The *Journal of Cotton Science 22:171–182 (2018)*
http://journal.cotton.org, © The Cotton Foundation 2018

BREEDING AND GENETICS

History of Cotton Breeding and Genetics at the University of Arkansas

Freddie M. Bourland*

ABSTRACT

Cotton breeding research was initiated at the University of Arkansas (UA) in early 1900's. Early work focused on evaluating cultivars and on making plant selections out of established cultivars. J.O. Ware who began breeding cotton in the early 1920's studied the genetics and interrelationships of several cotton traits, and released several cultivars. In 1935, he became Senior Agronomist at the United States Department of Agriculture (USDA), Beltsville, MD, then returned to UA in 1950. Several breeders followed Ware at UA. L.M. Humphrey and Ware were responsible for a series of Rowden cultivars. From 1948 until 1986, UA maintained two cotton breeding programs, one on the main campus and the other at the Cotton Branch Station, Marianna, AR. The Marianna program, directed by C.A. Moosberg (1948-1972) and C.W. Smith (1974-1986), was responsible for the release of several Rex cultivars, two stripper cultivars, and Arkot 518. Based on the main campus, B.A. Waddle (1951-1986) continued some of Ware work, and focused on early maturity, seedling vigor, host plant resistance (including the Frego bract trait), and naked and tufted seed. J.McD. Stewart filled the position held by Waddle from 1986 until his death in 2012. His work primarily focused on germplasm exploration and introgression, and cotton biotechnology. In 1988, the two traditional breeding programs were merged into one campus-based program. The program was subsequently moved to the Northeast Research and Extension Center, Keiser, AR, in 1997. F.M. Bourland has led the program since 1988, and has been responsible for almost 100 germplasm and cultivar releases and has established methods for evaluating and selecting several cotton traits. The cotton breeding program at UA continues to develop well-adapted lines and concepts that promote profitable cotton production in Arkansas.

F.M. Bourland*, Northeast Research & Extension Center, University of Arkansas, P.O. Box 48, Keiser, AR 72351.
*Corresponding author: bourland@uark.edu

Cotton (*Gossypium hirsutum* L.) has been a major crop in Arkansas for over 150 years. Arkansas cotton occupied a record of 3.577 mil acres (1.45 mil ha) in 1930 (over 10% of the total land area of the state), but produced only 119 lb A^{-1} (133 kg ha^{-1}). Historically, cotton has been commercially produced in every county of the state, but is now mostly grown within a two county tier of the Mississippi River. Before mandated acreage reduction in the 1960's, over one-half of the state's annual crop income was generated by cotton production.

Due to the United States Department of Agriculture (USDA) Agricultural Adjustment Act of 1933, acreage dropped from the high in 1930 to 2.196 mil acres (0.889 mil ha) in 1934, and continued to drop over the next 50 years while yields trended upward. In 1983, cotton acreage declined to 320k acres (130k ha) - partly due to the USDA Payment-in-Kind program. Low cotton prices accompanied with poor planting conditions caused acreage to decline to 205k acres (81k ha) in 2015, but acreage rebounded to over 400k (157k ha) in 2017 and in 2018. Average statewide cotton yields first exceeded 1000 lb A^{-1} (1120 kg ha^{-1}) in 2004, and have averaged over 1000 lb A^{-1} each year since then. Record statewide yield of 1205 lb A^{-1} (1350 kg ha^{-1}) was attained in 2017.

The efforts of cotton breeders at the University of Arkansas (UA), in collaboration with scientists of other disciplines, have been and continue to be committed to the enhancement of cotton as an important commodity to Arkansas. While several improved cultivars have been developed in the UA cotton breeding programs, the primary goal in recent years has been to develop genotypes and corresponding management systems, which permit optimum utilization of these resources. Cotton cultivars developed by private industry are dominant in the United States (U.S.) and Arkansas. A primary role of public breeding programs has been to support the private programs by contributing novel germplasm, establishing breeding approaches, and evaluating differential effects of pest and environments on cotton genotypes.

UA COTTON BREEDERS – 1908 TO 1920

Breeding work by careful "selection" of cotton (and other crops) was reported by the Agronomy Department, UA, Fayetteville, AR, in 1908 (Anonymous, 1908). According to Ware (1937), the cotton breeding program was initiated at the UA in about 1912 by W.C. Lassetter and M.S. Baker. Lassetter and Baker were mainly concerned with improving 'Allen Long Staple' and 'Cleveland' by direct selection and by crossing the two cultivars. Some straight selections were also made in 'Trice' and a few other cultivars. In 1915, Lassetter transferred to the extension service and Baker resigned. From 1916 to 1919, W.E. Ayres began new work dealing with selections of 'Foster 120' (for high and low oil and protein), 'Mebane Triumph' (for size of boll, length of staple, and lint percentage), and 'Express 432' (for wilt resistance). Ayres subsequently moved to Stoneville, MS, and initiated long-staple breeding work in 1920 at the Delta Branch Station, Mississippi State University. E.A. Hodson continued Ayers' work at the UA until July 1920 and published an important paper on a method of estimating lint frequency (Hodson, 1920a), as well as, a report on the pedigree selection in Trice cotton (Hodson, 1920b). The latter paper documents the degree of variation associated with seven years (1912 through 1918) of pedigree selection by different breeders from one Trice plant. He noted that the variation may have been attributed to the different breeders, cross-pollination (apparently unintentional), and the environment.

Cotton cultivars released by the UA are listed in Table 1. Documentation of formal release of lines from this period and the subsequent period are often missing. Therefore, determination of whether a line was released to the public as a cultivar or was simply evaluated in advanced tests is often difficult to discern.

Table l. List of cotton cultivars released[z] by the UA cotton breeding program

Year	Cultivar	Primary breeder	Reference number/citation
1920's	Arkansas Rowden 40	Ware	Brannen, 1934; Ware 1937
1920's	Arkansas Acala 37	Ware	Brannen, 1934; Ware 1937
1920's	Arkansas Acala 31	Ware	Brannen, 1934; Ware 1937
1920's	Arkansas Acala 34	Ware	Brannen, 1934; Ware 1937
1936	Arkansas Rowden 2088	Ware	Ware, 1937
1939	Rowden 41B	Humphey	Anonymous, 1940
1939	Rowden 41A	Humphey	Anonymous, 1940
1939	Rowden 42A	Humphey	Anonymous, 1940
1939	Rowden 42C	Humphey	Anonymous, 1940
1945	Rowden 60A	Humphey	Shank, 1948
1945	Arkot 1	Humphey	Shank, 1948
1945	Arkot 2	Humphey	Shank, 1948
1949	Arkot 2-1	Humphey	Humphrey et al., 1950
1957	Rex	Moosberg	Waddle, 1957
1963	Rex Smoothleaf	Moosberg	NSL 31459
1968	Rex Smoothleaf 66	Moosberg	NSL 67879
1968	Rex 61-28	Moosberg	Moosberg, 1968b
1976	New Rex / Rex 713	Moosberg	PI 529583
1967	Quapaw	Moosberg	PI 607169, PVP 7200069
1988	Arkot 518	Smith	PI 510667, PVP 8700165
1992	H1330	Bourland	CV-108, PI 583875, PVP 94000270
2010	UA48	Bourland	CV-129, PI 660508, PVP 200100041, Patent no. 8492618 issued July 23, 2013
2011	UA222	Bourland	CV-130, PI 664929, Patent no. 848287 issued Oct 13, 2014
2011	UA103	Bourland	CV-131, PI 664928, Patent no. 8552274 issued Oct. 8, 2013
2017	UA107	Bourland	PI 685638, Patent pending
2017	UA114	Bourland	PI 685639, Patent pending
2018	UA212ne	Bourland	Pending

[z] The dates and release status of lines released prior to the 1960's were often unclear.

UA COTTON BREEDERS – 1920 TO 1948

In the 1920's, research was initiated to develop genotypes and techniques to combat the damages inflicted by a relatively new pest, the cotton boll weevil (*Anthonomus grandis* Boheman). Until effective insecticides became available, research efforts were directed toward discovering effective methods to produce cotton in spite of this insect pest. Escape of late season boll weevil damage by the development of cultivars and systems, which shortened the production season, provided the only means of control. The establishment of the Cotton Branch Station near Marianna in 1927 significantly advanced these research efforts (Ashley, 1975). The Cotton Branch Station was renamed the Lon Mann Cotton Research Station in 2005.

J.O. Ware succeeded Hodson in 1921, and continued with the station until 1935, when he became Senior Agronomist, Division of Cotton and Other Fiber Crops and Diseases, Bureau of Plant Industry, USDA, Washington, D.C. During his career, Ware published extensively on inheritance and relationships of various cotton traits including red leaf color (Ware, 1927; 1929b), plant spacing (Ware, 1929a; 1929b), fiber length (Ware, 1929b), leaf shape (Ware, 1929b; 1934), sparse/naked seed (Ware, 1941), and cotton cultivars. Ware also conducted pioneering work in host-plant resistance traits of cotton. He cooperated with V.H. Young, a plant pathologist, to verify resistance to Fusarium wilt (Ware et al., 1932, 1934). Dwight Isley, an entomologist, and Ware demonstrated that boll weevils preferred green leaf cottons over red leaf cottons (Anonymous, 1927). Bourland and Waddle (1988) suggested that this might be the first documented account of insect resistance in cotton. In addition, Ware (1937, 1952a, 1952b) provided extensive reviews of the history of cotton breeding in the U.S, and co-authored a reference book on cotton in 1958 (Brown and Ware, 1958).

Most of the studies inaugurated and developed by Lassetter, Baker and Ayres were continued during the period of Hodson's and Ware's tenures (Ware, 1937). Ware made selections from 'Rowden' (obtained from Rowden Brothers, Wills Point, TX), 'Acala', 'Meade', 'Lone Star', and additional strains of 'Express' in 1921. By 1923 and 1924, several new strains were isolated, including Triumph 154, an early strain from Mebane Triumph lines; Trice 323 from the old Trice lines; and Foster 140 from the 'Foster 120' oil and protein study lines.

In the late 1920's, 'Arkansas Rowden 40' and 'Arkansas 17' (Express) were developed from the Rowden and Express materials, respectively, and 'Arkansas Acala 31, Arkansas Acala 34' and 'Arkansas Acala 37' were selected from the Acala material (Brannen, 1934). Arkansas Rowden 40 became very popular and was estimated to occupied 50% of the Arkansas's cotton acreage in the mid-1930's - when Arkansas cotton acreage exceeded two mil acres (810,000 ha) - and had spread to adjacent states. Arkansas 17 appeared to be particularly adapted to the "lowlands". 'Arkansas Rowden 2088' was selected out of Arkansas Rowden 40 and began to rapidly replace its parental cultivar (Ware, 1937). Arkansas Rowden 40 was earlier and more uniform than the old parental Rowden cultivar, and had high fiber quality (staple length of 1 to 1 1/16 inches (25.4 to 27.0 mm)), big bolls, storm resistance, hardiness to drought, considerable wilt resistance, and produced high yields.

Breeding methods used, number of lines evaluated, and test terminology employed by Ware were very similar to those currently used in the UA Cotton Breeding Program (Bourland, 2004; 2013). In an annual experiment station report, Ware (1929) indicated that:

"Around 1,000 individual plants are selected each year, the selector keeping in mind freedom from disease, productivity, size of boll, desirable staple, ease of picking, storm resistance, and other observable qualities. Each of these plants is ginned separately, the percentage of lint calculated, and the character and length of staple determined. About 250, or one-fourth of the more desirable of these plants, as indicated by the laboratory tests, are planted in plant-to-the-row or progeny row tests. Approximately one-fourth of the progeny rows are harvested separately, and the yield, the size of boll, the size of seed, the lint index, the lint percentage, and the quality of the lint are determined."

He further noted that the harvested progenies were propagated in increase blocks and then tested in the "newest strain test" where yields, relative earliness, size of bolls, percentage of lint, size of seed, lint index, quality of lint ("character and length of staple"), and storm resistance were determined. Outstanding "newest strains" were promoted to the "advanced strain test", where they were evaluated in subsequent years. Breeding objectives of the UA cotton breeding program in 1936 listed in order of their importance included: 1) early maturity, 2) high yield, 3) medium to large bolls, 4) medium staple length for upland, longer staple for bottom land, 4) generally good fiber quality, 5) high lint percentage, 6) wilt tolerance or resistance, and 7) storm resistance (Ware, 1937).

Several cotton breeders followed Ware in the 1930's and 1940's. O.A. Pope worked with Ware from 1930 to 1935 and specialized in the study of the cotton fiber with special reference to the breeding program (Pope, 1936). While at UA, Pope developed the concept of using photoelectric cells to measure the average length of lint fibers. Johnson (1939) acknowledged Pope as forming the principle for the apparatus that he described and modified. The subsequent development to the fibrograph has greatly influenced the cotton industry. Pope resigned in November, 1935, and was replaced by L.M. Humphrey who continued previous work until he resigned after the 1941 tests were concluded.

In 1939, Humphrey released four additional Rowden cultivars – 'Rowden 41A', 'Rowden 41B', 'Rowden 42A', and 'Rowden 42C' (Anonymous, 1940). Rowden 41B was the most popular of these releases and provided an important cotton cultivar for rain-grown areas. Recognized for its high quality, this large stalk cultivar was dominant until the 1950's (Bourland and Waddle, 1988). The advent of mechanical harvest and the improved ability to control insects by organic pesticides caused the more prolific, later maturing delta type cottons to become preferred over Rowden 41B.

The Delta Substation of the Cotton Branch Station was established at Clarkedale, AR, (just north of Memphis, TN) in 1939 (Williams, 1975). Because of its soil type (Dundee silt loam), incidence of Verticillium wilt, and northern Arkansas site, the station was a favored location for UA cotton breeders. The Delta Substation became the Delta Branch Experiment Station in 1957. In 2005, most research on the station was transferred to the Judd Hill Cooperative Research Station, which has the same soil type and is located 24 miles (39 kg) northwest of the Clarkedale station.

During the period of 1941 and 1945, UA released 'Rowden 60A', 'Arkot 1', and 'Arkot 2' (Shank, 1948). Shank included cultivar test results from multiple years and noted the release of these cultivars but did not report any other breeding activity. Humphrey was likely the breeder of record for these three cultivars, but Ware probably provided the initial work on these cultivars. Both Rowden 60A and Arkot 1 were derived from Rowden parental material. The selection of Rowden 60A was an attempt to meet cultivar needs for recently introduced mechanical harvesters. The cultivar had an upright growth with short lateral branches, Rowden fiber, and the large Rowden boll. Unfortunately, its ability to yield well in normal row widths was limited by very short lateral branches. The cover of the Fifty-Sixth Annual Report of the Arkansas Agricultural Experiment Station featured a photograph of Rowden 60A (Figure 1). Compared to older Rowden cultivars, Arkot 1 possessed a similar plant shape, but improved fiber quality having a finer fiber. Arkot 2 was a selection derived from 'Stoneville 2-B', and was similar to its parental stock, but was somewhat more resistant to Fusarium wilt.

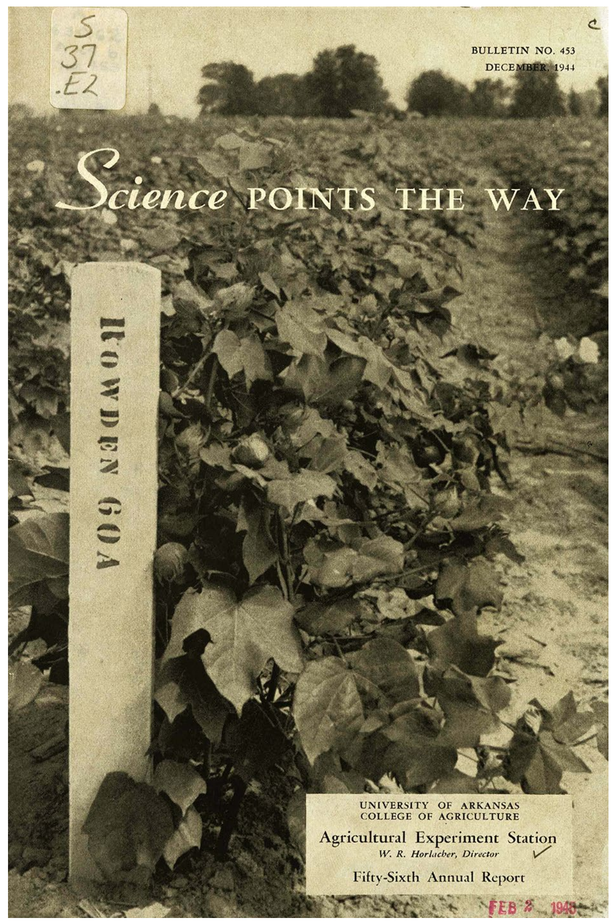


Figure 1. Cover of Fifty-Sixth Annual Report of the Arkansas Agricultural Experiment Station featuring a protograph of Rowden 60A.

Shank, nor any cotton breeder, was not listed among the faculty in the June 1948 Annual Report (Anonymous, 1948). In that annual report, Arkot 2-1 was noted as a new cotton cultivar, and was subsequently released in 1949 (Humphrey et al., 1950). A single plant selection made out of Stoneville 2B by Humphrey in 1937 gave rise to Arkot 2-1. D.B. Shank, C.A. Moosberg and J.L. Dameron (Station Director of the Cotton Branch Station) were given credit for assisting with the development and increase of this cultivar.

In ca. 1940, Mr. George Frego of Manila, AR, found a plant possessing a mutant bract shape (later named “Frego bract”) in a Mississippi County field of Stoneville 2B. He harvested the individual plant, hand-ginned the cotton, and planted seed in his garden the following year. His primary interest in the Frego bract cotton was its relative ease of hand-picking. He subsequently increased the seed and alerted the local county agent (Mr. Keith Bilbrey). Some of the seed were send to USDA laboratories at Stoneville, MS. This discovery led to much cooperative work with entomologists. Genotypes displaying this unusual bract characteristic incurred less boll weevil damage than normal bract cottons. However, the high sensitivity to plant bugs (Lygus spp.) and generally low productivity associated with the Frego bract character deterred commercial use of the trait. Due to this multiple insect complex, the intricate insect by plant interactions, and the easy recognition associated with this mutant, the Frego bract character became the catalyst for work that has led to many modern concepts of host plant resistance; and continues to be used in some South American cotton breeding programs.

UA COTTON BREEDERS – 1948 TO 1986

C.A. Moosberg bred cotton at the UA Cotton Branch Station (now Lon Mann Cotton Research Station) at Marianna from 1948 to 1972, working first for United States Department of Agriculture - Agricultural Research Service (USDA-ARS) and then as a research agronomist with the UA. Prior to Moosberg, all UA cotton breeders were assigned to the main campus in Fayetteville. Cotton breeders based in Fayetteville were provided advantages associated with student training, campus life and professional associations, but were far removed (about 300 miles or 483 km) from the major cotton growing area and cotton research stations in the state. During most of his time in Arkansas, Moosberg worked closely with B.A. Waddle, cotton breeder located on campus in the Department of Agronomy from 1951 to 1986.

Much of Moosberg’s efforts were focused on combining resistance to bacterial blight (caused by *Xanthomonas citra* pv *malvacearum* (ex Smith 1901) Schaad et al. 2007) (Moosberg, 1953), high fiber quality (Moosberg, 1956), and high yield. While approaching a basic research question of whether resistance to bacterial blight could be transferred to standard cultivars without sacrificing yield, Moosberg developed ‘Rex’ cotton at the Cotton Branch Station in 1957. The release of Rex was described by Waddle (1957). The combination of high yield potential, early maturity and resistance to storm loss, bacterial blight, and Fusarium wilt made Rex a popular cultivar. In an effort to improve fiber grade, ‘Rex Smoothleaf’ was developed and released in 1960 but was not as widely accepted as Rex cotton (Bourland and Waddle, 1988). Selection from Rex Smoothleaf produced ‘Rex Smoothleaf 66’ (Moosberg, 1968). A subsequent single plant selection from Rex Smoothleaf 66 produced ‘New Rex’, released in 1976 (Smith and Waddle, 1976). New Rex was described as being similar to original Rex but with less leaf pubescence. The words “new” and “nu” in the cultivar name were rejected when Plant Variety Protection (PVP) application was made, so the name of New Rex was changed to ‘Rex 713’ (Smith, personal communication).

The potential of stripper harvest for reducing production costs attracted much interest in the 1960’s. Before this potential could be properly evaluated, stripper type cotton cultivars that were adapted to Arkansas had to be developed. Moosberg (1968) indicated the shortened fruiting period and stormproof bolls of ‘Arkansas 61-28’ made it well suited for stripper harvest. Hinkle (1974) included Arkansas 61-28 and ‘Stripper 31’ in a list of cotton cultivar releases from the UA Agronomy Department. The name of Arkansas 61-28 was subsequently changed to ‘Quapaw’. Rogers Delinted Cottonseed Company (Waco, TX) purchased the rights to Quapaw in 1985. No other release information on Stripper 31 could be found. After he retired, Moosberg moved to the Texas High Plains and continued work on stripper cottons. While working for Growers Seed Association (Lubbock, TX), he released ‘Stripper 31A’ in 1973. Subsequent cooperative research with agricultural engineers and economists indicated little advantage to stripper production and a potentially severe problem of field deterioration associated with growing stripper cottons in the Mid-south.

A list of cultivars released by UA was attached to a letter from Nancy Wyatt, Publications Editor - UA Agricultural Publications, to Waddle in 1989. The list included NR-AHA as a cotton cultivar released in 1955. Moosberg (1956) noted several strains of the NR-AHA family, but documentation of a specific cultivar released from this family of strains was not found.

Ware returned to the UA in 1950 while maintaining his appointment as Senior Agronomist with Division of Cotton and Other Fiber Crops and Diseases, USDA (Anonymous, 1950). Some of his work focused on development of cultivars more suitable for mechanical harvest (Ware, 1952a). He noted several important plant characteristics including boll character, coarse lint of medium length, reduced plant hair density on leaves and bracts, and ability to produce uniform stands. With regard to boll character, he indicated that the most desirable bolls were "Snowball-like open bolls that do not drop locks when shaken by the wind or the machine."

Ware subsequently authored a book detailing the origin, rise and development of American Upland cotton varieties (Ware, 1952b). Unfortunately, the book was published as an unnumbered "mimeograph series" and is not publicaly available. Adjunct to this book, he published a bulletin that provided details of the principal cotton cultivars grown in Arkansas at the time, and included cultivar testing data for 1946-1950 (Ware, 1952c). This bulletin included charts showing the origin of Deltapine (Fig. 2) and Stoneville (Fig. 3) cultivars. Interestingly, he developed a suggested key for identifying nine cotton cultivars commonly grown in Arkansas (Fig. 4). Detailed drawings of leaves, bracts, flowers, and bolls that depicted variation in the cultivars accompanied this key. Ware shared an office with Waddle and maintained emeritus status in the department until his death in 1977.

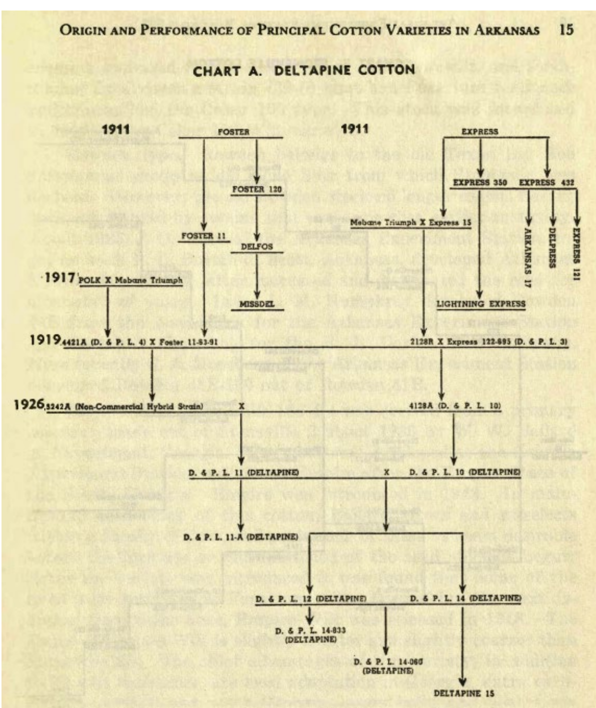


Figure 2. Chart showing origin of Deltapine cotton (copied from Ware 1952b).

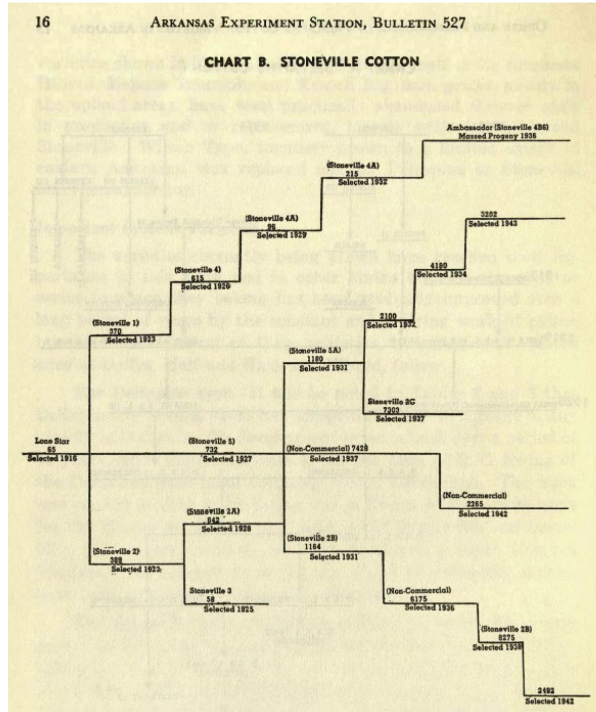
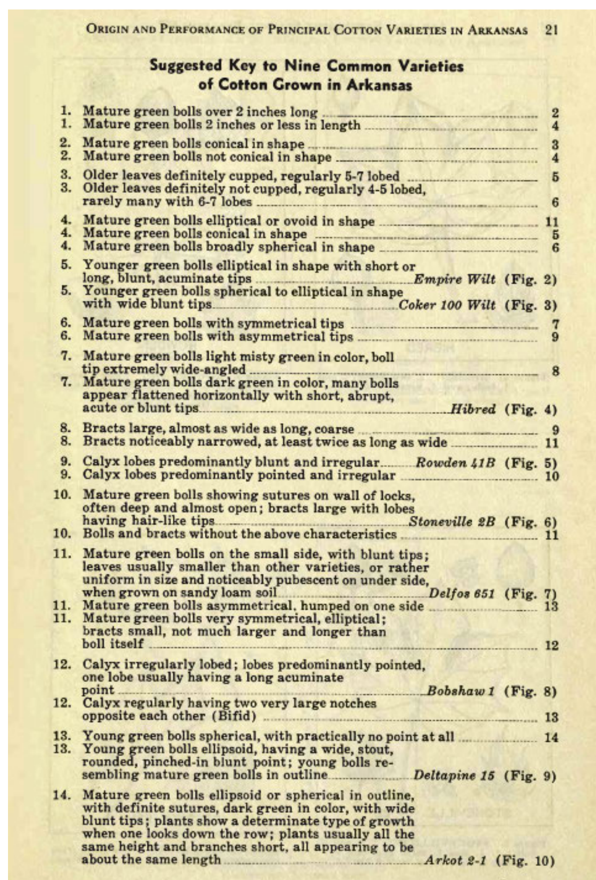


Figure 3. Chart showing the origin of Stoneville cotton (copied from Ware 1952b).


ORIGIN AND PERFORMANCE OF PRINCIPAL COTTON VARIETIES IN ARKANSAS 21

Suggested Key to Nine Common Varieties of Cotton Grown in Arkansas

1. Mature green bolls over 2 inches long 2
1. Mature green bolls 2 inches or less in length 4
2. Mature green bolls conical in shape 3
2. Mature green bolls not conical in shape 4
3. Older leaves definitely cupped, regularly 5-7 lobed 5
3. Older leaves definitely not cupped, regularly 4-5 lobed, rarely many with 6-7 lobes 6
4. Mature green bolls elliptical or ovoid in shape 11
4. Mature green bolls conical in shape 5
4. Mature green bolls broadly spherical in shape 6
5. Younger green bolls elliptical in shape with short or long, blunt, acuminate tips .... *Empire Wilt* (Fig. 2)
5. Younger green bolls spherical to elliptical in shape with wide blunt tips .... *Coker 100 Wilt* (Fig. 3)
6. Mature green bolls with symmetrical tips 7
6. Mature green bolls with asymmetrical tips 9
7. Mature green bolls light misty green in color, boll tip extremely wide-angled 8
7. Mature green bolls dark green in color, many bolls appear flattened horizontally with short, abrupt, acute or blunt tips .... *Hibred* (Fig. 4)
8. Bracts large, almost as wide as long, coarse 9
8. Bracts noticeably narrowed, at least twice as long as wide 11
9. Calyx lobes predominantly blunt and irregular .... *Rowden 41B* (Fig. 5)
9. Calyx lobes predominantly pointed and irregular 10
10. Mature green bolls showing sutures on wall of locks, often deep and almost open; bracts large with lobes having hair-like tips .... *Stoneville 2B* (Fig. 6)
10. Bolls and bracts without the above characteristics 11
11. Mature green bolls on the small side, with blunt tips; leaves usually smaller than other varieties, or rather uniform in size and noticeably pubescent on under side, when grown on sandy loam soil .... *Delfos 651* (Fig. 7)
11. Mature green bolls asymmetrical, humped on one side 13
11. Mature green bolls very symmetrical, elliptical; bracts small, not much larger and longer than boll itself 12
12. Calyx irregularly lobed; lobes predominantly pointed, one lobe usually having a long acuminate point .... *Bobshaw 1* (Fig. 8)
12. Calyx regularly having two very large notches opposite each other (Bifid) 13
13. Young green bolls spherical, with practically no point at all 14
13. Young green bolls ellipsoid, having a wide, stout, rounded, pinched-in blunt point; young bolls resembling mature green bolls in outline .... *Deltapine 15* (Fig. 9)
14. Mature green bolls ellipsoid or spherical in outline, with definite sutures, dark green in color, with wide blunt tips; plants show a determinate type of growth when one looks down the row; plants usually all the same height and branches short, all appearing to be about the same length .... *Arkot 2-1* (Fig. 10)

Figure 4. Suggested key to identify common varieties grown in Arkansas (copied from Ware, 1952b).

Beginning in 1951, B.A. Waddle laid the foundation for advances in cotton genetics and management as a teacher and researcher. His breeding program encompassed a wide range of topics including breeding for resistance to seedling disease (Waddle, 1961), Verticillium wilt (Waddle et al., 1955), boll weevils (Hunter and Waddle, 1958; Lincoln and Waddle, 1966; Waddle, 1971), and the Fusarium-nematode complex (Fulton and Waddle, 1959). He also conducted research on early crop maturity (Waddle, 1961b; Waddle and Appleberry, 1970; Waddle, 1971), seed fuzz (Waddle, 1977), mechanical harvesting (Moosberg and Waddle, 1961a; Waddle and Hughes, 1964), and evaluating seed cotton storage (Anderson and Waddle, 1963). His germplasm included an extensive collection of lines that varied in seed fuzz (naked seed and variations of tufted seed), Frego bract (Arkansas Frego #25) and Yugoslavian (ArkYugo 4, a very early maturity) cottons. Waddle was widely considered to excel as a "cotton agronomist", as indicated by being invited to write the chapter titled "Crop Growing Practices" in the 1984 American Society of Agronomy "Cotton" book (Waddle, 1984).

In 1957, UA cotton breeders gained access to two additional research stations in the Mississippi River Delta region. One of initial purposes for the Northeast Branch Station at Keiser was to learn how to grow cotton on a Sharkey clay soil. The Northeast Branch Station was expanded to the Northeast Research and Extension Center in 1980, and now houses the UA cotton breeding program. Formerly, the Northeast Branch Station was an expansion and transfer of work associated with the Alfalfa Substation, established in 1948 at Osceola, AR (Taylor, 1975). In the following year, research on Verticillium wilt and other cotton diseases was initiated on on-farm sites. From 1950 to 1969, a Verticillium wilt nursery was conducted by Waddle at Nodena, community near Osceola (Young et al., 1959). Companion to the regional Fusarium wilt nursery operative at Tallassee, AL, germplasm lines submitted by cotton breeders from across the Cotton Belt were screened in this nursery. In cooperation with plant pathologist N.D. Fulton, the understanding of this disease was advanced (Fulton and Waddle, 1959). Concurrent work on seed deterioration and seedling disease led to better concepts of and control of these diseases.

The second station established in 1957 was the Southeast Branch Experiment Station near Rohwer, AR, now known as the Rohwer Research Station (Smith, 1975). University of Arkansas cotton breeders currently have ready access to four Mississippi River Delta research stations. These stations span a distance about 145 miles (235 kg) north to south, and provide contrasting soils, pests, crop management and climate conditions each year.

C.W. Smith began his tenure at the UA Cotton Branch Station in October 1974 and left in May 1986 to assume a cotton breeding position at Texas A&M University. He released two germplasm lines (UArk 1 and UArk 2) based on their early maturity (Smith, 1983). In 1987, he released 'Arkot 518' (Smith, 1988), which was an early to midseason cultivar with longer fiber length than all other adapted cultivars grown in the UA Cotton Variety trials in the mid 1980's.

UA COTTON BREEDERS – 1986 TO PRESENT

From 1986 until his death in 2012, J. McD. Stewart filled the position previously held by Waddle. Unlike Waddle and other UA cotton breeders, Stewart's research focused on cotton biotechnology, but ranged from taxonomy to germplasm characterization to introgression of interspecific genes into tetraploid cotton (*Gossypium hirsutum* L. and *G. barbadense* L.) (Stewart, 2010). Stewart introgressed six new cytoplasms from six species (*G. mustelelinum* (AD_4), *G. darwinii* (AD_5), *G. sturtianum* (C_1), *G. davidsonii* ($D_{3\text{-}d}$), *G. trilobum* (D_8), and *G. stocksii* (E_1)) into *G. barbadense* (57-4 and Vsg7) semigamy background for rapid nuclear replacement. Notably, he developed a new cytoplasmic male-sterile/restorer system in cotton based on the *G. trilobum* (D_8) cytoplasm (Zhang and Stewart, 2001). Other research involved several traits including red anther (from *G. armourianum*), red boll/calyx (from an accession of *G. herbacium*), and shortened or absent second sympodial internode (from *G. hirsutum* × *G. herbaceum* × *G. armourianum*), and waxy leaf/elongated palisade cells (from *G. armourianum*). Additionally, he evaluated Asiatic cotton germplasm for fiber quality, yield potential, and for pest resistance.

After conducting a cotton breeding program at Mississippi State University for ten years, F.M. Bourland moved to the UA in 1988, and assumed the breeding responsibilities previously performed by Waddle and Smith. Bourland worked with Waddle on an M.S. degree and with L.S. Bird (Texas A&M Multi-Adversity Resistance Program) on his Ph.D. degree. In 1997, he and his program transferred from the main campus in Fayetteville to the Northeast Research and Extension Center in Keiser. In his early years, Bourland primarily crossed materials developed by Bird (1982) with materials adapted to the Mississippi River Delta with the goal of integrating improved host plant resistance traits into adapted lines. Lines developed from these crosses were usually crossed with other well-adapted lines and subsequent lines that demonstrated good host plant resistance traits and adaptation were selected. In recent years, his crosses have concentrated on interbreeding his selected lines and crossing his lines with lines from other public and private breeders via material transfer agreements.

The breeding program of Bourland (2004, 2013) includes modified bulk selection in the F_2 and F_3 generations followed by individual plant selections in the F_4 generation. Individual plant selections are evaluated as progeny rows (multiple locations) for two years. Selected progenies are promoted to strain status and evaluated for up to four years at four Arkansas research stations (noted above). Lines in all generations are selected for appropriate morphological traits and for resistance to bacterial blight In separate tests, advanced strains are evaluated for resistance to tarnished plant bug (*Lygus lineolaris* (Palisot de Beauvois)) and Verticillium wilt (caused by *Verticillium dahliae* Kleb.). Selected advanced strains are further evaluated in regional tests (Regional Breeders' Network Test; Regional High Quality Test).

From 1986 through 2017, Bourland released 91 cotton germplasm lines, 12 of which were released via Mississippi Agricultural and Forestry Experiment Station (MAFES) and four jointly with MAFES. Bourland (2013) provided a list of lines released from 1986 through 2011. Subsequently released germplasm lines include Arkot 0111, Arkot 0113, and Arkot 0114 (Bourland and Jones, 2014a); Arkot 0219 and Arkot 0222 (Bourland and Jones, 2014b); Arkot 0305, Arkot 0306, Arkot 0309, and Arkot 0316 (Bourland and Jones, 2015a); Arkot 0403ne, Arkot 0401, and Arkot 0410HG (Bourland and Jones, 2015b); Arkot 0503ne, Arkot 0504ne, Arkot 0506ne, and Arkot 0517HG (Bourland and Jones, 2017); Arkot 0705 and Arkot 0711 (Bourland and Jones, 2018c); and Arkot 0611, Arkot 0617, and Arkot 0712 (Bourland et al., 2019).

Due to incorporation of the Texas A&M germplasm and evaluation of lines in the northern region of the U.S. Cotton Belt, all of Bourland's lines are early maturing. Additionally, all but 12 of the 91 lines are resistant to bacterial blight. Variation in resistance to other diseases (particularly Verticillium wilt and Fusarium wilt) and some insects (particularly tarnished plant bug, (*Lygus lineolaris* Palisot de Beauvois)) has been documented in these lines. Most of the lines have reduced leaf and stem pubescence, and many have lowered marginal bract trichome density. Fiber quality of all of the lines are generally within acceptable ranges, but several recent releases have outstanding fiber quality.

In addition to the germplasm lines, Bourland has released seven cultivars in the U.S. – all are early maturing and resistant to bacterial blight. The cultivar 'H1330', released by UA in 1992, was licensed to Hartz Seed Company, Stuttgart, AR (Bourland, 1996). H1330, derived from a cross of 'DES 119' (Bridge, 1986) and Miscot 7803-52 (Bourland and White, 1989), was early maturing and yielded well over multiple environments. Hartz Seed Company subsequently developed transgenic forms for H1330, which were assigned to the Arkansas Agricultural Experiment Station - 'H1330 BG/RR' (PVP 9700109), 'H1330 BG' (PVP 9700110), and 'H1330 RR' (PVP 9700111).

'UA48', a cultivar that combined very early maturation, resistance to bacterial blight good host plant resistance traits, competitive yielding, low plant pubescence, and excellent fiber quality, was released in 2010 (Bourland and Jones, 2012). Its fiber length (1.29 in or 32.8 mm), length uniformity index (87.0%), and fiber strength (35.5 g tex^{-1} or 348 kN m kg^{-1}) set new standards for the U.S. Upland cotton industry.

In 2011, two additional conventional cultivars – 'UA222' (Bourland and Jones, 2012) and 'UA103' (Bourland and Jones, 2013) – were released. UA222 was derived from crossing Arkot 9111 (Bourland and Jones, 2005) with STX8M007 (released as 'ST 457'). The fiber quality of UA222 is not as good as that of UA48, but exceeds most other cultivars. UA222 possesses a relatively high level of resistance to tarnished plant bugs and has proven to be adapted to a very wide range of conditions. UA103 is an open canopy (okra leaf) cotton derived from a cross of Arkot 8712 (Bourland et al., 2005) and 'FiberMax 832'. UA103 is not as widely adapted as UA222, but has performed very well at certain locations. Its fiber quality is similar to that of UA222.

Two additional cultivars were released in 2016 – 'UA107' (Bourland and Jones, 2018a) and 'UA114' (Bourland and Jones, 2018b). Parents of UA107, another open canopy cotton, were UA103 and Arkot 9704 (Bourland and Jones, 2009b). UA107 has outperformed UA103 in terms of yield and range of adaptation, but is similar to UA103 in maturity, fiber quality and pest resistance. Parents of UA114 were Arkot 9623 (Bourland and Jones, 2009a) and Arkot 9721 (Bourland and Jones, 2009c). UA114 is similar to UA222 but has produced higher yields in most direct comparisons.

The most recent cultivar released by Bourland is 'UA212ne', which was derived from crossing Arkot 0016 (Bourland and Jones, 2011) and JAJO 4141 (nectariless breeding line obtained from Dr. Jack Jones). UA212ne combines the nectariless trait with other beneficial host plant resistance traits, high yields, early maturity, and very good fiber quality. Jenkins and Wilson (1996) reviewed articles indicating that the absence of nectaries on leaves and flowers confers resistance to tarnished plant bug (*Lygus lineolaris* (Palisot de Beauvois)).

Bourland has also developed several concepts and methods associated with measuring seed and seedling vigor (Bourland, 1992), plant mapping (Bourland and Watson, 1990), leaf pubescence (Bourland et al., 2003), bract trichomes (Bourland and Hornbeck, 2007; Bourland and Gbur, 2017), fiber quality index (Bourland et al., 2010), plant maturity (Bowman et al., 2016), and yield components (Groves and Bourland, 2010; Groves et al., 2016). He also was a member of a research team that established the plant measurements and associated decision framework of the cotton management system COTMAN (Bourland et al., 2008).

In many ways, cotton breeding research in Arkansas has paralleled that of other cotton producing states with regard to major issues and problems addressed. Two distinctive differences have been that the distance of the main campus from primary cotton growing areas and the proximity of its cotton growing area in the northern extreme of the Cotton Belt. The application of cotton research on the main campus in the Ozark Mountains of northwest Arkansas is greatly hindered by its distance from a major cotton growing area. Early Arkansas cotton breeders should be commended for being able to accomplish their research in a time when travel across the state was very difficult and trying. The northern proximity of the state pushed Arkansas cotton breeders to focus on early maturation, seed and seedling vigor, and seedling maladies. This focus has led to the development of early maturing lines and concepts of early maturation and protection of early plant growth. UA cotton breeders have and continue to make valuable contributions to the entire cotton industry and to Arkansas in particular.

REFERENCES

Anderson, F.B., and B.A. Waddle. 1963. Value of lint from seedcotton stored in gin-press packages. Ark. Farm Research. Vol. 12, No. 3, p.3.

Anonymous. 1908. Agronomy Department. p. 11. *In* Twenty-first Annual Report. University of Arkansas College of Agriculture Agricultural Experiment Station.

Anonymous. 1927. Entomology. p. 34. *In* Thirty-ninth Annual Report. University of Arkansas College of Agriculture Agricultural Experiment Station.

Anonymous. 1940. Production of new cotton varieties. pp. 29-31. *In* Science Works for the Farmer. Fifty-second Anual Report. University of Arkansas College of Agriculture Agricultural Experiment Station. Bulletin No. 405.

Anonymous. 1948. pp. 5 and 16. *In* Fifty-Eighth Annual Report. University of Arkansas College of Agriculture Agricultural Experiment Station. Bulletin 483.

Anonymous. 1950. pp. 15 and 26. *In* Fifty-Ninth Annual Report. University of Arkansas College of Agriculture Agricultural Experiment Station. Bulletin 505.

Ashley, T.J. 1975. The Cotton Branch Station. Ark. Farm Research. Vol. 24, No. 4, p 10-11.

Bird, L.S. 1982. The MAR (Multi-Adversity Resistance) system for genetic improvement of cotton. Plant Disease 66:172-176.

Bourland, F.M. 1992. Characterization and improvement of seed and seedling vigor in cotton. p. 13261329. *In* Proc. Beltwide Cotton Production Research Conferences, Nashville, TN. 610 Jan. 1992. National Cotton Council, Memphis, TN.

Bourland, F.M. 1996. Registration of 'H1330' cotton. Crop Sci. 36:813.

Bourland, F.M. 2004. Overview of the University of Arkansas Cotton Breeding Program. pp. 1093-1097. In Proc. Beltwide Cotton Prod. Res. Conf., San Antonio, TX. 59 Jan. 2004. National Cotton Council, Memphis, TN.

Bourland, F.M. 2013. Novel approaches used in the University of Arkansas cotton breeding program. pp. 409-418. *In* Proc., Beltwide Cotton Prod. Res. Conf., San Antonio, TX. 7-10 Jan. Nat'l, Cotton Counc. Am., Memphis, TN.

Bourland, F.M. and D.C. Jones. 2005. Registration of Arkot 9111 germplasm line of cotton. Crop Sci. 45:2127-2128.

Bourland, F.M. and D.C. Jones. 2009a. Registration of Arkot 9623 and Arkot 9625 germplasm lines of cotton. J. Plant Registrations 3:69-72.

Bourland, F.M. and D.C. Jones. 2009b. Registration of Arkot 9704 and Arkot 9706 germplasm lines of cotton. J. Plant Registrations 3:289-292.

Bourland, F.M. and D.C. Jones. 2009c. Registration of Arkot 9721 germplasm line of cotton. J. Plant Registrations 3:293-296.

Bourland, F.M., and D.C. Jones. 2011. Registration of Arkot 0015a, Arkot 0015b, and Arkot 0016 germplasm lines of cotton. J. Plant Registrations 5:379-383.

Bourland, F.M., and D.C. Jones. 2012a. Registration of 'UA48' cotton cultivar. J. Plant Registrations 6:15-18.

Bourland, F.M., and D.C. Jones. 2012b. Registration of 'UA222' cotton cultivar. J. Plant Registrations 6:259-262.

Bourland, F.M., and D.C. Jones. 2013. Registration of 'UA103' cotton cultivar. J. Plant Reg. 7:135-139.

Bourland, F.M., and D.C. Jones. 2014a. Registration of Arkot 0111, Arkot 0113, and Arkot 0114 Germplasm Lines of Cotton. J. Plant Registration 8:68-72.

Bourland, F.M., and D.C. Jones. 2014b. Registration of Arkot 0219 and Arkot 0222 Germplasm Lines of Cotton. J. Plant Registration 8:73-76.

Bourland, F.M., and D.C. Jones. 2015a. Registration of Arkot 0305, Arkot 0306, Arkot 0309, and Arkot 0316 germplasm lines of cotton. J. Plant Registrations 9:94-98.

Bourland, F.M., and D.C. Jones. 2015b. Registration of Arkot 0403ne, Arkot 0409, and Arkot 0410HG germplasm lines of cotton. J. Plant Registrations 9:353-357.

Bourland, F.M., and D.C. Jones. 2017. Registration of Arkot 0502ne, Arkot 0504ne, Arkot 0506ne, and Arkot 0517HG Germplasm Lines of Cotton.. J. Plant Registrations 11:66-70.

Bourland, F.M., and D.C. Jones. 2018a. Registration of 'UA107'okra leaf cultivar of cotton. J. Plant Registrations (in press).

Bourland, F.M., and D.C. Jones. 2018b. Registration of 'UA114' cultivar of cotton. J. Plant Registrations (in press).

Bourland, F.M., and D.C. Jones. 2018c. Registration of Arkot 0705 and Arkot 0711 cotton germplasm lines. J. Plant Registrations (accepted).

Bourland, F.M., C. Cook, and D.C. Jones. 2018. Registration of Arkot 0611, Arkot 0617, Arkot 0712 cotton germplasm lines. J. Plant Registrations (submitted).

Bourland, F.M., J.T. Johnson, and D. Jones. 2005. Registration of Arkot 8712 cotton germplasm line. Crop Sci. 1173-1174.

Bourland, F.M., R. Hogan, D.C. Jones, and E. Barnes. 2010. Development and utility of Q-score for characterizing cotton fiber quality. J. Cotton Sci. 14:53-63.

Bourland, F.M. and J.M. Hornbeck. 2007. Variation in marginal bract trichomes on Upland cotton. J. Cotton Sci. 11:242-251.

Bourland, F.M., J.M. Hornbeck, A.B. McFall, and S.D. Calhoun. 2003. A rating system for leaf pubescence of cotton J. Cotton Sci. 7:8-15.

Bourland, F.M., N.P. Tugwell, D.M. Oosterhuis, and M.J. Cochran. 2008. Chapter 2. Initial development of the COTMAN program. pp. 15-20. *In* D.M. Oosterhuis and F.M. Bourland (eds) COTMAN™ Crop Management System. Publ. Univ. of Ark., Ark. Agri. Exp. Sta., Fayetteville, AR.

Bourland, F.M. and C.E. Watson, Jr. 1990. COTMAP, a technique evaluating structure and yield of cotton. Crop Sci. 30: 224-226.

Bourland, F.M. and B.A. Waddle. 1988. Cotton Research Overview-Breeding. Ark. Farm Research. Vol. 37, No. 4, p.7.

Bourland, F. M. and B. W. White. 1989. Registration of Miscot 7803-51 and Miscot 7803-52 germplasm lines of cotton. Crop Sci. 29: 242-243.

Bowman, D.T., F. Bourland, and V. Kuraparthy. 2016. Measuring maturity in cotton cultivar trails. J. Cotton Sci. 20:40-45.

Brannen, C.O. 1934. Cotton. pp. 9-14. *In* Summary of Research, 1887-1933. Forty-fifth Annual Report. University of Arkansas College of Agriculture Agricultural Experiment Station. Bulletin No. 297.

Bridge, R.R. 1986. Registration of 'DES 119' cotton. Crop Sci. 18:523.

Brown, H.B., and J.O. Ware. 1958. Cotton. 3rd edition. McGraw-Hill Book Company, Inc. New York, Toronto, London. 566 pages.

Fulton, N.D. and B.A. Waddle. 1959. A serious disease of cotton – the Fusarium-nematode complex. Ark. Farm Research Vol. 8, No. 3, p. 12.

Groves, F.E., and F.M. Bourland. 2010. Estimating seed surface area of cottonseed. J. Cotton Sci. 14:74-81.

Groves, F.E., F. M. Bourland, and D.C. Jones. 2016. Relationships of yield component variables to yield and fiber quality parameters. J. Cotton Sci. 20:320-329.

Hinkle, D.A. 1974. The Department of Agronomy. Ark. Farm Research Vol. 23, No. 6. pp. 6-7.

Hodson, E.A. 1920a. Lint frequency in cotton with a method for determination. University of Arkansas College of Agriculture Agricultural Experiment Station. Bulletin No. 168. 11 pages.

Hodson, E.A. 1920b. Results of seven years of pedigree selection in Trice cotton. University of Arkansas College of Agriculture Agricultural Experiment Station. Bulletin No. 171. 27 pages.

Humphrey, L.M., D.B. Shank, C.A. Moosberg, and J.L. Dameron. 1950. Arkot 2-1, the new Arkansas cotton. University of Arkansas College of Agriculture Agricultural Experiment Station. Report Series 19. 8 pages.

Hunter, R.C., and B.A. Waddle. 1958. Cotton varieties resistant to boll weevils a possibility. Ark. Farm Research, Vol. 7, No. 6, p. 12.

Jenkins, J.N., and F.D. Wilson. 1996. Host plant resistance. p. 563-597. *In* E.G. King et al. (ed.) Cotton insects and mites: Characterization and management. The Cotton Foundation, Memphis, TN.

Johnson, B. 1939. Apparatus for measurements of lengths of cotton fibers. University of Arkansas College of Agriculture Agricultural Experiment Station. Bulletin No. 381. 22 pages.

Lincoln, C., and B.A. Waddle. 1966. Insect resistance of Frego-type cotton. Ark. Farm Research. Vol. 15, No. 1, p.5.

Moosberg, C.A. 1953. Breeding cotton resistant to bacterial blight disease. University of Arkansas College of Agriculture Agricultural Experiment Station. Bulletin No. 534. 21 pages.

Moosberg, C.A. 1956. Cotton breeding with special emphasis on coarseness and maturity. University of Arkansas College of Agriculture Agricultural Experiment Station. Bulletin No. 581. 54 pages.

Moosberg, C.A. 1968a. Rex Smoothleaf 66, a superior cotton. Ark. Farm Research Vol. 17, No. 3. p. 5.

Moosberg, C.A. 1968b. Rex 61-28, a new cotton variety. Ark. Farm Research. Vol. 17, no. 5, p. 3.

Moosberg, C.A., and B.A. Waddle. 1961. Breeding stripper cotton for Arkansas. Ark. Farm Research. Vol. 10, No. 6, p. 3.

Pope, O.A. 1936. Length-diameter relationships in cotton fiber. University of Arkansas College of Agriculture Agricultural Experiment Station. Bulletin No. 327. 22 pages.

Shank,D.B. 1948. Cotton variety tests, 1941-1945. University of Arkansas College of Agriculture Agricultural Experiment Station. Bulletin No. 475. 80 pages.

Smith, C.W. 1983. Registration of UArk1 and UArk2 cotton germplasm. Crop Sci. 23:1226-1227).

Smith, C.W. 1988. Registration of ‘Arkot 518’ upland cotton cultivar. Crop Sci. 28:190.

Smith, C.W., and B.A. Waddle. 1976. New Rex, a new cotton for Arkansas. Ark. Farm Research. Vol. 25, No. 4, p. 3.

Smith, K.B. 1975. The Southeast Branch Experiment Station. Ark. Farm Research. Vol. 24, No. 5, pp. 5-6.

Stewart, J.McD., 2010. Germplasm resources for physiological research and development. pp. 19-23. *In* J. McD. Stewart, D.M. Oosterhuis, J.J. Heitholt, and J.R. Mauney (ed.). Physiology of cotton. Springer Science+Business Media. Sordrecht, Heidelbrecht, London, New York.

Taylor, M.H. 1975. The Northeast Branch Station. Ark. Farm Research. Vol. 24, No. 5, pp. 8-9.

Waddle, B.A. 1957. Rex, a new Arkansas cotton. Ark. Farm Research. Vol. 6, No. 3, p 5.

Waddle, B.A. 1961a. Cotton breeding in Arkansas. Ark. Farm Research Vol. 10, No. 3, p. 3.

Waddle, B.A. 1961b. Response of Rex cotton to early defruiting. Ark. Farm Research Vol. 10, No. 6, p. 6.

Waddle, B.A. 1971. Earliness of Frego-bract cottons. Ark. Farm Research Vol. 20, No. 6, p. 4.

Waddle, B.A. 1984. Crop growing practices. pp. 234-263. *In* Cotton. R.J. Kohel and C.F. Lewis (eds). American Society of Agronomy. No. 24 in the series Agronomy.

Waddle, B.A. and M. Appleberry. 1970. Lint quality of late-set bolls. Ark. Farm Research Vol. 19, No. 3, p. 2.

Waddle, B.A., N.D. Fulton, and V.H. Young. 1955. Verticillium wilt disease of cotton. Ark. Farm Research Vol 4, No. 4, p. 2.

Waddle, B.A. and C. Hughes. 1964. Comparative fiber properties of selected stripper-type cotton strain. Ark. Farm Research Vol. 19, No. 6, p. 3.

Ware, J.O. 1927. The inheritance of red plant color in cotton. July 1927. University of Arkansas College of Agriculture Agricultural Experiment Station. Bulletin No. 220. 80 p.

Ware, J.O. 1929a. Cotton spacing. I. Studies of the effects on yield and earliness. January 1929. University of Arkansas College of Agriculture Agricultural Experiment Station. Bulletin No. 230. 84 p.

Ware, J.O. 1929b. Cotton breeding studies. I. Inheritance of fiber length, II. Heritable relationship of red plant color and leaf shape. June 1929. University of Arkansas College of Agriculture Agricultural Experiment Station. Bulletin No. 220. 38 p.

Ware, J.O. 1929c. Cotton breeding, spacing, and variety tests. pp. 33-37. *In* Forty-first Annual Report, December 1929. University of Arkansas College of Agriculture Agricultural Experiment Station. Bulletin No. 246.

Ware, J.O. 1930. Cotton spacing. II. Effects of blooming and earliness, fruit set, and yield. June 1930. University of Arkansas College of Agriculture Agricultural Experiment Station. Bulletin No. 253. 64 p.

Ware, J.O. 1933. Genetic relations of red plant color, leaf shape, and fiber colors in Upland cotton. May 1934. University of Arkansas College of Agriculture Agricultural Experiment Station. Bulletin No. 294. 60 p.

Ware, J.O. 1934. Genetic relations of Nankeen lint to plant color and leaf shape in Upland cotton. May 1934. University of Arkansas College of Agriculture Agricultural Experiment Station. Bulletin No. 230. 44 p.

Ware, J.O. 1937. Plant breeding and the cotton industry. pp. 657-744. *In* 1936 United States Department of Agriculture Yearbook. U.S. Government Printing Office, Washington, D.C.

Ware, J.O. 1941. Genetic relations of sparse lint, naked seeds, and some other characters in Upland cotton. University of Arkansas College of Agriculture Agricultural Experiment Station. Bulletin No. 406. 31 pages.

Ware, J.O. 1952a. Origin, rise and development of American Upland varieties and their status at present. University of Arkansas, Department of Agronomy, Fayetteville, AR (Processed.)

Ware, J.O. 1952b. Origin and performance of principal cotton varieties in Arkansas. June 1952. University of Arkansas College of Agriculture Agricultural Experiment Station. Bulletin No. 527.

Ware, J.O. 1952c. Breeding varieties of cotton for mechanical picking. Ark. Farm Research, Vol. 1, No. 4, p.3.

Ware, J.O., and V.H. Young. 1934. Control of cotton wilt and "rust". University of Arkansas College of Agriculture Agricultural Experiment Station. Bulletin No. 308. 23 pages.

Ware, J.O., V.H. Young, and George Janssen. 1932. Cotton wilt studies. III. The behavior of certain cotton varieties grown on soil artificially infested with the cotton wilt organism. University of Arkansas College of Agriculture Agricultural Experiment Station. Bulletin No. 269. 51 pages.

Williams, W. 1975. The Delta Branch Station. Ark. Farm Research. Vol. 24, No. 6, pp. 8-9.

Young, V.H., N.D. Fulton, and B.A. Waddle. 1959. Factors affecting the incidence and severity of Verticillium wilt diseass of cotton. University of Arkansas College of Agriculture Agricultural Experiment Station. Bulletin No. 308. 26 pages.

Zhang, J.F., and J. McD. Stewart. 2001. CMS-D8 restoration in cotton is conditioned by one dominant gene. Crop Sci. 41:283-288.