately, these attempts were not successful due to lack of information about breeding and agrotechnology requirements for *G. barbadense*; moreover, introduced Pima cultivars were very late-maturing. Therefore, all efforts were directed for further exploitation and improvement of Upland cotton (*G. hirsutum*) as a straightforward and more profitable crop. Since 1905 the studies of Extra Long Staple (ELS) cotton, introduced from Egypt, were continued in Uzbekistan at the experimental stations in Tashkent, Andijan, Namangan and Ashkhabad (Turkmenistan).

Starting from 1910 to 1915, more cultivars of *G. barbadense* cotton were introduced to Central Asia. Among those *G. barbadense* cultivars, the most prospective and early-maturing was 'Ashmouni' (Mauer 1954). Since Egyptian cottons considered as a low-yield crop with small bolls, most breeders and scientists did not pay attention to study Egyptian cotton. During 1926-1930, many studies of Egyptian cottons were started; for this purpose, several experimental stations were founded in Tajikistan and Turkmenistan. At the same time, studies of *G. barbadense* were started at the Central breeding station in Tashkent and Fergana regions of Uzbekistan and at the Azerbaijan Cotton Research Institute (AzNIHI) in Azerbaijan. For investigations and breeding, several Egyptian cultivars ('Ashmouni', 'Sakel' and 'Zagora') were chosen. Breeding were conducted under supervision of famous breeders and agronomists such as A. I. Avtonomov, M. Kajakin, V. Krasichkov, P. Artemov, etc. Gradually, Egyptian cultivars introduced were replaced by more prospective Egyptian-American cultivars such as 'Maarad' and 'Pima' because of their high-yield performance.

Unfortunately, Egyptian-American cotton cultivars still were not early maturing enough to fit agronomic climate conditions of Uzbekistan (Avtonomov 1948). Since Uzbekistan located on the Northern border of "cotton belt" *G. barbadense* cultivars required more effective temperature conditions (Avtonomov 1936; 1948; 1956, 1973; Kimsanbaev 1998; Avtonomov *et al.* 2009). Consequently, in Central Asia, a breeding of *G. barbadense* is restricted by earliness. Therefore, breeding process in Central Asian region aimed to develop early-maturing and highly productive varieties of *G. barbadense*.

In the beginning of 1950, in Central Asia, several *G. barbadense* cultivars ('2-I-3', '35-1', '35-2', '2365', '2966', '504-B', '5476-I', '5904' and others) were developed, comprising improved traits such as earliness, fiber yield and quality compared to initially introduced Egyptian cottons (Mauer 1954). From 1927 to 1948, in Azerbaijan, cultivar 'Fuadi' was developed using wide individual selection approach from an Egyptian cultivar germplasm. Later, 'Fuadi-Improved' cultivar was developed with improved valuable agronomic traits and fitted to local environmental conditions compared to the original 'Fuadi' variety. In 1935, in Azerbaijan, by the same approach from original 'Giza-7', cultivar '2966-1' was developed, which had increased tolerance to viral and bacterial infections.

Almost at the same period (1933-1936), at the Central breeding station (Tashkent) Dr. A. Avtonomov developed '35-1' and '35-2' cultivars using individual selection from population of Ashmouni (Avtonomov 1948, 1960). Cultivars developed by A. Avtonomov were resistant to *Fusarium* wilt. In 1943, at the Iolatan experimental station (Tajikistan), cultivar '2365' was developed by crossing '35-2' and 'Sea Island-1' cultivars. Breeding efforts at that Iolatan with hybrid material of Egyptian and local varieties resulted in development of a cultivar '5904-И'. The cultivar '5904-И' was widely cultivated in Turkmenistan during 50's and from 1961, it was cultivated in Uzbekistan. At that time, A. Avtonomov also developed high-yield varieties of *G. barbadense* such as '2836', '2850', '6002' and '6022' in Uzbekistan (Ibragimov *et al.* 2008). It is important to note that an initial plant material for development of Uzbek ELS cotton cultivars was Egyptian and Egypt-American varieties ('Ashmouni', 'Giza', 'Fuadi', 'Sakel', 'Maarad' and 'Pima'). These varieties were subjected to crossings and/or individual selection with further selection of plants suitable for local agricultural and environmental conditions.

Uzbek scientists strongly recommended the utilization of wild forms of *G. barbadense* ssp. *peruvianum* from germplasm collection for development of novel ELS cotton varieties because wild forms were thought to be responsible for *Fusarium* wilt resistance, superior fiber yield and quality (Avtonomov 1948, 1973; Abdullaev 1964, 1974). In the 1970-1980s, new program was initiated on genetic improvement of ELS cotton cultivars. During this period, a number of *G. barbadense* cultivars ('C-6029', 'C-6030', 'C-6037', 'C-6040', 'Termez-14', 'Termez-16' and 'Termez-31') were developed. For example, cultivar 'Termez-14' is early maturing cultivar (124-127 days) with high yield (up to 5 t/ha). In 1987, ELS cotton in Uzbekistan cultivated on >200 thousand hectares and yielded a crop for 600 thousand metric tons. At that period, Uzbekistan was on the second place worldwide on Pima cotton production. After independence of Uzbekistan (1991), a number of new *G. barbadense* cultivars were developed such as 'Surkhan-9', 'Surk-

Table 6 Evaluations of prospective varieties germplasm in different environmental conditions of Uzbekistan.*

	Region/Control variety	Year of evaluation	Cotton yield (centner**/ha)		Vegetation time	Boll weight (g)	Verticillium wilt resistance (% of diseased plants)	Fiber yield (%)
			Raw cotton	Fiber				
#	1	2	3	4	5	6	7	8
Andijan-37								
1	Andijon/C-6524	2006-2010	36.4	13.5	122	5.7	8.0	37.2
			-1.0	0.5	3	0.0	-0.3	2.2
2	Andijon/Andijan-36	2006-2010	39.6	14.8	128	5.6	0.0	37.3
			0.4	0.5	0	-0.1	0.0	0.9
3	Fergana/C-6524	2008-2010	29.6	11.1	129	5.3	0.0	36.8
			2.8	0.4	4	0.0	0.0	1.3
4	Syrdaruo/C-6541	2010	28.5	10.6	128	5.2	0.0	37.2
			-3.5	-0.7	8	0.3	0.0	1.8
5	Djizzah/Bukhara-6	2006-2010	35.3	12.6	113	5.5	0.0	36.9
			45	-1.9	-4	-1.5	0.0	0.6
Andijan-36								
1	Andijon/C-6524	2006-2010	38.3	14.0	122	5.8	7.3	36.9
			0.9	1.0	3	0.1	-1.0	1.9
2	Andijon	2006-2010	39.2	14.3	128	5.7	0.0	36.8
3	Namangan	2010	42.8	15.8	117	4.6	0.0	37.0
4	Fergana/C-6524	2010	32.5	12.1	130	5.7	0.0	35.8
			9.2	1.1	0	0.4	0.0	0.2
5	Fergana/Andijan-35	2010	34.6	10.7	125	4.4	0.0	37.1
			4.3	0.0	-1	-0.9	0.0	1.7
6	Fergana	2006-2010	32.4	12.1	117	4.7	0.0	37.4
	Namangan	2010	37.2	13.5	121	5.0	0.0	37.2
8	Namangan/C-6524	2006-2010	38.5	13.8	127	5.1	0.0	36.5
			3.3	1.4	3	0.5	0.0	1.2
Namangan-34								
1	Namangan/Andijan-36	2010-2011	31.3	10.4	123	4.8	0.0	35.6
			-7.1	-3.4	0	-0.4	0.0	-1.6
2	Samarkand/Bukhara-102	2011	25.6	-	140	6.1	2.0	-
			43	-	5	-1.0	0.0	-
3	Namangan/Andijan-36	2011	36.4	-	127	4.8	0.0	-
			-3.8	-	-1	-0.2	-4.0	-
4	Fergana/Andijan-36	2011	35.6	-	125	4.0	0.0	-
			2.9	-	-1	-0.2	0.0	-
5	Fergana/Andijan-36	2011	20.6	-	118	0.5	0.0	-
			-11.6	-	2	0.2	0.0	-
Kelajak								
1	Fergana/Andijan-35	2008-2010						
			34.6	10.2	123	4.6	0.0	36.2
			2.3	-0.5	-2	-0.2	0.0	0.2
2	Syrdaruo/C-6524	2010	32.6	11.7	122	4.9	0.0	35.2
			-1.4	-0.5	4	0.2	0.0	0.2
3	Jizzakh/C-6524	2009-2010	29.8	10.9	118	5.1	3.0	36.8
			2.5	1.5	6	0.7	-0.6	2.4
4	Karshi/Bukhara-6	2010	40.4	14.8	125	4.8	0.0	36.6
			-1.2	-0.8	-1	-1.0	0.0	-1.0
5	Jizzakh/Bukhara-6	2008-2010	35.0	12.8	119	5.9	0.0	36.4
			-3.9	-0.6	-2	-0.9	0.0	1.9
6	Shhrisabz/Bukhara-6	2010	51.7	18.6	-	6.5	0.0	36.4
			8.3	3.5	-	0.9	0.0	1.3
7	Syrhandaryo/Namangan-77	2007-2010	37.5	-	114	5.2	0.0	-
			-4.8	-	-2	-0.2_	0.0	-
8	Bukhara/Bukhara-6	2010	52.0	19.7	114	6.1	0.0	38.0
			0.0	1.1	-3	-0.9	0.0	2.2
9	Khorazm/Khorazm-127	2010	24.7	9.2	124	4.8	0.0	37.2
			-5.9	-2.1	-1	-0.2	0.0	0.2
10	Karakalpak/Akdaryo-6	2010	53.0	18.5	122	6.3	0.0	35.0
			3.1	1.0	-1	-0.2	0.0	0.0

Table 6 (Cont.)

	Region/Control variety	Year of evaluation	Cotton yield (centner/ha)		Vegetation time	Boll weight (g)	Verticillium wilt resistance (% of diseased plants)	Fiber yield (%)
			Raw cotton	Fiber				
#	1	2	3	4	5	6	7	8
AN-419								
1	Fergana/Andijan-36	2010	40.7	15.2	116	4.4	0.0	37.4
			-2.1	-0.6	-1	-0.2	0.0	0.4
2	Fergana/Andijan-36	2008-2010	27.9	9.7	117	3.8	0.0	34.B
			-3.2	-0.7	2	-0.9	0.0	-1.8
3	Jizzakh/C-6524	2009-2010	21.5	7.4	115	3.9	3.3	34.6
			-5.8	-2.0	3	-0.5	-0.3	0.2
4	Jizzakh/Bukhara-6	2008-2010	35.9	-	121	5.7	0.0	-
			-5.9	-	-1	-1.6	0.0	-
5	Bukhara/Bukhara-6	2010	32.4	11.7	115	4.6	10.5	36.0
			-1.7	-0.2	1	-1.9	1.3	1.0
6	Karshi/Bukhara-6	2008-2010	39.0	14.4	126	4.1	0.0	36.9
			-2.4	-0.8	-1	-1.7	0.0	0.1
7	Jizzakh/Bukhara-6	2008-2010	33.8	12.1	118	5.2	0.0	35.7
			-5.1	-1.3	-3	1.6	0.0	1.2
8	Termez/Namangan-77	2008-2010	41.1	14.3	114	5.2	0.0	37.0
			3.2	0.0	2	-0.1	0.0	0.8
9	Khiva/Khorezm-127	2008-2010	24.9	9.0	124	5.3	0.0	36.0
			-5.3	-1.7	0	0.0	0.0	0.5

*Datawas kindly provided by Dr. A. Narimanov, head of the cotton variety testing department, State variety testing committee of Uzbekistan; ** 1 centner = 100 kg

han-12', 'Surkhan-100' and 'Surkhan-101'. Presently, there are three cultivars ('Termez-31', 'Surkhan-9' and 'Surkhan-16') of *G. barbadense* cultivated in Uzbekistan. Most of the Uzbek ELS cotton cultivars represent fiber type 2-3, fiber yield 4-5 т/ha, micronaire 3.7 – 4.2, matures in 117-122 days and have good resistance to *Fusarium oxysporum*. Recently, Uzbek scientists developed unique prospective early maturing variety of *G. barbadense* – 'Kleystogam-1', with superior fiber quality and cleistogamous flowers (Muhitddinov 2010).

Unfortunately, there are no ELS cultivars in Uzbekistan with type 1 fiber. The Uzbek cultivar 'C-6037' only had type 1 fiber, but there is no consensus of opinion among experts because in different sources it mentioned as type 1 or/and 2 (Ibragimov *et al.* 2008; Kimsanboev *et al.* 2010). In contrast, there are two Turkmenian cultivars with type 1 fiber ('6947-И' and newly developed 'Ashkhabad-25'). These cultivars were introduced to Uzbekistan for breeding process of local cultivars suitable to Uzbek environmental conditions with the first type of fiber. Due to low economic efficiency and requirements of special technique for cultivation and harvesting of Pima cottons in Uzbekistan, the areas occupied by *G. barbadense* cultivars significantly reduced from 200.000 ha in 1987 to only 4.000 ha in 2011 (Abdullaev Abdumavlyan, a curator of Germplasm Unit of the Institute, pers. comm.).

STORAGE AND PROPAGATION

In Uzbekistan, the cotton germplasm maintained under room temperature conditions (20-23°C). As reported by Campbell *et al.* (2010), there is no facility available for cold storage of germplasm accessions. Ginned seeds are placed in to parchment paper bags. Each bag has catalogue number, accession name, year of collection and origin. The weight of seeds per bag is 50 g or 100 g (individual or total pick respectively). Bags are stored in special metal boxes (30 × 11 cm) and boxes are placed in wooden-cases. Insufficient funds are available to construct a facility with long-term cold storage capabilities. Consequently, there is a standard procedure for seed renewal every 8-10 years under forced self-pollination in the field (Campbell *et al.* 2010).

Annually, at least 300-400 accessions of *G. hirsutum*, 100-200 of *G. barbadense* and 20-30 of *G. herbaceum* and *G. arboreum* are renewed. Seeds are usually soaked in water for 1 day and then planted according to 60 × 25 × 1 scheme (60 cm inter-row distance, 25 cm between wells in 1 row), in each well 10-15 seeds are planted with 10 wells per accession. The planting usually starts at the second or third decade of April. Observation and phenotype data collection are performed during main phases of vegetation (from planting to 50% of germination, from germination to 50% of flowering and from flowering to 50% of opened bolls). Collection of morphological data starts from August, 15. Plants are forced to self-pollinate from July 1 to August 10 of the season using handmade paper bags and/or wire. Accessions are evaluated in every seed renewal period taking into account, at least, 50 morphological traits (**Table 7**) and fiber quality data. Most of fiber quality traits measured by HVI. For evaluations, no written guidelines were developed until 2010, but recently the Uzbekistan collection is adopting a policy to implement IPGRI cotton descriptor guidelines with some modifications (**Table 7**).

Wild and exotic cotton species and most of their hybrids are maintained as perennial plants at the greenhouse conditions in individual 15 liter volume pots filled with the composite medium (soil – 50%, sand – 35% and humus – 15%). Beginning from May to the end of September they are subjected to photoperiodic conditions (10 h of daylight from 8:00 AM to 6:00 PM). All data collected are stored as a hard copy catalogue book that is being converted to electronic format. Collaborative efforts are underway to develop a pcGRIN format database that currently stores all morphological and molecular data for 1000 *G. hirsutum* accessions (Abdurakhmonov *et al.* 2006, 2007; Campbell *et al.* 2010).

UTILIZATION

On-time guidance of Drs. A. Abdullaev and F. M. Mauer in early 1960s on the potential utilization of wild cotton germplams resources as donor lines in cotton breeding programs resulted in wide utilization of wild cotton germplams in Uzbekistan (Abdullaev *et al.* 2009). Success stories were well decried in a recent review papers (Abdukarimov *et al.* 2003; Abdurakhmonov 2007; Campbell *et al.* 2010) regarding to the development of wilt resistant, salt tolerant and naturally leaf defoliating germplasm. In addition to those success stories highlighted in previous papers, utilization of wild species and their synthetic hybrids led to development of 18 novel cotton cultivars by scientists of IGPEB ('AN-Chilyaki', 'AN-306', 'AN-510', 'AN-513', 'AN-514', 'AN-517', 'AN-512-U', 'Hamkor', 'AN-Uzbekistan-3', 'IGPEB-1', 'Genofond-2', 'Sharof-75', 'Besh-Kahramon', 'Ijod', 'Kupaysin', 'Nasaf', 'UzFA-703', 'Ishonch'). For example, application of radiation mutagenesis (Abdurakhmonov *et al.* 2007) to wild Upland cotton (*G. hirsutum* ssp.

Table 7 The descriptor developed for Uzbek cotton germplasm collection.*

No	Trait	Characteristic or short description	Value	Notes
1	SCIENTIFIC NAME	Latin name		Name of genus, species, subspecies etc. (ex.: *Gossypium hirsutum* spp. *mexicanum*)
2	ACCESSION NAME	Name of line or cultivar		Ex.: TM-1, 3-79
3	ACCESSION NUMBER	Number of accession in collection catalogue		Ex.: 1, 2, 3…
4	ORIGIN	Place of sample origin		Collection, author/scientist, country etc.
5	YEAR	Year of acceptance to collection		YYYY
6	RENEWAL	Last time of seeds renewal		DD.MM.YYYY
7	HOMOGENEITY	Not uniform	0	Homogeneity of cotton germplasm population
		Uniform	1	
8	GROWTH HABIT	Prostrate	3	Growth of habit (bush shape)
		Compact	5	
		Erect	7	
9	ANTOCYAN	Weak	0	Color of the plant in general
		Middle	1	
		Strong	2	
		Not became brown	3	
10	STEM HAIRINESS	Naked	1	Hairiness of the plant stem
		Very weak	2	
		Weak	3	
		Middle	5	
		Strong	7	
11	LEAF HAIRINESS	As above		Hairiness of the leaves
12	LEAF SHAPE	Palmate (normal)	1	Leaf shape
		Semi-digitate (semi-okra)	2	
		Digitate (okra)	3	
		Lanceolate (super okra)	4	
13	LOBE NUMBER		Numeric	Number of leaf lobe
14	EMERGENCE		Numeric	Days to emergence of cotton seedlings
15	SEED ENERGY %		Numeric	The energy required for seed germination
16	SEED TERM %	Seed energy in thermostat (%)	Numeric	The energy required for seed germination in thermostat
17	BRANCH HEIGHT (HS)		Numeric	Height of the first fruit branch in cm
18	BRANCH TYPE	Branching type		Distance of first sympodial fruit branch from first fruit brunch in cm
		0-5 cm	1	
		5-10 cm	2	
		10-15 cm	3	
		15-20 cm	4	
19	HEIGHT (cm)		Numeric	Plant height in cm
20	MONO		Numeric	Number of monopodia
21	SYMP		Numeric	Number of sympodia
22	STEM NODE		Numeric	Number of total stem nodes
23	PETAL COLOR	White	1	Petal color
		Cream	2	
		Light yellow	3	
		Yellow	4	
		Lavender	5	
		Red	6	
		Bicolor	7	
24	PETAL SPOT	absent	1	Petal spot
		present	9	
25	POLLEN COLOR	White	1	Pollen color
		Cream	2	
		Yellow	3	
		Purple	4	
26	PHOTOPERIODISM	Not photoperiodic	0	Sensitivity to day/night length
		Slightly photoperiodic	1	
		Photoperiodic	2	
		Strictly photoperiodic	3	
27	FLOWERING		Numeric	Days to 50% of plants flowering
28	OPENING		Numeric	Days to 50% of bolls opening
29	BOLL SHAPE	Round	1	Boll shape
		Oval	2	
		Conical	3	
30	BOLL OPEN	Normal	1	Level of boll opening
		Intermediate	2	
		Strom-proof	3	
31	BOLL NUMBER		Numeric	Number of boll
32	BOLL WEIGHT	Boll weight (g)	Numeric	Average weight in grams of a 10 boll sample
33	LOCULES NUMBER		Numeric	Locules per boll
34	SEED WEIGHT		Numeric	Weight of 100 seeds in g (could be applied to cultivated plants only)
35	SEED FUZZINESS	Fuzzy	1	Fuzz grade (amount of fuzz on seeds)
		Sparsely fuzzy	2	
		Naked seed	3	

Table 7 (Cont.)

No	Trait	Characteristic or short description	Value	Notes
36	FUZZ COLOR	White	1	Fuzz color
		Green	2	
		Grey	3	
		Brown (tan)	4	
37	LINT COLOR	White	1	Lint color
		Cream	2	
		Light brown	3	
		Brown	4	
		Green	5	
38	FIBER LENGTH		Numeric	Fiber length in mm
39	T0	Fiber strength (g/tex)	Numeric	The fiber strength of a bundle of fibers measured on a Stelometre with the jaws holding the fiber bundle tightly apprised. Measured in grams force per tex.
40	MIC	Micronaire	Numeric	The fitness of the sample taken from the ginned lint measured by the micronaire and expressed in standard curvilinear micronaire units
41	UI%		Numeric	Fiber maturity in %
42	YELLOWNESS	Fiber yellowness	Numeric	Hunter's B value, a measure of increasing yellowness of the cotton, taken with a Nickerson-Hunter Colorimeter
43	REFLECTANCE	Reflectance (RD)	Numeric	A measure of the percentage of reflectance on a Nickerson-Hunter Colorimeter. The higher the value the lighter the cotton.
44	LINT	Lint (yield) percentage	Numeric	The weight of lint ginned from sample of seed cotton expressed as percentage of the weight of seed cotton
45	LINT INDEX		Numeric	The weight of lint from 100 seed in g
46	ELONGATION	The percentage of fiber elongation	Numeric	The percentage of elongation at break of the center 1/8 each of the fiber bundle measured for T1 strength on the stelometer.
47	CGRD		Numeric	Color grade of fiber
48	AREA	Area of seed in %	Numeric	Seed covered area with fiber
49	DISEASE RESISTANCE	Highly Resistant (≥86% -100%)	1	Percentage of plants Resistant to pests/insects or phytopathogen (fungi, bacteria, virus, etc.)
		Resistant (≥76%-85%)	2	
		Moderate (≥51%-75%)	3	
		Susceptible (≥31%-50%)	4	
		Highly susceptible (1%-30%)	5	
50	ENVIRONMENTAL RESISTANCE	Special resistance to environmental conditions	As above	Resistance to salt, drought, low water, temperature etc.

*Data was obtained from Cotton Germplasm Unit (IGPEB) internal reports

tricuspidatum var. *El-salvador*) resulted in development of early maturing (114-118 days), *Verticillium* wilt resistant cultivar 'Kupaysin'. Traits, fiber characteristics and performance in different environmental conditions and appearance of some new prospective varieties recently developed in IGPEB are shown in **Table 8** and **Fig. 4**.

SHARING AND EXCHANGE

Within the country, to get any cotton germplasm seeds researchers can freely request the germplasm curator. Upon the request, the germplasm curator discuss the purpose of use and grants the seeds under bi-lateral agreement with registration in germplasm exchange book. For foreign organizations, requesting the germplasm seeds, we developed Material Transfer Agreement (MTA) with the restriction of "research purposes only". No germplasm is sent under agreement of 'commercial use' or to any private company. As described by Campbell *et al.* (2010), a request with proper "research purpose only" justification should be sent to germplasm curators, and upon agreement and review of the National Coordinator of Plant Genetic Resources (PGR) of Uzbekistan, the Ministry of Agriculture and Water Resources of Uzbekistan approves an exchange of the material under MTA.

LOCATION, MAINTENANCE AND FUNDING

Cotton germplasm collections in Uzbekistan currently reside in three locations that include the Cotton Breeding Institute of Ministry of Agriculture and Water Resources of Uzbekistan, the Institute of Genetics and Plant Experimental Biology at the Academy of Sciences of Uzbekistan, and the National University of Uzbekistan at Tashkent. These three-location cotton germplasm collections are funded by the Ministry of Agriculture and Water Resources of Uzbekistan, Academy of Sciences of Uzbekistan, and Committee for Coordination of Science and Technology Development (CCSTD) under the Cabinet Ministry of Uzbekistan (Campbell *et al.* 2010). There is a huge need of both local and international funding of current germplasm collection to 1) provide construction of modern long-term storage facility of the collection and 2) characterize this large germplasm accessions in both genetic, breeding and molecular genetics aspects.

CURRENT EFFORTS ON CHARACTERIZATION OF THE COLLECTION

Characterization and evaluation of germplasm collections is perhaps the greatest challenge facing all world collections. Campbell *et al.* (2010), clearly demonstrate the vast germplasm resources present across the eight major cotton germplasm collections worldwide. However, there is a huge need for detail characterization of cotton germplasm accessions in these eight collections using novel molecular genetics and genomics technologies that would allow to compare the cotton collections in the future. In this regard, our Cotton Germplasm Center in the IGPEB involved in extensive collaborative research efforts on understanding the molecular basis of our cotton germplasm collection.

Molecular tagging of fiber quality traits in a natural fiber mutant derived RIL lines and natural leaf defoliation trait introgressed from wild germplasm in tri-genomic hybridization were also conducted in our laboratory that accelerates utilization of useful diversity in the current cotton

Table 8 New prospective varieties developed in Institute of Genetics and Plant Experimental Biology.

Variety/trait	Plant height (cm)	Vegetation (ripening) (days)	Cotton yield (center/ha)	Boll weight (grams)	1000 seeds weight (g)	Fiber yield (%)	Fiber length (mm)	Fiber type
Mehnat	-	110-120	-	6.5-7	117-130	39-40	34-35	4
Gulbahor-2	110-120	120	40-42	6-6.5	-	38-39	34-35	5
AN-514	100-120	115-118	34-40	5.6-6.2	120-128	37.5	34-35	5
AN-517	70-80	113-118	32-34	5.8-6.2	116-118	36-37	34-36	5
AN-516-DV	90-110	116	30.8	5.6	126	37.9	36-37	4
Ishonch	90-100	114-116	35-37	5.7-5.9	115-120	37-38	33.5-34.5	4
UzFA-703	100-120	112-117	37-43	5.8-6.2	121-124	37-39	34.5-35.5	4
Kupaysin	110-120	114-118	36-45	5.4-5.6	113-119	37-38	34.5-35.5	4
Kelajak	80-90	115-119	35-43	5.8-6.3	117-120	37-38	34.5-35.5	4
AN-16	100-110	113	34-40	6.5	134-137	37	34-35	4
Besh-kahramon	110-120	98-105; 111-113*	39	5-6	118	40-42	33.5-34.1	4
Navbahor-2	110-120	121-123	45-50	6.5-7	125-130	40-42	36-37	4

Variety/trait	MIC	UHML	STR (g/tex)	Length code	Yellowness	Additional information
Mehnat	4.5	-	29.7	35	8,2	Verticillium wilt resistant
Gulbahor-2	4.6	-	26.4	-	-	
AN-514	4.5-4.6	1.14	27.6	36-37	6.3	Fast boll opening
AN-517	4.4-4.6	1.15	27.7	37	7	Fast boll opening
AN-516-DV	4.1-4.3	1.19-1.23	28.5	38-39	7.3	High temperature resistant, moderate drought resistant
Ishonch	4.3-4.4	1.18	28	37	6.5	Salt and drought tolerant
UzFA-703	4-4.4	1.13-1.17	29-31	37	7	Salt and drought tolerant
Kupaysin	4.4-4.5	1.15-1.18	30.6-30.8	37	7	Salt, drought and disease resistant
Kelajak	3.9-4.4	1.13-1.17	28-30	37	7.2	Salt and drought tolerant
AN-16	4.2-4.3	1.16-1.18	28.9-30	37-38	7.7	Pest and disease resistant, fast boll opening
Besh-kahramon	4.5	1.13	32.1	37	8.3	Early maturing
Navbahor-2	4.2	1.23	26.8-27.8	39	8.1	Drought resistant, universal to all soils and environmental conditions

* in the Southern regions and Tashkent respectively

Data was summarized from information kindly provided by Dr. A. Akhmedjanov, a head of the laboratory of variety testing and commercialization, Institute of Genetics and Plant Experimental Biology

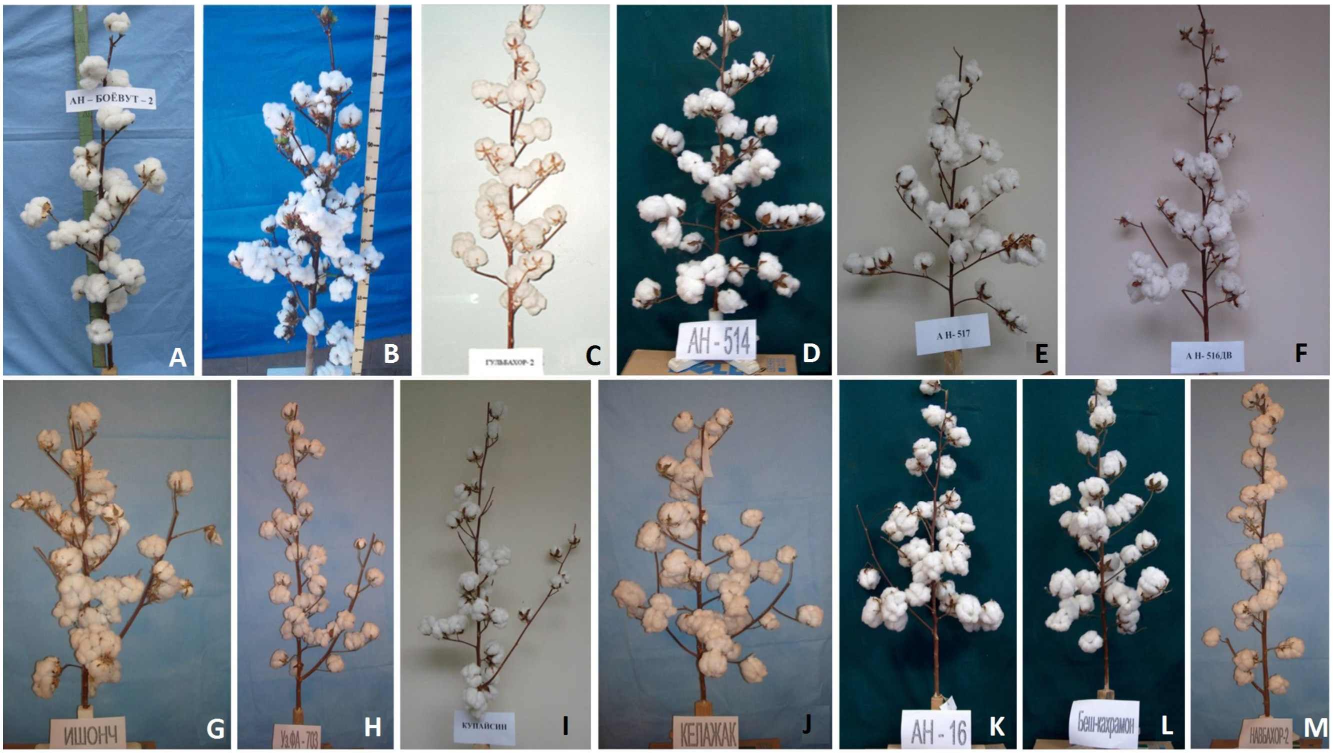

Fig. 4 Cultivar and prospective varieties developed in IGPEB. (**A**) Commercial cultivar AN-Bayaut-2; prospective varieties: (**B**) Mehnat; (**C**) Gulbahor-2; (**D**) AN-514; (**E**) AN-517; (**F**) AN-516-DV; (**G**) Ishonch; (**H**) UzFA-703; (**I**) Kupaysin; (**J**) Kelajak; (**K**) AN-16; (**L**) Besh-kahramon; (**M**) Navbahor-2. Source: from the Uzbek Cotton Germplasm plant photo collection.

breeding programs of Uzbekistan (Abdurakhmonov *et al.* 2005, 2007a). We are also extensively characterizing ~1000 *G. hirsutum* germplasm resources in both phenotypic and molecular levels to revel potential new genetic diversity (Abdurakhmonov *et al.* 2008, 2009). Recently, we also started molecular and phenotypic (including fiber parameters) characterization of ~300 *G. barbadense* germplasm resources in two environmental conditions (Tashkent and Shafter, California).

As mentioned above, within the frame of our international collaborative projects, we are developing electronic database for characterized cotton germplasm resources using pcGRIN (pcGRIN Data Management version 1.21) and Microsoft Access software that contains 72 characteristics for each accession, including passport data, collection data, site data, plant data and inflorescence and fruit data including all main fiber quality traits recorded from two very diverse environments, Uzbekistan and Mexico (Abdurakhmonov *et al.* 2006). We also keep enriching our collection through international collaborations. Recently, a collaborative research project between US and our institute provided an opportunity to exchange ~ 1000 cotton germplasm accessions and to develop a germplasm passport database system in Uzbekistan that is based on molecular and phenotypic data including agronomic and end-use traits (Abdurakhmonov and Abdukarimov 2008; Abdurakhmonov *et al.* 2008, 2009).

CONCLUSIONS

Thus, Uzbekistan has one of the largest and richest cotton germplasm collections in the world, covering most of the species for the *Gossypium* genus. Cotton accessions and species in our collection encompass wide geographic and ecological niches and represents large amplitude of morphobiological and genetic diversity. Current efforts of Uzbek scientists toward detail characterization, effective maintenance and continual renewal is the main factor to preserve the collection for the next generations of cotton scientists and farmers not only in Uzbekistan but also worldwide. Current extensive efforts toward application modern science technologies in characterization of our collection together with availability of the largest cotton collection in Uzbekistan put our Cotton Germplasm Center in the leading position that will provide cotton science and breeding research in competitive level of development in Uzbekistan. At the same time, this will require continual efforts, investment and base-line funding for further best-level preservation and maintenance of this unique cotton germplasm collection.

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REFERENCES

*** In Russian**

Abdalla AM, Reddy OUK, El-Zik KM, Pepper AE (2001) Genetic diversity and relationships of diploid and tetraploid cottons revealed using AFLP. *Theoretical and Applied Genetics* **102**, 222-229

Abdukarimov A, Djataev S, Abdurakhmonov IY (2003) Cotton research in Uzbekistan: Elite varieties and future of cotton breeding. In: Swaneopel (Ed) *Proceedings of World Cotton Research Conference-3*, Cape Town, South Africa, pp 5-15

Abdullaev AA (1964) The wilt resistance of some cotton forms and varieties. *Journal of Agrobiology* **3 (147)**, 374-378*

Abdullaev AA (1974) *Evolution and Systematic of Polyploid Cotton Species,* Fan, Tashkent, 258 pp*

Abdullaev AA, Klyat VP, Rizaeva SM (2009) Cotton introduction in Uzbekistan - history and perspectives of using of plant introduction: problems and perspectives. In: *Proceedings of 4th National scientific-applied conference*; July 3-4; Tashkent Uzbekistan; 59-61*

Abdurakhmonov I, Abdullaev A, Saha S, Buriev Z, Arslanov D, Kuryazov Z, Mavlonov G, Rizaeva S, Reddy U, Jenkins J, Abdullaev A, Abdukarimov A (2005) Simple sequence repeat marker associated with a natural leaf defoliation trait in tetraploid cotton. *Journal of Heredity* **96**, 644-653

Abdurakhmonov I, Buriev Z, Salakhuddinov I, Rizaeva S, Adylova A, Shermatov S, Adukarimov A, Kohel R, Yu J, Pepper A, Saha S, Jenkins J (2006) Characterization of *G. hirsutum* wild and variety accessions from Uzbek cotton germplasm collection for morphological and fiber quality traits and database development. In: *Cotton Beltwide Conference Proceedings*, Jan. 3-6, San Antonio, Texas, USA

Abdurakhmonov I, Kohel R, Yu J, Pepper A, Abdullaev A, Kushanov F, Salakhutdinov I, Buriev Z, Saha S, Scheffler B, Jenkins J, Abdukarimov A (2008) Molecular diversity and association mapping of fiber quality traits in exotic *G. hirsutum* L. germplasm. *Genomics* **98**, 478-487

Abdurakhmonov I, Kushanov F, Djaniqulov F, Buriev Z, Pepper A, Fayzieva N, Mavlonov G, Saha S, Jenkins J, Abdukarimov A (2007) The role of induced mutation in conversion of photoperiod dependence in cotton. *Journal of Heredity* **98**, 258-266

Abdurakhmonov I, Saha S, Jenkins J, Buriev Z, Shermatov S, Scheffler B, Pepper A, Yu J, Kohel R, Abdukarimov A (2009) Linkage disequilibrium based association mapping of fiber quality traits in *G. hirsutum* L. variety germplasm. *Genetica* **136**, 401-417

Abdurakhmonov IY (2007) Exploiting genetic diversity. In: Ethridge D (Ed) *Plenary Presentations and Papers: Proceedings of World Cotton Research Conference-4*, 2007 Sept 10-14, Lubbock, Texas, 2153 pp

Abdurakhmonov IY, Abdukarimov A (2008) Application of association mapping to understanding the genetic diversity of plant germplasm resources. *International Journal of Plant Genomics* **2008**, 574927

Abdurakhmonov IY, Buriev Zt, Shermatov SE, Abdullaev AA, Urmonov H, Kushanov FN, Egamberdiev SS, Shapulatov U, Abdukarimov AA, Sukumar S, Jenkins JN, Kohel RJ, Yu JZ, Pepper AE, Kumpatala SP, Ulloa M (2012) Genetic diversity of *Gossypium* genus. In: Caliskan (Ed) *Plant Genetic Diversity*, Intech, Croatia, pp 313-338

Adams KL, Percifield R, Wendel JF (2004) Organ-specific silencing of duplicated genes in a newly synthesized cotton allotetraploid. *Genetics* **168 (4)**, 2217-2226

Avtonomov AA (1973) *Breeding of Long Staple Cotton Varieties*, Fan, Tashkent, 176 pp*

Avtonomov AI (1937) The Egyptian cotton. In: *The Directory on Cotton Growing*, SoyuzNIXI Press, Tashkent, pp 96-104*

Avtonomov AI (1948) Breeding of the Egyptian cotton. In: *Cotton Breeding*, Government Press, Tashkent, pp 109-136*

Avtonomov AI (1956) Ways of breeding of the Soviet long staple cotton varieties. In: *Proceedings of Scientific Papers*, AN UzSSR, Tashkent, pp 512-516*

Avtonomov AI (1973) *Breeding of Long Stapled-fiber Varieties*, Tashkent Press, Tashkent, 144 pp*

Avtonomov VA, Egamberdiev RR, Kimsanbaev MH (2009) *Hybridization of Geographically Distant Genotypes in Breeding of G. barbadense L*, Tashkent Press, Tashkent, 229 pp*

Brubaker CL, Paterson AH, Wendel JF (1999) Comparative genetic mapping of allotetraploid cotton and its diploid progenitors. *Genome* **42**, 184-203

Campbell BT, Saha S, Percy R, Frelichowski J, Jenkins JN, Park W, Mayee CD, Gotmare V, Dessauw D, Giband M, Du X, Jia Y, Constable G, Dillon S, Abdurakhmonov IY, Abdukarimov A, Rizaeva SM, Abdullaev A, Barroso PA, Padua JG, Hoffmann LV, Podolnaya L (2010) Status of the global cotton germplasm resources. *Crop Science* **50**, 1161-1179

Dejoode DR, Wendel JF (1992) Genetic diversity and origin of the Hawaiian-Islands cotton, *Gossypium tomentosum*. *American Journal of Botany* **79**, 1311-1319

Djaniqulov F (2002) About relation between radio- sensitivity and mutability of wild and tropical cultivated cotton forms. *Proceedings of the Russian Academy of Agricultural Sciences* **2**, 19-22*

Endrizzi JE, Turcotte EL, Kohel RJ (1985) Genetics, cytology, and evolution of *Gossypium*. *Advances in Genetics* **23**, 272-375

Fryxell PA (1979) *Natural History of the Cotton Tribe*, Texas A&M University Press, College Station, Texas, 264 pp

Galicinskiy P, Demidov S, Obuhov M, Samoilov A (1962) Cotton Varieties in Uzbekistan. In: *Results of State Varieties Testing during 1950-1959*, Government Press, Tashkent, pp 17-19*

Hawkins JS, Pleassants J, Wendel JF (2005) Identification of AFLP markers that discriminate between cultivated cotton and the Hawaiian island endimic, *Gossypium tomentosum* nuttall *ex* seeman. *Genetic Resources and Crop Evolution* **52**, 1069-1078

Ibragimov AP, Avtonomov VA, Imamkhodjaeva AC (2009) A new *G. hirsutum* variety – SB-6. In: *Cotton and Lucerne Breeding*, Tashkent, pp 250-252*

Ibragimov P, Avtonomov V, Amanturdiev A, Namazov S, Zaurov D, Molnar T, Eisenman S, Orton T, Funk R, Edward Percival A Jr. (2008) Uzbek scientific research institute of cotton breeding and seed production: Breeding and germplasm resources. *The Journal of Cotton Science* **12**, 62-72

Kimsanbaev OH (1998) Inheritance of fiber turnout at interlinear hybridization of long staple cotton *G. barbadense* L. PhD thesis, Tashkent Press, Tashkent, 23 pp*

Kimsanboev O, Avtonomov V, Namazov Sh (2010) Breeding of early maturity, high-yielding and tolerant to *Fusarium oxysporum* cotton varieties of *G. barbadense* L. differing with increased fiber quality and quantity. In: *The 5th Asian Cotton Research and Development Network conference*, Lahore, Pakistan

Kuziev R (2005) Current situation of irrigated soils in Uzbekistan. *Bulletin of Superior Testing Committee of Uzbekistan* **1**, 38-42*

Mauer FM (1954) Origin and taxonomy of cotton. *Cotton*, Academy of Sciences of USSR, Tashkent, Volume **1**, 383 pp*

Muhitdinov T, Abdukarimov A, Abdullaev A (2010) Development of Kleystogam-1 variety. *Proceedings of Uzbek Academy of Sciences* **3**, 101-105*

Musaev JA, Abzalov MF, Almatov A, Sanamyan MF, Gubanova N, Nadjimov U (2000) Cotton genetics and genetic collection of isogenic, monosomic and translocation lines. *Bulletins SCST of the Republic of Uzbekistan* **4**, 28-39*

Najimov N (2010) Cotton industry of Uzbekistan: Recent achievements, production and consumption in 2010/2011. In: *Proceedings of VI International Uzbek Cotton Fair*, Tashkent, October 13, 2010

Percival AE, Stewart JM, Wendel JF (1999) Taxonomy and germplasm resources. In: Smith CW, Cothren JT (Eds) *Cotton: Origin, History, Technology and Production*, John Wiley, New York, pp 33-63

Percy RG, Wendel JF (1990) Allozyme evidence for origin and diversification of *Gossypium barbadense* L. *Theoretical and Applied Genetics* **79**, 529-542

Phillips LL (1964) Segregation in new allopolyploids of *Gossypium*. V. Multivalent formation in New world x Asiatic and New world x wild American hexaploid. *American Journal of Botany* **51**, 324-329

Rizaeva SM, Abdullaev AA, Klyat VP, Arslonov DM, Kuryazov ZB (2001) Creation of donors with naturally early leaf defoliation. *Uzbek Biology Journal* **4**, 65-70*

Sanamyan MF, Rakhmatullina EM (2003) Cytogenetic analysis of translocations in cotton. *Plant Breeding* **122 (6)**, 511-516

Stelly DM, Lacape J-M, Dessauw DE, Kohel R, Mergeai G, Saha S, Sanamyan M, Abdurakhmonov IY, Zhang T, Wang K, Zhou B, Frelichowski J (2007) International genetic, cytogenetic and germplasm resources for cotton genomics and genetic improvement. In: Ethridge D (Ed) *Plenary Presentations and Papers: Proceedings of World Cotton Research Conference-4*, 2007 Sept 10-14, Lubbock, Texas, 2154 pp

Ter-Avanesyan DV (1973) *Cotton*, “Kolos” Press, Leningrad, 9 pp*

Ulloa M, Stewart JM, Garcia EA, Goday SA, Gaytan AM, Acosta SN (2006) Cotton genetic resources in the western states of Mexico: *In situ* conservation status and germplasm collection for *ex situ* preservation. *Genetic Resources and Crop Evolution* **53**, 653-668

Wendel JF, Albert VA (1992) Phylogenetics of the cotton genus (*Gossypium*) - character state weighted Parsimony analysis of chloroplast-DNA restriction site data and its systematic and biogeographic implications. *Systematic Botany* **17**, 115-143

Wendel JF (1995) Cotton. In: Simmonds S, Smartt J (Eds) *Evolution of Crop Plants* (1st Edn), Longman, London, pp 358-366

Wendel JF, Percy RG (1990) Allozyme diversity and introgression in the Galapagos-Islands endemic *Gossypium darwinii* and its relationship to continental *Gossypium barbadense*. *Biochemical Systematics and Ecology* **18**, 517-528

Wendel JF, Rowley R, Stewart JM (1994) Genetic diversity in and phylogenetic-relationships of Brazilian endemic cotton, *Gossypium mustelinum* (Malvaceae). *Plant Systematics and Evolution* **192**, 49-50

Westengen OT, Huaman Z, Heum M (2005) Genetic diversity and geographic pattern in early South American cotton domestication. *Theoretical and Applied Genetics* **110**, 392-402

Wilkins AI (1899) *A Basis of American Cottons in Turkestan*, Tashkent Press, Tashkent, 127 pp*