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BREEDING AND GENETICS

Evaluation of the USDA Shafter Cotton (*Gossypium* spp.) Collection for Agronomic and Fiber Traits

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ABSTRACT

Many of the recent additions to the US Cotton Germplasm collection are uncharacterized for common germplasm descriptors. The objective of this study was to evaluate a subset of cotton germplasm for their potential to contribute to future plant improvement efforts. One hundred fifty four cotton germplasm accessions from the former USDA cotton breeding program at Shafter, California were evaluated in the field (LSU AgCenter Northeast Research Station, Saint Joseph, LA) in 2003 along with three modern commercial check varieties (Delta and Pine Land 'DeltaPearl', 'Fibermax 958', and 'Phytogen 355') using an unreplicated modified augmented statistical design-2. The following descriptors were considered: leaf and calyx pubescence; flower maturity; leaf, pollen and petal color; petal spot; glanding; presence of extra floral nectarines; and bract shape. Fiber properties as determined by High Volume Instrumentation: length, strength, micronaire, uniformity, and elongation; and cotton fiber yield were also recorded. Eleven germplasm accessions produced yields within 10% of the check average. The top three highest yielding germplasm accessions, SA 1961, SA 1962 and SA 1960 produced 1833, 1656, and 1613 kg h^{-1}, respectively. Many of the accessions had a long fiber with three accessions, SA 2093, SA 1983, and SA 2091, having fiber lengths greater than 31.8 mm. Much of the germplasm (82%) was characterized as having very strong fiber. Over half of the germplasm evaluated (55%) had micronaire between 3.8 and 4.6. In summary, these recent additions to the US Cotton Germplasm Collection provide a valuable genetic resource for improving yield, fiber quality and other agronomic traits of modern cotton varieties.

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INTRODUCTION

Cotton (*Gossypium* spp.), is the most important textile fiber crop in the world and second only to soybean as the most important oilseed crop. (Khan, *et al*, 2002). Despite this importance there has been concern about stagnation in Upland cotton yields in the United States (US) (American Cotton Producers, 1999). Additionally, the advent of new spinning technologies and the transition to an export driven market for US Cotton has placed increased demands on fiber quality. Genetic improvements to yield and quality of US cotton is required to remain competitive. Improvement requires genetic diversity, yet diversity in cotton has narrowed in recent years because many successful varieties share common parents and grandparents.

Germplasm screening for useful characteristics and then making that information available to plant breeders is a pre-requisite for exploitation of genetic variability. It is important to include data from as many descriptors as possible so that users can select material from the germplasm collection that is most likely to serve their particular needs. Descriptors include traits such as plant stature, flower color, fruit size, geographic provenance, resistance to diseases or pests, fiber properties, phytochemical characters, etc.

While continued efforts to collect germplasm remain important, increasing attention is given to the evaluation of extant germplasm resources. If a germplasm collection is to be utilized fully, information on the accessions must be documented so that plant breeders can identify potentially useful strains. Descriptor data is aided by a computerized information retrieval system, such as, the computerized Germplasm Resources Information Network (GRIN) maintained by the United States Department of Agriculture (USDA). Without this information, a breeder may need to screen thousands of entries to find accessions with the desired genes. The GRIN is part of a large Data Base Management System (DBMS), maintained by the USDA Plant Genetics and Germplasm Institute, Beltsville, Maryland (Percival, 1987).

The National Collection of *Gossypium* germplasm is maintained by the USDA-ARS at College Station, TX. The number of accessions in the cotton collection is over 10,000. While the number of cotton accessions is small compared to other major crop collections it is a repository of significant genotypic variability. The collection provides source material for basic studies in genetics, cytogenetics, taxonomy, and other disciplines, as well as for applied studies in screening for resistance to pests and diseases, environmental stress, and in plant productivity. Seed from the collection continues to be made available to cooperators and researchers from around the world (Percival, 2004. Personal Communication).

The former USDA breeding program at Shafter, California, was once heavily involved in the development of improved *G. hirsutum*, mostly Acala type cotton. In the early 1990's a program decision was made by the USDA to discontinue cotton cultivar development and this led to the subsequent closure of its improvement program at Shafter. In an effort to preserve the valuable germplasm developed at Shafter, advanced breeding lines were donated to the U.S. cotton collection. Datum on the merits of this material however was not produced. One relevant way to have cotton germplasm information available for breeding purposes is through the thorough evaluation of the existent, yet uncharacterized material. To this end, the Louisiana State University AgCenter and Mississippi State University are collectively evaluating different accessions from the National Collection of *Gossypium* germplasm to identify desirable characteristics for use in germplasm development. We report here on the evaluation of 154 accessions acquired from the former USDA breeding program in Shafter, CA for their potential to contribute to the agronomic and fiber quality improvement of cotton.

MATERIALS AND METHODS

The one hundred fifty four cotton germplasm accessions evaluated herein was a subset from the National Collection of *Gossypium* germplasm. The subset of Shafter accessions (SA) evaluated are numbered from SA 1956 through SA 2113, with the exception of SA 1972, SA 2052, SA 2076, and SA 2077 due to limited seed availability. The accessions and check varieties were planted on May, 2003 in St. Joseph, LA at the LSU AgCenter Northeast Research Station. Field plots were maintained by Station personnel as recommended by LA Cooperative Extension Service guidelines.

Field plots consisted of rows 6.2 meters long, spaced 102 cm apart, with an intra row seed density of 7-10 plants per meter. Due to limited seed availability, the trial was planned as a modified augmented (MAD) type-2 design using Agrobase Generation II (Agronomix, 2004). This design provides row and column error controls using both systematic (control plot) and random (control subplots) placement of repeating checks. It is specifically designed for the unreplicated testing of a large number of treatments. In this specific case, each whole control plot was planted to 'Phytogen PSC 355'. To estimate error, a random number of whole plots were selected and checks (Delta and Pine Land 'DeltaPearl' or 'Fibermax 958') assigned to control subplots.

Descriptor data was recorded as per Germplasm Resources Information Network (GRIN) guidelines and augmented with several additional phenotypic measurements. Field data was collected at three different times. The first data set was collected at flowering, approximately 75 DAP, and included the follow traits: photoperiodicity, calyx pubescence, leaf color, leaf hair, petal color, petal spot, pollen color, and stem pubescence. The second data set was collected prior to harvest when the commercial check, Phytogen PSC 355, had 50% of its bolls open to determine relative maturity of the accessions. The third data set was collected at harvest and consisted of plant height followed by harvest with a one-row picker to determine plot weight.

In addition, a 25 boll sample of each accession was collected prior to machine harvest. Bolls were picked at random locations from within plants and at least 1 m away from row ends in an effort to simulate machine picking. Samples were ginned at the LSU AgCenter Cotton Breeding Lab using a 7 saw laboratory gin (Porter-Morrison, Dennis Manufacturing Inc.). Lint and cottonseed weights were recorded, fuzzy cottonseed was acid delinted, and the number of seed counted.

Plot weights were converted into seedcotton yields (kg h^{-1}). Lint yields were calculated by multiplying seedcotton yield by lint percent as determined from ginned boll samples. Lint yields were analyzed using Agrobase Generation II according to the trial design and are reported as unadjusted and adjusted lint yields in kg h^{-1}.

Lint collected from the ginning process was analyzed using High Volume Instrumentation (HVI

900™ Zellweger Uster), at the LSU AgCenter Cotton Fiber Lab. HVI fiber characteristics determined included: fiber length (mm), fiber uniformity (%), fiber strength (mN tex^{-1}), fiber elongation (%), and fiber fineness (micronaire).

RESULTS AND DISCUSSION

Botanic and Agronomic Traits. No plant among the germplasm accessions evaluated showed a deviant characteristic from the mentioned descriptors. The commercial check control plot, PSC 355, was the reference against which percent open bolls at maturity was scored. Only two germplasm accessions (SA 1993 and SA 1995) matured (50% open bolls) a week earlier than PSC 355; nineteen germplasm accessions matured their bolls at the same time as PSC 355; twenty germplasm accessions were a week later than PSC 355; most of the germplasm accessions evaluated (96) were between one and one half or two weeks later than PSC 355; and seventeen germplasm accessions were two or more weeks later than PSC 355. The control subplot checks, FM 958 and Delta Pearl, were just a few days (less than a week) later maturing than PSC 355. Depending on the cotton breeders' objectives and their locations, maturity preferences may range from full season to early maturity cotton. Flowers of all the germplasm accessions and commercial checks were in bloom at the same time, indicating the absence of photoperiodicity in this subset of germplasm accessions.

With regards to stem pubescence, two commercial checks, Delta Pearl and PSC 355, were graded as hairy plants and the commercial check FM 958 was graded as having few hairs. There were five germplasm accessions with no hairs (glabrous) (SA 1965, SA 1975, SA 1978, SA 2057, and SA 2088). There were twelve hairy germplasm accessions (SA 1976, SA 1978, SA 1979 SA 2014, SA 2015, SA2017, SA 2047, SA 2049, SA 2066, SA 2072, SA 2095, and SA 2111), and one (SA 1986) rated as very hairy. The remaining germplasm accessions had few hairs on the plants.

A hairy stemmed plant is a common cotton characteristic and most cotton breeders would rather have smooth plants in their program. Wilson and Shepherd, (1987) found no significant differences in yield between hirsute cotton (hairy) and glabrous cotton (smooth). Jones *et al*. (1971) also reported no differences in yield between hairy and smooth cotton with the average lint percent for smooth and hairy being 37.7% and 38%, respectively. Since smooth cottons are known to produce less gin trash than normal hirsute cottons, lint of the hairy cotton may have contained more trash than the lint of smooth cottons and therefore had an inflated lint percent (lint + leaf debris / bolls wt). Ledge *et al*. (1992) reported that glabrousness reduces egg laying by as much as 50% by making the plant unattractive as an oviposition site for the bollworm [*Helicoverpa zea* (Boddie)].

The commercial checks, Delta Pearl and FM 958, were graded as having few hairs on cotton leaves and the commercial check PSC 355 was considered intermediate. Twenty six germplasm accessions had smooth leaves; most of the germplasm accessions evaluated had few to intermediate leaf hairs. All the commercial checks and one hundred eighteen of the germplasm accessions evaluated had few hairs on their calyx; twenty seven germplasm accessions did not have calyx hairs.

Only one germplasm line (SA 2087) had the frego bract shape. All remaining accessions, including the commercial checks had a normal bract shape. Jones and Andries (1969) reported that frego bract biotypes average up to 69% less loss from boll rot than their near-isogenic normal bract strains; Jones *et al*. (1978) reported that frego bract is susceptible to tarnished plant bugs, and it is sufficient to cause excessive delays in maturity and severe reductions in lint yields in some years.

Most of the germplasm accessions evaluated and all of the commercial checks were glanded; five germplasm accessions were glandless (SA 2012, SA 2013, SA 2037, SA 2074, and SA 2110), and three germplasm accessions were segregating (SA 2066, SA 2078, and SA 2080) for the glanding trait. Bottger *et al*. (1964) reported that glanded cottons have 3 to 4 ½ times more gossypol in the seedling and leaves, respectively, than in comparable samples of glandless cottons. Further, he reported that gossypol has a toxic effect on *Spodoptera exigua* (Hubner) (armyworms), *Helicoverpa zea* (Bobbie) (Bollworms), *Spanogonicus albofasciatus* (Reuter) (black fleahopper), and *Maecolaspis flavida* (Say) (grape colaspis), or at least inhibits their growth. According to Calhoun (1997), some breeding programs aimed at insect resistance have been selecting for the presence of glands on the sepal margin, because of the high correlation between high gossypol content and frequency of glands on the upper edge of sepals in Upland cottons.

All the commercial checks were nectaried; only one germplasm line was nectarless (SA 2085), and one germplasm line was segregating (SA 2089) for the nectarless trait. McCarty *et al*. (1983) noted that over a three years period, nectarless cottons averaged 5.7% higher total yields than nectaried cottons, when grown without early season insect control. However, no differences in total yield were detected between the nectaried/nectarless cottons when grown with early season insect control. Nectarless cottons tend to be earlier maturing than their nectaried counterparts and result in reduced *Heliothis* spp. oviposition, reduced pink bollworm damage, and reduced numbers of tarnished plant bugs, *Lygus lineolaris* (McCarty, 1983).

All germplasm accessions and the commercial checks evaluated had a uniform green leaf color. The cream flower color is a common flower characteristic of Upland cotton, and all germplasm accessions evaluated, including the commercial checks, had a cream petal color. Petal spot is a distinguishing characteristic of Acala and Pima cottons. All germplasm accessions evaluated, including the commercial checks, lacked a flower petal spot. All the commercial checks and most of the germplasm evaluated had cream pollen color; seven germplasm accessions had yellow pollen color (SA 1974, SA 2017, SA 2027, SA 2041, SA 2065, SA 2088, and SA 2105), and one germplasm line was segregating (SA 2071) for pollen color.

The height of plants in this study varied widely from between 66.8 to 240.5 cm (Table 1). Plant heights for Delta Pearl, FM 958, and PSC 355 were 121.9, 103.9, and 122.7 cm, respectively. Most cotton breeding programs would prefer to have plant heights between 90 cm and 140 cm, to facilitate machine harvesting.

Cotton Fiber Quality Traits. Variability in fiber properties in cotton is an unfavorable element of this natural fiber as opposed to synthetic fiber, which represents a more uniform product. Fiber properties vary as a function of the cultivar but also as a function of the environment and production practices employed (Clouvel *et al*. 1998). Ratings for fiber quality standards were taken from the Cotton Incorporated, U. S. Cotton Fiber Chart for 2001. Cotton fiber quality descriptors measured were: fineness (micronaire), strength (mN tex^{-1}), and length (mm).

Eighty four germplasm accessions had an "ideal" fineness of between 3.8-4.6 micronaire (Table 2) and sixty eight were high in micronaire

Table 1. Plant heights for 154 germplasm accessions of the USDA Shafter Cotton Collection

Number SA.	Height cm	Number SA.	Height cm	Number SA.	Height cm	Number SA.	Height cm
1956	98.3	1997	113.5	2037	151.6	2080	99.8
1957	137.9	1998	137.2	2038	144.0	2081	94.7
1958	100.8	1999	153.2	2039	136.4	2082	132.8
1959	104.9	2000	121.9	2040	142.2	2083	116.1
1960	136.4	2001	112.5	2041	127.8	2084	115.1
1961	132.1	2002	130.3	2042	135.4	2085	127.0
1962	131.3	2003	127.0	2043	114.3	2086	96.5
1963	113.5	2004	121.9	2044	125.2	2087	112.5
1964	149.9	2005	137.9	2045	117.6	2088	129.5
1965	116.8	2006	90.7	2046	103.4	2089	134.6
1966	130.3	2007	100.8	2047	111.0	2090	105.9
1967	117.6	2008	116.1	2048	139.7	2091	141.5
1968	124.5	2009	116.8	2049	132.8	2092	111.0
1969	128.8	2010	90.7	2050	125.2	2093	95.8
1970	100.8	2011	114.3	2051	94.0	2094	130.3
1971	116.1	2012	127.0	2053	111.8	2095	130.3
1973	128.8	2013	134.6	2054	108.5	2096	146.6
1974	121.9	2014	116.8	2055	118.6	2097	136.4
1975	106.7	2015	152.4	2056	114.3	2098	148.1
1976	149.1	2016	132.1	2057	123.7	2099	170.9
1977	123.7	2017	100.8	2058	96.5	2100	99.1
1978	88.9	2018	140.5	2059	127.0	2101	134.6
1979	94.0	2019	128.8	2060	92.2	2102	135.4
1980	115.1	2020	125.2	2061	110.0	2103	144.8
1981	132.1	2021	127.0	2062	113.5	2104	96.5
1982	177.0	2022	116.1	2063	105.9	2105	126.2
1983	132.8	2023	132.8	2064	66.8	2106	128.8
1984	102.4	2024	121.2	2065	91.4	2107	109.2
1985	132.1	2025	131.3	2066	114.3	2108	134.6
1986	134.6	2026	136.4	2067	130.3	2109	144.0
1987	144.8	2027	128.8	2068	112.5	2110	130.3
1988	144.0	2028	185.4	2069	123.7	2111	134.6
1989	175.3	2029	165.9	2070	101.6	2112	105.9
1990	135.4	2030	144.0	2071	86.4	2113	112.5
1991	127.8	2031	176.0	2072	99.1	Delta Pearl	121.9
1992	141.5	2032	164.3	2073	74.4	FM 958	103.9
1993	90.7	2033	140.5	2074	240.5	PSC 355	122.7
1994	111.0	2034	140.5	2075	86.4		
1995	88.1	2035	147.3	2078	121.2		
1996	125.2	2036	170.2	2079	97.3		

(above 4.6). All of the commercial checks had fineness above the ideal range with values of 4.9, 5.0, and 5.2 for FM 958, Delta Pearl, and PSC 355, respectively. Allen (1998) reported that cotton with a micronaire value of 4.5 or greater is more desirable for use in nonwoven roll goods manufacturing since high micronaire cotton contains fewer neps (small bundles of entrangled fibers) which result in unsightly appearing fabric; it is well documented that finer fibers (lower micronaire) are more prone to nep formation.

One hundred forty five germplasm accessions had strong or very strong fiber (Table 3), with strengths above 294 mN tex^{-1}. Nine germplasm accessions had a base strength of 255-284 mN tex^{-1}. The commercial check Delta Pearl, had strong fiber (311 mN tex^{-1}), and the two commercial checks, FM 958 and PSC 355, were considered very strong both with values of 327 mN tex^{-1}. High fiber strength lines are desirable as Artzt (1998) and Suh *et al*. (1998) found that there is a direct correlation between fiber strength and yarn tenacity or yarn strength.

Most of the germplasm accessions evaluated, including the commercial checks, were considered to have long fiber with an upper half mean (UHM) length between 28.2–32.0 mm (Table 4). One germplasm line (SA 2093) had extra long fiber with an UHM length of 32.3 mm. Germplasm line SA 2063 (not shown) had a short fiber length with an UHM of 25.1 mm.

Yield Parameters. Prior to harvest, a 25 cotton boll sample was collected by hand from each germplasm row, and the bolls were ginned and the seed delinted. Yield parameters tabulated from boll samples included: boll weight (g/boll), lint percent, fuzzy seed weight (g), lint index (g), and delinted seed wt (g).

Most bolls of the germplasm accessions were heavier than bolls of the commercial checks, with the heaviest boll weight belonging to SA 2045 at 8.1 grams per boll (Table 5). Few germplasm accessions had lighter bolls than the commercial checks.

The fraction (by weight) of the lint separated from a seedcotton sample by ginning is called lint percent, and is an important yield determining parameter. The three commercial checks had the highest lint percent with values of 42.7, 42.2, and 42.1 for Delta Pearl, PSC 355, and FM 958, respectively (Table 6). Accessions SA 2063 and SA 2024 had the highest lint percentage among the germplasm accessions evaluated with values of 40.2 and 40.1, respectively. Lint percent values determined on a commercial gin are typically reduced a few percentage points compared to values determined on a smaller laboratory gin. However any lint percent value above 38-39% would be considered good (Dr. Jack E. Jones, personal communication).

After ginning the cotton boll samples in the lab, a total of 100 seed of each germplasm accession were weighed before and after acid delinting. A majority of the Shafter accessions had fuzzy seed

Table 2. USDA Shafter Cotton Collection Germplasm accessions with micronaire between 3.8-4.6

Number SA	Micronaire	Number SA	Micronaire	Number SA	Micronaire
1956	4.3	1996	4.5	2053	4.4
1957	4.4	1998	4.3	2054	4.3
1958	4.4	2000	4.6	2056	4.4
1959	4.1	2001	4.6	2057	4.4
1960	4.6	2004	4.4	2058	4.3
1961	4.6	2005	4.4	2061	3.8
1963	4.3	2006	4.1	2062	3.8
1964	4.4	2007	4.2	2065	4.4
1965	4.4	2008	4.3	2066	4.4
1967	4.6	2010	4.6	2067	4.6
1968	3.8	2011	4.5	2068	4.1
1970	4.6	2015	4.6	2070	4.6
1971	4.6	2016	4.5	2071	4.3
1973	4.3	2019	4.6	2072	4.6
1974	4.1	2020	4.6	2073	4.4
1977	4.1	2023	4.6	2079	4.3
1978	4.5	2028	4.1	2080	4.3
1979	4.5	2030	4.4	2083	4.4
1980	4.4	2031	4.2	2084	4.5
1981	4.4	2032	4.4	2088	3.8
1982	4.6	2036	4.5	2089	4.5
1983	4.0	2039	4.6	2093	4.2
1985	4.3	2041	4.3	2107	4.6
1986	4.4	2045	4.5	2110	4.6
1989	4.0	2046	4.3	2111	4.6
1991	4.5	2048	4.4	2112	4.3
1993	4.0	2049	4.5	Delta Pearl	5.0
1994	4.0	2050	4.6	FM 958	4.9
1995	4.5	2051	4.3	PSC 355	5.2

weights greater than the commercial checks (data not presented). Lint index (fuzzy seed weight – delinted seed weight) values for FM 958, PSC 355, and Delta Pearl were 1.4, 1.3, and 1.3 g, respectively. Most of the accessions evaluated had a relatively high lint index with accession SA 2032 having the highest at 2.9 g and accession SA 2075 having the lowest at 0.9 g. Paradoxically, SA 2075 also had a very low lint percentage. Considering its low boll weight (4.1 g), large seed size, and HVI fiber characteristics, this implies that SA 2075 may have a relatively low number of fibers per seed.

Yield was analyzed according to the modified augmented design-2 subroutine of Agrobase Generation II. Significant row variation was detected in an analysis of variance, therefore control plot mean deviations from the overall control plot mean are calculated. These deviations were used to adjust treatment values. Neither column or subplots effects were significant. Adjusted mean lint yield for the control plot entry, PSC 355, was 1659 kg h^{-1} (Table 7). Control subplot adjusted means were 1742 and 1324 kg h^{-1} for DeltaPearl and FM 958, respectively. Eleven germplasm accessions had adjusted mean yields that were within 10% of the control plot or subplot entry mean yields (above 1417 kg h^{-1}) and included SA 1960, SA 1961, SA 1962, SA 1964, SA 1965, SA 1967, SA 1997, SA 2002, SA 2081, and SA2087. Two germplasm accessions, SA 2046 and SA 2051, had an adjusted negative yield. In this case, their single rows did not produce a yield above the adjusted mean of their subplot.

No Acala type cotton lines were found in the subset evaluated. However, this material as a whole exhibited superior fiber quality characteristics when compared to the included commercial checks. In summary, these recent additions to the US Cotton Germplasm Collection present a valuable resource for improving cotton varieties with resistance to insects, better yield and fiber quality. To achieve the crossing objectives, crosses might be made with high glanded, high strength fiber and lower micronaire germplasm accessions. The collected data for the lines evaluated has been submitted for inclusion in GRIN.

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Table 3. USDA Shafter Cotton Collection germplasm accessions with strength above 294 mN tex^{-1}

Number SA	Strength mN tex^{-1}	Number SA	Strength mN tex^{-1}	Number SA	Strength mN tex^{-1}	Number SA	Strength mN tex^{-1}
1956	330	1997	354	2036	397	2085	392
1957	321	1998	369	2037	337	2086	320
1958	319	1999	349	2038	383	2087	324
1960	365	2000	337	2039	380	2088	322
1961	336	2002	353	2040	327	2089	355
1962	362	2004	333	2041	344	2090	361
1963	368	2005	335	2042	354	2091	372
1964	332	2006	369	2043	347	2092	346
1965	347	2007	363	2044	389	2093	333
1966	349	2008	327	2045	379	2094	369
1967	348	2009	368	2046	375	2095	354
1969	330	2012	330	2047	375	2096	366
1970	348	2013	368	2049	378	2097	338
1971	354	2014	338	2050	358	2098	352
1973	325	2015	371	2055	324	2099	333
1975	331	2016	330	2056	317	2100	354
1976	359	2018	374	2057	322	2101	356
1977	321	2019	373	2059	359	2102	374
1978	361	2020	370	2060	341	2103	364
1979	364	2021	354	2061	326	2104	336
1981	331	2022	344	2062	336	2105	327
1982	370	2023	344	2066	330	2106	352
1983	340	2024	360	2067	344	2107	332
1984	335	2025	352	2068	333	2108	373
1986	355	2026	364	2070	329	2109	347
1987	332	2028	333	2071	331	2110	359
1988	351	2029	321	2072	341	2111	345
1989	379	2030	351	2073	333	2112	330
1990	362	2031	355	2074	337	2113	343
1991	328	2032	353	2075	340	Delta Pearl	311
1992	335	2033	362	2078	366	FM 958	327
1994	329	2034	372	2082	336	PSC 355	327
1996	314	2035	377	2083	326		

Table 4. USDA Shafter Cotton Collection germplasm accessions with UHM length above 28.2 mm

Number SA	Length mm	Number SA	Length mm	Number SA	Length mm	Number SA	Length mm
1957	28.2	1991	29.5	2028	29.2	2073	29.0
1959	28.7	1993	30.0	2029	28.2	2080	28.4
1960	28.2	1994	31.2	2030	28.4	2083	28.4
1963	29.7	1996	29.2	2036	29.2	2085	28.4
1964	29.5	1998	29.2	2037	28.4	2086	29.5
1965	29.2	1999	28.4	2039	29.2	2089	28.7
1966	28.4	2000	29.2	2040	29.2	2090	29.0
1967	28.2	2001	28.4	2041	28.2	2091	31.8
1968	30.5	2002	29.5	2042	28.2	2092	29.7
1970	29.7	2004	30.7	2045	29.0	2093	32.3
1971	28.4	2005	29.5	2046	29.7	2097	29.2
1973	28.4	2006	28.4	2049	30.2	2098	29.0
1974	30.2	2008	28.2	2050	29.7	2099	28.2
1976	28.7	2009	29.5	2051	28.4	2100	29.5
1977	29.2	2010	29.0	2053	28.2	2103	28.2
1978	29.0	2012	28.4	2056	28.7	2104	28.4
1979	29.5	2013	29.0	2058	29.0	2106	29.0
1980	28.7	2014	29.0	2060	28.7	2107	29.0
1981	30.0	2015	28.4	2061	31.0	2108	30.0
1982	28.4	2018	29.2	2064	28.7	2110	28.7
1983	32.0	2019	29.0	2065	28.7	2111	30.0
1984	29.7	2020	30.2	2066	28.7	2112	30.0
1986	29.7	2021	30.0	2068	28.7	2113	28.7
1988	28.2	2023	28.4	2070	28.7	Delta Pearl	30.2
1989	29.7	2025	29.5	2071	30.2	FM 958	29.5
1990	28.7	2026	28.7	2072	28.4	PSC 355	28.2

Table 5. Top 10 ranked boll weights

Number SA	Boll weight - g/boll -
2045	8.1
2015	8.0
2031	8.0
1960	7.9
1987	7.8
1965	7.7
1961	7.6
2093	7.5
1977	7.4
2020	7.4
FM 958	5.7
Delta Pearl	4.9
PSC 355	4.8

Table 6. Top 10 ranked lint percent

Number SA	Lint percent %
Delta Pearl	42.7
PSC 355	42.2
FM 958	42.1
2063	40.2
2024	40.1
2023	39.3
2086	39.2
1998	38.9
2037	38.9
2051	38.8
2081	38.8
2094	38.6
2033	38.6

Table 7. USDA Shafter Cotton Collection germplasm accessions with adjusted lint yields above 840 kg h^{-1}

Number SA	Adjusted yield Kg ha^{-1}	Unadjusted yield Kg ha^{-1}	Number SA	Adjusted yield Kg ha^{-1}	Unadjusted yield Kg ha^{-1}
1961	1833	1422	1996	1146	1098
Delta Pearl	1742	1524	2106	1144	1111
PSC 355	1659	1682	2011	1142	1217
1962	1655	1216	2029	1133	1295
1960	1613	1202	1970	1104	807
2002	1570	1551	2023	1093	1282
2087	1517	1234	2073	1083	686
1965	1504	1066	1999	1079	1032
2099	1504	1613	2086	1078	796
1964	1499	1059	2080	1065	811
1967	1476	1038	2068	1061	666
1997	1468	1421	1979	1054	729
2081	1435	1180	2037	1052	1608
1977	1412	1088	2113	1042	1037
1966	1408	968	1975	1040	715
2102	1380	1488	2091	1019	736
2065	1360	992	2111	1013	1009
1957	1348	937	2070	1005	609
FM 958	1324	1151	1959	1000	588
2069	1302	907	1963	994	556
2097	1301	1382	2094	983	1064
2089	1254	972	2024	974	1163
1973	1248	952	1976	963	638
2108	1243	1211	2025	963	1152
2062	1228	861	2084	958	677
2001	1221	1202	1988	956	1051
2082	1217	963	1990	945	1040
2063	1214	846	1998	922	875
2105	1212	1179	2083	908	653
1971	1211	915	1982	905	972
2110	1193	1188	2003	903	884
2000	1189	1142	2085	901	619
2071	1172	777	2109	900	866
2067	1171	803	2012	898	972
2072	1162	767	1958	890	479
1980	1150	826	2049	877	1318
1969	1148	851	2095	875	956
2066	1148	779	2079	841	586

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