PUBLIC BREEDING IN THE SOUTHEAST

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Introduction

Thank you for the opportunity to participate in the 50th anniversary of the Cotton Improvement Conference at San Diego, CA. It is good to know that you are still remembered after over 10 years of retirement. That is not always the case. I got out of my car at the Shelburne Museum, Burlington, VT. and noticed a tour bus unloading passengers. To my surprise, off stepped H. B. Cooper and his wife. I immediately hollowed, "When did they let you out of California, 'Coop'? He came over and we shook hands just like long time coworkers should do; however, he looked at me and said, "I would know that face any where, but for the life of me, I can't place it with a name." If I can't come up with one of your names during this meeting, simply chalk it up to being out of circulation for too long.

I need to clear up an important point before I begin. I was watching the History Channel on TV and the speaker was describing how easy it is today to massage historical happenings and make them palatable to the listener. I want you to know that I have disregarded palatability, but have massaged my brain to recall happenings and hope that I haven't strayed too far from the truth. Most public breeders understand that we had to work under many rules, regulations and laws. I don't think that I ever broke any of them, but I certainly bent a bunch of them out of shape to get the job done. Forgive me if I have bent the truth out of ignorance or memory failure.

I came to work on the Cotton Improvement Program at the Pee Dee Experiment Station, Florence, SC, 28 February 1968. I had met Billy M. Waddle, Branch Chief, Cotton Division, USDA, at the 1967 Agronomy Meetings in Washington, D.C., and he asked me if I would be interested in going to work at Florence. I went to Florence over the Thanksgiving Holidays, met with Cuttino Harrell, talked with him about the breeding program and became very interested in the job. Because I had been involved with several exercises in futility and could not see my breeding progress until I dug the peanut plants, I contacted Billy, told him that I liked the opportunity to work with cotton, and if he would get me a grade raise, I would be his new Florence man. Billy got what I asked and Florence became my home for some 20 years. The move to Florence was one of the best decisions that I ever made.

I attended most of the Cotton Improvement Conferences from 1969 until my retirement in January 1987, and was an active participant most years. If I did not give a paper at a conference, I was always accused of causing some problem or letting everyone know that I was around. It was Cuttino Harrell who forgot to bring his slides and paper to the 1974 Cotton Improvement Conference at Dallas TX, but the next year Bob Bridge accused me of being forgetful, borrowing some slides from Bill Meredith, and making a better talk than if I had brought my own material.

I don't know why my slides always worked wonderfully at home, but would sometimes misbehave during a presentation at the conference. During one of my presentations of a paper, a slide stuck and Johnie Jenkins went to help Jack McCarty get everything straightened out. The next thing that I saw was three or four of my slides jump out of the carousel and fly across the room. Everyone had a big laugh and it was obvious that they were much more interested in my predicament than what I had to report. After that incident, which I had nothing to do with, no one slept when I had the floor.

Researchers working in the eastern states always seemed to have difficulty finding funds to attend conferences in the western states. (I believe supervisors thought that we were only trying to find an excuse to go on a western vacation.) It's funny that there were always several supervisors at the western meetings that knew nothing about cotton. (That always made me wonder who was looking for a vacation). In 1973, we were informed from the Area Office that there were not sufficient funds for Cuttino and me to travel to the Cotton Conferences in Phoenix, AZ; therefore, we stayed at home, but told everyone why we were not attending. Shortly after the meetings were over, the Area Director called and wanted to be informed whenever we were told that there were no funds for travel to the Cotton Improvement Conferences. Never again did we have lack of funds as the excuse for travel.

It was my privilege to be the Chairman of the 1980 Cotton Improvement Conference held in St. Louis, MO. You haven't lived until you try to get all the papers scheduled properly for the various sessions to everyone's satisfaction, collect and edit them for style and content, and returned to the Editor on time for publishing. Jim Brown and his secretary, Bonnie, were most helpful at every turn. It was my experience that the conferences were most helpful to researchers in obtaining new information, formulating ideas, and cementing relationships that have lasted a lifetime.

Some Early Recollections

My first experience with Cotton Research came in 1951 when I received an assistantship to attend graduate school at Texas A&M College (now Texas A & M University). The Texas Cottonseed Crushers Association at Dallas, TX put up the funds for the scholarship to study (work) with Murray L. Kinman developing alternative or new oilseed crops, primarily sesame. Murray considered that graduate students were extra hands and cheap labor. I must admit

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that this was as close to cotton as I ever hoped to get because I grew up on a South Carolina cotton farm and will never forget the horrible, backbreaking work required to grow the crop in the 1930's and 40's.

I soon found out that Texas A&M was considered by many researchers to be the only center of cotton research in the world. On my first day at A&M, I helped Murray move offices from the first floor of the Agronomy Building to more spacious quarters on the first floor of the Red Building next door. I never really found out if we needed more space or if T. R. Richmond wanted the entire first floor for his cotton empire. He made no bones about believing that the Texas Cottonseed Crushers Association would have gotten more from their funds if they had given them to his organization.

Tom Richmond lived up to my expectations of a typical Texas Cowboy. He was tall, lanky, and rolled his own Marlboros. Murray introduced us during the moving process. Tom was busy getting ready to smoke. He offered us the makings. I rolled one and lit it up while Murray spilled half-a-sack of tobacco on the floor. Tom's only remarks were: "I guess you will do if you don't get to be too much like Murray Kinman".

In addition to Tom Richmond, Charles F. Lewis, Mada S. Brown, Margaret Y. Menzel, Paul A. Frexell, and John E. Endrizzi, were part of the Cotton Team at Texas A&M. There were other distinguished cotton research workers in the process of leaving for other employment. C.W. 'Bill' Manning was closing out his work and moving to the Stoneville Pedigreed Seed Company at Stoneville, MS to replace Dr. J. W. 'Jim' Neely who had taken a position with Coker's Pedigreed Seed Company at Hartsville, SC. Dr. Neely's position was the talk of the town throughout the Cotton Belt because rumor had him moving for the unheard of salary of $15,000/year. Being on an assistantship of $1800/year, $15,000/year was something to dream for in the future. (Henry Webb said he was not sure that Dr. Neely got such an offer because Mr. Coker didn't throw money around to anyone). In addition, Dr. Harold D. Loden came by in route from the University of Georgia, Athens, GA to Anderson Clayton, Plainview, TX to give a seminar, *Hybrid vigor in cotton-cytogenetic aspects and practical applications.*

I soon found myself in classes with such distinguished and renown students as Billy M. Waddle, Warner Fisher, Warren W. Bradford, Dave Ranney, Lambert Wilkes, Luther S. Bird, and several Egyptian and Indian students who later distinguished themselves in various fields of cotton research. One afternoon while putting up planting seed at the Field Laboratory, we heard an awful racket down in the cotton nursery. Tom Richmond was swearing, berating, and threating to kill one of the Indian students working on his project. Tom and the entire cotton crew, including Charlie Lewis, were transplanting greenhouse material to the field for this student's thesis. It was hot and very humid and when they looked for the student whose thesis material they were planting, he could not be found. A search of the field, trucks, and nearby grounds found the student asleep under a sassafras bush. When asked why he was not helping with the transplanting, his only reply was, "I do not have to do this in my country". This was the straw that broke the camel's back and set Tom off on a tirade. That Indian doesn't realize to this day how close he was to being shipped home, and I would have hated to have Tom as the chairman of my graduate committee under the circumstances.

Tom Richmond served on my graduate committee, and although he never let me forget that I was there on cotton money, I got my MS degree in plant breeding 23 January 1953. In June 1954, I completed the course work for the PhD in plant breeding, was offered and accepted a position as an Agent with USDA working with Murray L. Kinman on Oilseed and Special Crops and finishing my dissertation in my spare time. Although Murray was a nonconventional teacher and often a controversial plant breeder, he taught me to question textbook methods and established techniques of plant breeding. He furnished excellent hands-on-experience in field plot techniques, statistical designs, and procedures for maintaining and utilizing genetic purity and diversity. On 24 August 1956, I received the PhD in plant breeding.

In December 1957, I was transferred to the Delta Branch Experiment Station, Stoneville, MS to develop sesame and castors adapted to that area, and began the fight with cotton personnel for plot land, equipment, and farm labor. Mr. J. B. 'Jimmy' Dick was bad about taking equipment that he might use and hiding it behind or in the Genetics Building. Other cotton personnel at the station when I arrived, in addition to J. B. Dick, were James R. Meyer, Vesta G. Meyer, Norman Justus, Harry Carnes, Bruce Roark, Murrill N. Christiansen, O. B. Wooten, Bufort Williamson, and a number of Cotton Entomologists and Ginning Specialists. Someone reported that there were over 60 Entomologists working on cotton and that insect pests got worse every year. John Greene had just left the station for South America. H. H. Ramey was away at North Carolina State working on his PhD. He returned for a short period before accepting a position with the National Cotton Council in Memphis, TN. W.R. Meredith and R. R. Bridge came to work at the station just before I was transferred to Virginia. On several trips back to College Station for work reviews with Murray Kinman, I met and got to know Russell J. Kohel and Thomas G. White.

I made a trip by car in February to the First Plant Breeding Symposium at Iowa State University, Ames, IA with Drs. Paul Rothman and (of all people) Jim Meyer. Besides fighting the snow and listening to Jim talk most of the days, it was an experience that I will never forget. The symposium was one of the best that I ever attended and gave us the opportunity to meet famous plant breeders from around the world. I will never forget that during the "Question and Answer" periods you could always count on at least one question from Brubaker! Hawaii. Drs. Brubaker and Walt Gregory, Peanut Breeder (mutations), got into a heated argument over the value of mutation breeding and the validity of the mathematical explanation of what had occurred.

On the way home, Jim kept saying that we had to stop by Columbia and St. Louis, MO to see 'Ernie' and 'Andy'. 'Ernie' turned out to be Dr. E. R. Sears, the famous wheat researcher. We spent most of Saturday with him discussing his research and observing his facilities. I was surprised to see that he was using an old greenhouse with antique tools and equipment. I learned a great lesson that day. New equipment and new buildings do not equal good research. We drove on to St. Louis and visited with 'Andy', Dr. Edgar Anderson, Director of the St. Louis Botanical Garden. It was a pleasure having Dr. Anderson show us through the Climatron, describe the plants, explain his research, and listen to his and Jim's learned discussions on numerous subjects.

Life in Mississippi was very good to me. Dr. Leroy Zimmerman and I had almost developed a method, using heat sensitive germplasm, for commercial production of hybrid castors. (I almost became as famous as J. B. Weaver.) I had also found a source of resistance to leaf disease and capsule mold that, when transferred to productive cultivars, should make castors suitable for production in humid areas similar to the Mississippi Delta. The Mississippi Delta is an outdoorsman's paradise and, even though I worked hard and fished or hunted most of my off-hours, I found time to marry Jane Goodwin 7 May 1960. My daughters, Robin Anne and Catherine Jane, were born 2 April 196l and 18 April 1964, respectively, in Greenville, MS.

Everything was going smoothly when the first *Black Friday* hit us in 1964 when USDA decided to discontinue investigations of Oilseeds and Special Crops. Castor breeding investigations were closed out at Davis, CA and Stoneville, MS and the breeding material was moved to Dr. Raymond D. Brigham at Lubbock, TX. Sesame investigation was discontinued at Stoneville and breeding material was moved to Murray Kinman at College Station, TX. Other personnel were transferred to other crops at other locations and I was fortunate (thank goodness) to be transferred, 15 June 1965, to Holland, VA to develop disease and insect resistant peanuts.

Because resistance to the corn earworm had been found and I discovered resistance to the peanut stunt virus in a screening nursery, I was rapidly in the peanut breeding business. It seemed that I was getting more than my share of efforts in futility; therefore, I was in the mood for a change when Billy Waddle offered me a position as Agronomist at the Pee Dee Experiment Station, Florence, SC. I told Billy that I needed a grade raise to make the move. When Billy discussed the move with Dr. Robert Howell, Chief of Oilseed Crops, I got the raise (an answer to one of my efforts in futility) within 3 weeks, along with much encouragement to remain at the Tidewater Experiment Station, Holland, VA.

My wife and I visited the Pee Dee Experiment Station during Thanksgiving Holidays in 1967. I spent two half-days with Cuttino Harrell looking over what was left of the plantings in the fields and discussing the work he was doing, while my wife and Cuttino's wife, 'Goodie', investigated the town of Florence. We moved there, 28 February 1968, just in time for the planting season.

Moving to the Cotton Breeding Program at the Pee Dee Experiment Station was the best professional move that I ever made. Cuttino Harrell was one of the finest southern gentlemen that I have ever met and no one could ask for a better coworker on a cotton-breeding program. He was a most diligent worker. He would stand in the field all day combing cotton fibers, measuring fiber lengths, selecting plants, and describing their characteristics on 3X5 cards. It usually took him about two months to select the F2 and F3 plants in the 10 to 15 acres of segregating progenies. You would never know that he had a heart attack in 1965; however, you could sometimes catch him taking nitroglycerin on very hot days.

Cuttino was a dedicated Christian and a faithful worker at Ebenezer Baptist Church where he often served as Chairman of the Deacons. We were on a trip to the Mid-south when the pastor decided that they had to vote immediately to build an Education Building. The Question was called and the deacons voted 60% for and 40% against. When Cuttino arrived home, the church was in an uproar. His first comment, "Preacher I wouldn't hold a church supper on such a vote. Let me do some talking." The question was put before the Church some 10 days later, and construction of the building passed unanimously. You could always depend on Cuttino to get the job done. I lost a very good friend when he passed away.

When I came to work at the Pee Dee Experiment Station, Dr. John Pitner was the Superintendent. He understood what cooperative research was about and helped me get the job done whenever possible. I'm afraid that Cuttino and I got the best plot land for our research and preferential treatment, which did not always endear us to the other researchers.

Only cotton breeders know that there is always something to do on a cotton improvement program. There never seem to be enough hands to get every job done on time along with adequate supervision to know that the tasks were done properly. After Cuttino retired, I was always blessed with research leaders whose training was in Entomology or Soils and Water and had no idea of the workings of a cotton breeding program. It was hard for them to understand that there is no slack time when you can sit back in your chair and daydream about the perfect experiment, write papers, and hold meetings to discuss each other's work. They would criticize me for being a hands-on researcher, but I never met a successful plant breeder who sat at his desk and sent someone else to see what the plants looked like under different field environments and to make selections for future generations.

History Of Cotton Fiber Quality

Early in the 20th century, fiber quality in cotton was associated chiefly with long staple length. The highest fiber quality came from Sea Island (*Gossypium barbadense* L.) cultivars, which were grown in northern Florida and the coastal plains of Georgia and South Carolina. Early production of Sea Island in the United States ranged from 52,208 to119, 293 bales from 1899 to 1918 (Jenkins, 1948, 1953).

There was also considerable U.S. production of extra-long staple Upland (*G. hirsutum* L.) cultivars that ranged in staple length from 31.75 to over 38.1 mm (11/4 to over 11/2 inches). This type of cotton was grown in various parts of the Mississippi Delta and occasionally in the higher yielding areas of the Southeast. Separate statistics were not kept on the U.S. production of extra-long staple Uplands.

Before fiber and spinning tests were developed, early evaluation of cotton fiber quality came only through the experience of textile manufacturers. . Perkins, et al.(1984) state that the terms Sea Island, Santee, and Short Staple were used in Charleston, S.C. in 1816 as a basis for price quotations. Within the extra-long staples, mills recognized the superiority of Sea Island cotton and paid a premium for it in the market place. Extra-long staple cultivars of Egyptian (*G. barbadense* L.) cotton were generally more variable and were considered not equal in quality to Sea Islands. Extra-long staple Uplands were recognized by the mills as below Sea Island and Egyptian standards; however, they were bought at a lower price and had many uses in fine quality goods.

Ware and Harrell (1963) point out that Baines' (1835) and Scherer's (1916) description of the hand manufacture of cotton in ancient India, fineness of fiber was recognized as a major factor in the spinning of fine yarns. Fineness, or silkiness, of cotton lint, along with great strength and length of fibers, as found in Sea Island, Egyptian, and Pima (all *Gossypium barbadense* L.), or extra-long staple uplands (*G. hirsutum L.*) has been the basis of the fine-cotton spinning industry since the advent of the factory system. In short- and medium-staple uplands, fineness was not given much consideration as a factor in facilitating finer spinnings until about 50 years ago. Webb (1936) demonstrated that Sea Island fibers cut to the length of ordinary upland cotton produced yarn that had comparable strength as the long, fine cottons. Strength of yarn appeared to be more a result of fineness rather than length of fiber. Webb (1936) found that remarkably fine and strong yarns could be spun from naturally short and fine upland cottons. On one of the visits Cuttino's and I had with D. M. Simpson when he was at the Presbyterian Home at Summerville, SC, I mentioned reading this reference. His only remark was that it won't work and you are wasting time trying it. I've thought about that on a number of occasions and decided that our breeding for short stable cottons with extra fiber strength generally had finer fiber and matched this work perfectly. Modern U.S. spinners, however, prefer fineness of lint of uplands in an intermediate range rather than extremely fine or course. Yarns from extremely fine lint of uplands are apt to contain more neps. Extremely fine fibers are often mistaken and docked in the market place as immature cotton. Yarns from extremely coarse lint are likely to have less strength and rough texture. Thus, breeders of Upland and Pima cottons maintain fiber fineness within an acceptable range and spend very little effort in improving yield or fiber quality with this character. Dussen (1987) and Faerber (1995) have made a plea for cotton breeders to develop short staple cottons with fine and strong fibers to accommodate open-end spinning. There must be some monetary consideration to the farmer for growing this type of cotton and some money guarantee before breeders will tackle the problem.

On our visits with D. M. Simpson, I met Mrs. Sophia Jenkins, Mr. Willie Jenkin's wife and her sister, who were living at the Summerville Presbyterian Home. It was old home week for Cuttino, and I enjoyed the conversations about happenings on Johns Island and in Florence years ago. After Mr. Jenkins retired in the mid-fifties (1957?), he returned to the home place at Rockville, SC, and while fixing a pasture fence, had a heart attack and died. After Mr. Jenkins' retirement, Cuttino shifted the breeding emphasis to short staple cottons with extra strong fibers. Cuttino said that Bill had worked with Sea Island and Extra-long Staple Uplands so long that he could not bring himself to select a short staple cotton, much less propagate one.

In the United States, Sea Island cotton in general grew rank, was late maturing, and produced lower yields compared with Uplands. These characteristics made Sea Island cultivars poorly adapted to the ravages of the boll weevil (*Anthonomus grandis* Boheman) which first migrated into the southeastern U.S. in 1918. With the advent of the boll weevil, Sea Island production declined rapidly, and by 1922 the crop was abandoned in the United States (Jenkins, 1953; Culp and Harrell, 1974).

Dr. J. O. 'Jake' Ware (1937) published a very good early history of cotton breeding in the U. S. in the 1936 Year Book of Agriculture. It was interesting for me to learn that USDA began cooperative cotton improvement programs with the cotton producing states in 1935 and 1936. We are indebted to him for otherwise, this history would have been lost. I am taking the liberty to summarize some of this work and include the list of cotton breeders in the US in 1936 (Table 1) in order that you might have it here as a reference in one publication.

Dr. Ware retired from the USDA before I came to work at Florence; however, some of his old work clothes and crossing paraphernalia were in the gin room at Florence until we moved to the new Pee Dee Station in 1976. I was fortunate to meet Dr. Ware at his home at Fayetteville, AK during an S-77 meeting at that location. Billy Waddle, Tom Kerr, Hob Ramey, Cuttino Harrell, John Turner, and I went by after lunch for a quick visit. Dr. Ware had just gotten out of the hospital, but he was in good spirits and had to send out for a bottle of bourbon so that he could have a last drink with old friends. Of course, I was the young squirt driving the government car and had to pass up the honor.

Public Cotton Breeding In The Southeast

Cotton Breeding In North Carolina

Ware (1937) reported that R. Y. Winters began cotton breeding and improvement studies at the North Carolina Agricultural Experiment Station in 1914, over 80 years ago. He obtained 'Hope Mexican Big Boll' from J. D. Hope of Sharon, SC that was intermediate in maturity, ranked high in yield, was easy to pick, had short staple, lint percentage of about 35, and large, gray to brown seed. In addition, he worked with the cultivar King, an early, small-boll type grown extensively at that time in North Carolina.

Selfed lines from both types of cotton were developed and maintained through several generations. Several strains of 'King' were developed and distributed to farmers, but none were as satisfactory as the strains of Mexican Big Boll. 'Mexican 6' and 'Mexican 18' were introduced to farmers in 1920 and were widely grow for several years. 'Mexican 87' was developed from Mexican 18, and 'Mexican 128 and 'Mexican 58-14' were developed from Mexican 6 to guard against the cultivars "running out". These strains were developed from single plant selections by the plant to row and progeny test methods.

Ware (1937) wrote that P. H. Kline, V. R. Herman, and S. W. Hill assisted Winters in the breeding work. When Winters became director of the station in 1925, Kline took charge of the breeding and cotton improvement studies. These researchers conducted similar improvement studies with the Cleveland cultivars, and yield tests showed significant improvements in quality and yield. Herman and Hill accepted employment by the Edgecombe Seed Breeders Association of Tarboro, NC and sold these improved cultivars to farmers from 1921 to 1926.

Ware (1937) listed the cotton breeders of North Carolina in 1936 at Raleigh as P. H. Kline, (Federal and State cotton breeder) and J. H. Moore (Cotton breeding in reference to fiber). Cooperative breeding and improvement work between USDA and North Carolina was begun in 1935. It was about this time that Tom Kerr came to N.C. State as a Federally employed botanist (morphologist) and moved into his wife Elizabeth's home place near Meredith College. Tom would not have appeared on Wares' list even though he was at Raleigh, because he was not considered a plant breeder, but a botanist.

According to a telephone conversation with H. H. 'Hob' Ramey on the night of 3 December, 1997, I obtained the historical happenings that occurred at NC State in the late 1930's. Thomas Kerr received his BS, MS, and PhD from the University of Pennsylvania and taught for a few years at NYU. At this time, he became associated with a scientific group of researchers (may have been Buscey Institute) under the direction of Dr. (Liberty Hyde??) Bailey at Harvard University just before he came to NC State.

During this period, J. O. Beasley graduated from Texas A&M and went to Harvard for graduate studies. He wanted to work on cotton improvement, but Boston, MA was not an ideal location for cotton production. Because Drs. Bailey and Tom were research associates and good friends, Beasley cut the deal for two major professors. Dr. Bailey took the responsibility of directing his course work at Harvard, and he did his research for his dissertation under Tom Kerr's direction at NC State.

Beasley had already decided that he wanted to determine the origin of American tetraploid Cottons of the New World for his research project with Tom. In Kerr's graph (Figure1), Beasley made the first cross between *G. arboreum* L. (A2) X *G. thurberi* Tod. (D1) in 1938 and doubled the chromosomes with colchicine that same year. Colchicine treatment for the doubling of chromosomes had just been discovered. The chromosomal designation for this hybrid then was (A2D1) which Beasley crossed to the Upland (AD)1 cultivar, Coker 100 inbred in 1939. Tom Kerr remarked that he never saw Beasley so happy as the morning he walked into his office with the first triple hybrid flower. Beasley backcrossed the triple hybrid to Coker 100 inbred twice in 1940 and 1941, respectively. He published the results of this study in the American Naturalist (Beasley, 1940).

Hob Ramey told me that after Beasley published his findings, Tom Kerr went to a National meeting and Dr. Kearney, (USDA) would not speak to him because he was involved with Beasley's work. Dr. Kearney strongly supported the studies of Drs. J. M. and Irma Webber at Riverside, CA. They had made similar crosses to show the origin of cotton and were near the completion of their study when Beasley reported his findings. Several years passed before Dr. Kearney spoke to Tom Kerr.

Sometime in the late 1930's or very early 1940, Beasley received his PhD from Harvard University and returned to Texas AM as a professor (state employed) working on cytogenetics of cotton. It should be pointed out that Dr.

Beasley was back in Texas when he published his important papers. Dr. W. C. 'Bill' Manning went to Texas A&M in 1940 (57 years ago) for his MS under Dr. Beasley. He remembers that Dr. Beasley was a unique and very studious person. He did not have time to cut his lawn (hired an "Aggie" to do it) because he wanted to read and think. 'Bill' said that when he found out that he was having to leave for the army, he suggested that Texas A&M hire someone to keep his work going. He suggested only two people in the US that were capable of this task that he would recommend and they were working in crops other than cotton. Dr Manning could not remember their names. I think it is a shame that Dr. David Stelly spends less than 35% of his time working on cytogenetics of cotton and he is the only cytogenetist working on this crop in the US. Dr. Manning still remembers (its hard to forget the heat of Texas summers) making numerous crosses with the Triple Hybrid material for Dr. Beasley to integrate desirable characters into Upland cotton.

W. R. Meredith (Culp, 1982) accused R. R. Bridge and me of being *SERENDIPITY* breeders because we could not explain why we made certain crosses that produced excellent results. He also stated that we didn't plan our successes, but were just plain lucky. Bridge's reply was that it is much better to be lucky than smart. Meredith believed that no man in his right mind would have made a cross with such a worthless line as C6-5 (Anon., 1960) just because it had a high lint percentage. Bob Bridge and I were pleased to be called serendipity breeders because it put us in a class with such outstanding scientist as Dr. J. O. Beasley. Beasley demonstrated the origin of tetraploid cotton, which was a major scientific find in itself, but the serendipity of extra fiber strength in this material was no doubt of much greater economic value to the cotton industry. It is amazing to me that *G. thurberi* germplasm would have such an effect on fiber strength because it has naked seed. When working with *G. thurberi* plants, we had to bag the bolls to keep the seed from falling to the ground.

Thus, it was at N C State that Dr. J. O. Beasley (1940) made the now-famous Triple Hybrid cross and, therefore, became North Carolina's most famous Cotton Breeder, although very few people, including most cotton researchers even in North Carolina, know this fact. He simply wished to show that American tetraploid cottons were the result of the union of the A genome of the Old World with the D genome of the New World cottons. Fryxell (1969) has discussed the distribution of tetraploid cottons which occurs naturally only in the Americas. He has also given the phylogeny of the diploid species of *Gossypium* L. genomes found in the Old World (A, B, E, and F) that are vastly different from the D genomes found in the New World (D). The Australian cottons have also evolved into different genomes, C and G; however, Fryxell suggests a common origin. Beasley (1940) did not speculate as to how Old and New World cottons got together. Others have suggested that seed of Old World cottons were brought to the New World by birds or even early man. Others suggest that hard seed of old world cottons floated the several thousand miles to germinate in the soils of Central or South America and were united with diploid American cottons of the D genome living there. With the more recent plate theory of continental drift, it is more logical that cottons of the world had a common origin in Africa, India, or another site in the Old World. As the earth plates shifted on the molten core of the earth, North and South America may have broken away from the present landmass of Europe and Africa. Since wild life and vegetation in Australia is so different from the rest of the world, it is believed that Australia shifted from the land- mass that we know today as the South Pole. The South Pole may have been connected with today's Africa, India or even China. Vast differences in climatic conditions on the various land masses probably account for the genome variation in the old and new world, as well as Australia, over the period of eons. Differences in climatic conditions may also be responsible for the doubling (tetraploid conditions) of the chromosome of the union of the A & D genomes. Proponents of the plate theory of land distribution use the origin of tetraploid cotton and the distribution of the cotton genomes as strong support for their theory.

With the successful making of the triple hybrid cross and demonstrating the origin of tetraploid cotton, Beasley set out to utilize the useful genetic variability in this material. Unfortunately, Beasley had taken ROTC while at Texas A&M College for extra money to attend college, and obtained a commission as an officer in the U.S. Army. Dr. Manning remembers that Beasley was called into service just before he received his MS in 1942. In fact, Dr. Beasley was not there for his final examination because he had to report for duty in the U. S. Army. Dr. Beasley was killed some time during the invasion of Palermo, Sicily, from 10 July to 19 August 1943.

When I was at Texas A&M, A yellow brick building east of the Agronomy Building was named the ***Beasley Laboratory*.** It was in this building that the Cotton Cytogenetists were housed. Drs. Russell Kohel and David Shealy tell me that the building is no longer used for cotton research. The Cytogenetics Laboratory that David uses for his work was not officially named the Beasley Laboratory because, to name a building at Texas A&M, someone has to come up with thousands of dollars. The plaque, ***Beasley Laboratory,*** was moved to the new building and the name (Beasley laboratory) has caught on.

Dr. Manning got his MS at Texas A&M in 1942 and took a plant breeding position (state) at Texas A&M, where he continued to work on intergrating triple hybrid strength to upland cotton as initiated by Dr. Beasley. He also had other breeding objectives for cultivar improvements, and the large populations of essentially worthless plants that came out of triple hybrid crosses were a detriment to the overall program. Except for several six month leaves of absence to obtain his PhD from Iowa State, Bill remained at Texas A&M until 1951, when he replaced Dr. J. W. Neely as cotton breeder for Stoneville Pedigreed Seed Company. Bill said that he took some of this triple hybrid material with him to Stoneville and also shared it with Dr. C. Hoyt Rogers, Tobacco Breeder for Coker's Pedigreed Seed Company, who was at Texas A&M for studies in cotton research. There is no firm evidence that this germplasm was useful in cultivar development. Culp et al. (1992, 1993) suggested that because 'Coker 413' and related material with extra fiber strength crossed so successfully with the Pee Dee material, it might be closely related genetically.

While at Raleigh, NC, after Beasley left for Texas, Kerr began work with the Triple Hybrid material. In 1942 and 1943 (Figure 1), he grew the F2 and F3 generations and made the fourth backcross to Upland with F3 selections. The F1 generation of one cross between an F3 selection and 'Cook 144-133 inbred' was grown in 1944. (I often wondered why Tom chose this cultivar rather than backcrossing to Coker 100W. While writing this report, I noted that the source of resistance to the fusarium wilt – rootknot nematode complex in Empire and Auburn 56 was Cook 144. Tom was probably going back to the original cultivar for resistance, or he made a large number of crosses and the F1 with Cook144-133 was most promising.) The F2 of this cross was grown in 1946 and superior F2 plants were backcrossed to Upland (Coker 100 WR). The F1 generation was increased in the1946-47 Iguala, Mexico winter nursery. The F2 nursery was grown at Raleigh, NC in 1946, and pollen from superior F2 plants TH 108,TH 171, and TH 458 was shipped to Florence, SC by railroad overnight as unopened flowers and used in pollinations the next morning. Seed of these germplasm lines were made available to bonafide cotton geneticists and breeders in 1947. Tony Peacock said that everyone in USDA, and any state employees who wanted them, got seed. The progenies from crosses with this material were so sorry that many people discarded them immediately. Although TH 108, TH 171, and TH 458 were very poor specimens of upland cotton, these germplasm lines were outstanding in fiber strength, ranging around 200 pounds skein strength of 27-tex yarn (Quoted by Harrell and Kerr) as compared with 146 to 152 for Earlistaple-7 and Sealand 542 (Table 3). It is interesting to note that these three germplasm lines are the basis for improved cultivars with extra fiber strength in the North Carolina, Georgia, California, Missouri, and Pee Dee Cotton Improvement Programs.

From telephone conversations with Drs. P. A. Miller and J. A. Lee, I believe I have most of the important dates correct. Dr. Miller went to NC State as a state corn and cotton breeder in 1952. Dr. Tom Kerr had been transferred to Beltsville, MD as Investigations Leader on Cotton Breeding and Quality a few years earlier. Dr. Henry Barker, Head of the Cotton Division, was a cotton breeder and, according to Hob Ramey, kept his hand on what all the cotton breeders were doing. Therefore, Tom was primarily involved with the improvement of fiber quality in the crop as well as improving the methods of measuring fiber and yarn parameters. At this time, Drs. John Pressley, Investigations Leader on Plant Pathology, and Hardy Tharp, Investigations Leader on Plant Physiology, made up the USDA cotton research leadership under Dr. Barker.

Dr. S. G. Stevens, Head of the Department of Genetics at NC State, was actively working in germplasm collection and speciation of cotton. He went on several explorations to Central and South America as an active member of the teams searching for new germplasm. He had come to Raleigh from the Empire Cotton Growers Association of Trinidad. Joshua Lee told me that Dr. Stevens and Tom Kerr found him (wandering around) out in California and hired him to come to NC State as USDA Cotton Geneticist with the Department of Agronomy in 1958. In a few minutes, Dr. Lee will come and discuss his excellent work in genetics of cotton that spans 29 years at NC State.

Dr. Lee is also a well-known authority on mules. If you have not read his book, *Tales of Mule I've Known,* don't fail to do so. The stories about his good friend and playmate, Prince Albert Jackson, (Prince Albert's parents took his name from a tin of Prince Albert Smoking Tobacco) are priceless. I can't wait to read his sequel, *Mules and Some Asses I've Had to Put Up With in the Cotton Business*.

Dr. Claude Rhyne was also a Federally employed cotton geneticist at NC State for several years until he was transferred to Brownsville, TX shortly before retirement.

Also, in the 1950's, Dr. Lyle Phillips came to the N C State to work on cotton improvement. He was a prolific writer in the field of cytogenetics in the 1960's and 70's. On a Cotton Breeder's Tour to Clayton, NC, Lyle showed several populations that he was maintaining to increase genetic variation in cotton. He shared seed from these plantings with a number of researchers; however, I do not recall anyone finding useful material in these populations.

After the release of TH108, TH171, and TH458, Tom Kerr crossed TH108 with the Upland cultivar, Rowden 2088 inbred in 1947 (Figure 2). In 1948 and 1949 he grew out the F1 and F2 generations. I am not sure how he managed this material, but since most of the plants were worthless, he probably selected those that produced bolls and bulked their seed. The F3 generation was grown in 1950 and F3 selections were crossed to southeastern cultivars of Upland. The cross between an F3 selection and 'Empire 8' proved to be most productive. The F1 generation was grown in the 1950-51 Iguala nursery and the F2 generation was advanced at Raleigh, NC in 1951. The F3 generation was advanced in the 1951-52 Iguala Nursery. Thus, the F1, F2, and F3 generations were advanced during the period that Tom Kerr move to Beltsville, MD and Phil Miller came to NC State. Phil Miller made F4 selections at Raleigh in 1952 and advanced them a generation in the Iguala Nursery in 1952-53. F6 selection, 134-5, proved to be the most productive selection with extra fiber strength and was crossed for the 8th time to Upland (‘Empire 10’). The F1, F2, and F3 generations were advanced in the Raleigh and Iguala Nurseries in 1953-55. In the 1955 Raleigh Nursery, Miller selected a number of F4 lines and the selection TH 149-12-4 proved to be superior. Selection in the F5 generation produced TH 149-8 and TH 149-20 that were maintained as individual germplasm lines by bulk breeding (Anon., 1967). Dr. Miller said that Dr. Josh Lee helped him with this material from 1959 to 1965 when it was released. With the increase in demand and the offer of a premium for cultivars with extra fiber strength, Seed of TH 149-8 and TH 149-20 were combined and offered for sale to growers. The seed were sold as TH149 and distributed by McNair Seed Company under an agreement with NC State. This cultivar produced about 15% less yield when compared with that of cultivars without extra fiber strength, and with the cancellation of premiums, production of TH 149 ceased. TH149 was used widely in crosses by public and private breeders in their cotton improvement programs; however, its contribution to the germplasm of commercial cultivars does not appear important (Calhoun, et al., 1997).

Henry Goza and his mother operated a cotton farm near Sumter, SC, and grew TH 149 successfully for a number of years. They liked the way it responded to their management system and would have continued to grow it, if seed had been available.

Cotton Breeding In South Carolina

Ware (1937) reported that the first breeding work done by land-grant colleges was in Alabama and Georgia, but the first cultivars were produced in South Carolina and Tennessee. When H. J. Webber, USDA, and his associates began cotton breeding work in 1898, D. R. Coker, Hartsville, SC became interested in having some of this work done on his father, J. L. Coker’s, farm. A number of hybridizations with Egyptian and Upland cultivars were made, but none of this material proved to be useful. Therefore, the work of selecting upland plants with long fiber was begun. Using a plant-to-row breeding method, cultivars developed were ‘Hartsville’, ‘Columbia, ‘Webber’, ‘Deltatype Webber’, ‘Lightning Express’, ‘Super Seven’, ‘Wilds’, and ‘Coker Cleveland’ Strains ‘Farm Relief’, ‘Coker Clevewilt’, and ‘Coker Foster’. Relationships between cultivars have been demonstrated by Ramey (1966).

In 1895, cotton growers asked USDA for help in controlling the wilt fungus that was causing damage across the cotton belt. E. F. Smith was sent to James Island, SC and spent four weeks on W. G. Hinson’s farm investigating the nature and cause of the disease. During that year, E. L. Rivers, a neighbor of Hinson, began selection for a wilt-resistant cultivar in Sea Island cotton. Considerable progress in developing resistant cultivars was made, but they had such poor fiber quality that the work was discontinued. In 1898, H. J. Webber and W. A. Orten, USDA, visited James Island and consulted with Hinson and Rivers. They encouraged Hinson and Rivers to continue their work, and in 1902, some 15 acres of the wilt resistant strain were grown. This strain was released as the cultivar, Rivers. These workers selected other cultivars that possessed wilt resistance but none of them were equal in quality to the original Sea Island cultivars.

When the work was progressing on James Island, Orten started similar studies in Dillon and Lamar, SC and in Troy and Headland, AL. In 1900, Orten began selecting for wilt resistance on the H. L. Galloway farm in Dillon, SC. The cultivar, Dillon, was developed which had excellent resistance, but had very poor yield and quality. This cultivar was widely grown on heavily infested wilt land and was used in numerous hybridizations. Similar experiments were begun by other State Agricultural Experiment Stations and these cultivars became a source of resistance to the fusarium wilt-root knot nematode complex.

J. S. Newman probably started the first scientific cultivar improvement work at the South Carolina Agricultural Experiment Station (Ware, 1937). While inspecting the segregating progeny of an ‘Allen Long Staple’ X ‘Dickerson’ cross in about 1900, he found an unusual plant that he marked with a blue cigar band. This cross, along with several others, had been sent to Newman by P. H. Mell of the Alabama Agricultural Experiment Station.

The plant marked with the cigar band was picked separately, the seed was multiplied, and the breeding stock was named the Blue Ribbon cultivar. An early, black seed segregate, found in the Blue Ribbon Stock, became the Black-Seeded Blue Ribbon cultivar. The Blue Ribbon cultivar was a semicluster long-staple type. The cluster tendency came from Dickerson and long staple from the other parent.

C. L. Newman, the son of J. S. Newman, continued the breeding work at the South Carolina Station. In 1906 and 1907, he collected a large number of cultivars, tested their suitability for line selection and hybridization, and made some 300 crosses primarily between long and short staple types. During the next few years, Newman, J. N. Harper, and Burns Gillison developed several new cultivars from these crosses. Out of the line selections, new strains of Wannamaker-Cleveland, Toole, and Russell were developed. ‘Tillman Pride’ came from a single plant selection out of Black-Seeded Blue Ribbon.

In 1911, H. W. Barre of the South Carolina Agricultural Experiment Station, and his assistant, L. O. Watson, began cooperating with Orton and Gilbert of the Bureau of Plant Industry, USDA, in breeding wilt-resistant cultivars. Through the Pee Dee Branch Station at Florence and cooperative farmers, additional improvement and distribution of ‘Dixie’, ‘Dixie-Triumph’ and other wilt-resistant cultivars was conducted. After Watson replaced Gilbert in 1914, C. A. McLendon replaced Watson and held the position from 1914-16. After McLendon resigned in 1916 and Watson in 1920, breeding work was discontinued. It was realized that several commercial breeders (Coker's Pedigreed Seed Company, Wannamaker's and others) in the state were supplying farmers with reliable and ample supplies of planting seed of adapted cultivars and the station needed to direct its efforts toward solving other problems in cotton production.

Dr. Barre held a number of positions in South Carolina and eventually became Director of the South Carolina Agricultural Experiment Station. He also served as Director of the Cotton Division, Bureau of Plant Industry, USDA. As mentioned above, Dr. Henry Barker served as his assistant and later as Director of the organization.

In 1935, as part of the U.S. Department of Agriculture's efforts to revise Sea Island cultivation (Ware, 1937), a breeding program was instituted, in cooperation with Clemson A&M College, at the Pee Dee Experiment Station, Florence, S.C. Its objectives were to develop early maturing Sea Island cultivars and extra-long staple Uplands, with fiber properties similar to Sea Island cultivars that would produce profitably in spite of the boll weevil.

When the breeding program was initiated at Florence, Mr. Willie H. Jenkins was hired as Federal Cotton Breeder and David Cuttino Harrell joined him as Federal and State Agronomist (Agent) a few weeks later. Mr. Jenkins and Cuttino both graduated from Clemson A&M College with a 3-hour course in Genetics. For their lack of scientific knowledge in the newly developing field of Plant Breeding, they compensated with long hours, hard work, and on-the-job training, which involved the trial and error method, that most of us still use today.

In a telephone conversation with Hob Ramey, he mentioned that Dr. Cook, Director of the Bureau of Plant Industry "fell-out" with the way State Land-Grant Colleges were training plant breeders, hired his own breeders, and trained them in the Bureau. Some of the Clemson men hired and trained were: (1) W. W. Ballard, (2) J. B. Dick, (3) W. H. Jenkins, (4) Julian G. Jenkins, and (5) D. M. Simpson. Researchers in the western states included Ed Duncan and Buck Pressley. Ramey said that all of these breeders worked at Greenville, TX for their training period. This may explain why these researchers were so successful as cotton breeders. They were not just placed in a position and left to flounder on their own.

During the first year at Florence, Mr. Willie and Cuttino made a large number of crosses between border row of Sea Island, Extra-long staple Upland, and Upland cultivars in the State Cotton Tests grown by the Pee Dee Station Superintendent, Mr. E. E. Hall. In 1936, three Agricultural Aids joined the project and more than 9,200 crosses and backcrosses between fast growing Upland, slower growing extra-long staple Upland, and late maturing Sea Island cultivars were made (Culp and Harrell, 1974). It is of academic interest that nearly 2,000 crosses were made between Upland cultivars growing at Florence, S.C. and a new strain of extra-long staple Sea Island (Puerto Rican Sea Island) introduced from Puerto Rico and planted at Brooksville, FL. On the day before anthesis, the flower buds of the Sea Island introduction were cut and shipped by rail to Florence, a distance of about 600 miles, where the pollen was used in next day hybridizations. Unfortunately, none of the introduction of Puerto Rican Sea Island in this mass of material produced selections that found their way into improved cultivars.

It soon became apparent that a location with a longer growing season than Florence was needed for breeding Sea Island cotton; therefore, the Sea Island work was transferred from the Pee Dee Experiment Station to Johns Island, S.C. (near Charleston) in 1940 (Culp and Harrell, 1974). Because greater progress was being made in the development of adapted extra-long staple cultivars at Florence, by 1946, the Sea Island program was discontinued at Johns Island and absorbed into the breeding program at the Georgia Coastal Plain Experiment Station, Tifton, Ga. under the direction of Julian G. Jenkins (Culp and Harrell, 1974, Jenkins, 1948, 1953).

Primary breeding emphasis at Florence was given to the development of extra- long staple Upland cottons. Extra-long staple cultivars were better adapted and higher yielding than Sea Islands (Table 2). While this work was being done, our understanding of cotton quality and its measurement was not well developed but advancing rapidly. Until 1956, full evaluation of quality on germplasm lines and cultivars was performed only after development (Culp and Harrell, 1974). Few fiber determinations, except for the field combing and measuring of staple length, were made on individual plant and progeny row selections during the breeding process.

Thus, the work at Florence developed into a massive program of selecting desirable plants out of interspecific crosses and backcrosses (*G. hirsutum* L. X *G. barbadense* L.). A wide range of plant types—overwhelmingly worthless combinations—came out of these crosses. Promising combinations were obtained only after repeated backcrossing to *G. hirsutum* (one or more cultivars) and these continued to show wide variation in succeeding generations. To transfer desirable characters from *G. barbadense* to *G. hirsutum*, it was necessary to backcross three or more times; only then did we reach the stage where stable combinations were obtained.

As the work at Florence progressed, researchers (Culp and Harrell, 1974) came to believe that the common extra-long staple Upland cultivars ('Wilds', 'Deltatype Webber', 'Meade', and 'Tidewater') of the 1930's had arisen from previous introgression of *G. barbadense* genes into the germplasm of *G. hirsutum*. The best selections of crosses and backcrosses between Sea Island and Upland cultivars approached the combination of desired characters found in the commercial extra-long staple cultivars, but almost never equaled them. These well-known extra-long staple cultivars were used frequently as parents in the Pee Dee breeding program.

The first product of the Pee Dee program was the extra-long staple Upland cultivar 'Sealand 542' (Culp and Harrell, 1974). This cultivar came from 1943 progeny row 542. It was selected from a 'Bleak Hall' (Sea Island type) x 'Coker Wilds' hybrid backcrossed four times to the Wilds parent. Strain 542 was the strongest of 27 strains tested in 1943 and 1944 with Pressley strength indices of 9.2 and 8.6, respectively. The staple length of Sealand 542 was given as 34.9 to 39.7 mm (1-3/8 to 1-9/16 in) with a lint percentage of 33. This cultivar, released jointly by the Georgia and South Carolina Experiment Stations, was well received by growers in 1947 and approximately 1,000 acres were grown in South Carolina, Georgia, and Florida in 1948 (Culp and Harrell, 1974; Jenkins, 1948).

'Earlistaple 808' was the second extra-long staple Upland cultivar developed at Florence, S.C. This cultivar came from a selection out of 1946 progeny row 844 (Culp and Harrell, 1974). At this time, it was an F4 selection from the cross 'Tidewater Acala' x 'Coker Wilds'. This cultivar possessed fiber and spinning properties slightly poorer than Sealand 542, but produced significantly higher lint yields (Table 3). Selections from Earlistaple 808 exhibited differences in resistance to the fusarium wilt-root knot nematode complex. 'Earlistaple 7', a wilt-resistant selection, produced significantly higher yields and became the progenitor of later versions of this cultivar.

In the early stages of the breeding program, the difficulty of combining the high yields and early maturity of Upland with the extra-long staple fiber of Sea Island was recognized. We suggested (Culp and Harrell, 1974) that there was a strong inverse relationship between lint yield and fiber length and perhaps an even stronger inverse relationship between lint yield and fiber strength. These inverse relationships may be due to pleiotropic effects; genetic linkages between genes for length, strength, and yield; morphological or physiological processes involved in the development of longer and stronger fibers, or a combination of both genetic and physiological factors. We favored the last hypothesis because there is evidence for breaking linkages between yield and quality factors. It is reasonable to assume that fewer long, strong fibers will be produced since they must require more energy and photosynthates for development. After 38 years of breeding at the Pee Dee Station to overcome the yield-quality barrier in cottons of *G. hirsutum X G. barbadense* background, we (Culp and Harrell, 1974) concluded that for every major increase in lint yield, there was some decrease (not always proportionate) in fiber length, strength, or both.

The lint yield, fiber length, and fiber strength of the commercial Upland cultivar Coker 100 A and the extra-long staple cultivars Earlistaple 7 and Sealand 542, tested on the Pee Dee Station from 1956 to 1960 (Table 3) illustrate the adverse relationship between yield and quality. Coker 100 A had the shortest and weakest fibers, but produced significantly higher lint yields of 21% and 35% over Earlistaple 7 and Sealand 542, respectively. We did not find significant differences in fiber length or strength between Earlistaple 7 and Sealand 542, but Sealand 542 had yarn strength of 152, 6 pounds greater than Earlistaple 7, and a significantly lower lint yield of 119 pounds per acre.

The development of extra-long staple cottons outside the southeastern states gradually changed the picture of supply and demand for this type of lint. In the 1930's, breeders developed extra-long staple Egyptian cotton cultivars, which competed in quality with Sea Island (from the West Indies), but were much higher yielding. American-Egyptian cultivars such as 'Pima 32' with fiber properties similar to Egyptian cultivars were soon developed. The basic yield of extra-long staple cottons was again raised with the introduction of 'Pima S-1' and 'Pima S-2' (Feaster and Turcotte, 1962) (Table 4).

Harrell and Jenkins (Culp and Harrell, 1974) at Florence, SC received pollen of TH 108, TH 171, and TH 458 from Thomas Kerr at Raleigh, NC in 1946. They used the pollen (shipped by railroad) to make crosses with AHA 6-1-4 and Sealand in 1946 (Figure 3). These lines were intermated in 1947 and 1948. Earlistaple was introduced into these populations in 1949, 1950, and 1951. Selections within these populations produced lines A, F, J, N, and T that make up the basic germplasm pool that exists today (Culp and Harrell, 1974). These germplasm lines were intermated and selected for several generations without much success in breaking the strong linkage between yield and fiber strength. All of these PD germplasm lines had very low lint percentages (Culp and Harrell, 1975) until germplasm of C 6-5 (Anonymous, 1960) was introduced into the germplasm pool. Although a very poor agronomic type for the southeastern US, C 6-5 had excellent fiber strength and high lint percentage. From the cross, Line A x C 6-5 (AC), germplasm lines with 39% lint and yield increases of 12% above the previous highest yielding high fiber strength lines were selected (Table 5). With the use of the AC germplasm lines in the PD breeding program, we have maintained lint percentage around 39% and above by selection for this character. It is interesting to note that I know of no other breeder who has had success of any type with the use of C 6-5. It is extremely difficult to choose and predict the outcome of parents in cotton crosses.

The AC lines were crossed to most PD lines, derived from various intermatings, and to several commercial cultivars such as 'Auburn 56' (G) 'Dixie King' (D) and 'Coker 421' (H). Outstanding germplasm lines (Figure 3) Pee Dee 2165 (AC.FJA)(Culp and Harrell, 1979a), Pee Dee 4381 (AC.G)(Harrell and Culp, 1979), and Pee Dee 8623 (AC.D:H) were released to bonafide cotton geneticists and breeders in the late 1960's. These germplasm lines had extra fiber strength equivalent to Atlas, Mo-Del, Delcot 277, and TH 149 and produced similar yields of about 85% of commercial cultivars in production (Culp and Harrell, 1974). A number of these lines, in addition to 'Coker 413', were released to farmers with the hope of producing stronger, medium staple cottons to meet the needs of textile manufacturers.

Importance Of Fiber Quality

Although 'Prophets of Doom' in the early 1960's forecast (Culp, 1982) that the textile industry would soon require only cellulose to blend with man-made fibers, the demand for quality cotton has continued to increase. Dramatic changes in the harvesting and ginning of cotton and the speed of processing fibers in the textile industry accentuate the need for improved fiber quality in the general cotton crop. Stronger cotton fibers were needed to blend with man-made fibers that were taking a lion's share of the fiber market.

D. C. Harrell (1963) wrote: "From time to time there are glowing reports of excellent results obtained in the mills with certain growths of cottons from the Southeast. However, when the whole picture is taken into consideration there is cause for concern. In 1961 and 1962, 44% of the cotton produced in North Carolina, South Carolina, Georgia, Alabama, and Mississippi was still in the loan through the month of June. During the same period only 9% of the California production remained in the loan. There are several reasons for this difference, but chief among them is the lack of fiber strength in the varieties used to produce the southeastern cotton crop. There has been essentially no change in the strength of most commercial cotton varieties in the Southeast for the past 35 years."

I am pleased to report that major changes in fiber strength of several major cotton cultivars have occurred since 1965.

Although the need for improved fiber quality was given wide publicity, it took the below-average fiber crop of 1964 to motivate most cotton breeders to gear their breeding programs to the requirements of a quality-conscious textile industry. D. C. Harrell (1966) wrote, "In just two years, we have moved from apparent complacency regarding fiber quality to what seems to be the greatest revolution in cotton breeding since the advent of the boll weevil caused a similar breeding impetus in the nineteen twenties. Derivatives of the triple hybrids, Hopi, Acala, and *G. barbadense* are being crossed on the best commercial varieties in a serious attempt to raise the fiber quality of our general cotton crop to acceptable levels. Most public and private breeders are involved in this effort, and we need only to look at the results obtained in the twenties to grasp the possibilities of the present situation." Culp and Harrell (1974) pursued the question further: "Although the manufacturers generally do not show sufficient interest in improved fiber quality to offer premiums for it in the market place, the future of cotton production may well depend on improving the fiber strength, fiber fineness, and possibly the staple length of future cotton cultivars." Culp (1982) wrote, "If it is to survive, cotton must compete with synthetic fibers in the textile plant for ease and speed of processing, as well as meeting the demands of the consuming public, where wearing comfort and durability are paramount." When I came to work at Florence in 1976, man-made fibers were taking a larger share of the fiber market each year. The demand for cotton to insure wearing comfort of the younger generation turned the demand around for more cotton goods.

The cultivars that were released with extra fiber strength were grown on considerable acreage in the Southeast as long as the mills paid a premium or this type lint. When the premiums stopped, production of these cultivars was phased out.

When I came to the Pee Dee Experiment Station 31 March 1967, considerable progress had been made in the development and utilization of fiber and spinning measurements. USDA had established fiber and spinning laboratories at Knoxville, TN, and quality measurements were being made on fiber from individual plants and bulk samples. Tom Kerr stationed at Beltsville, MD supervised the work; therefore, we got fiber and yarn analyses on more than our share of genetic material. Smith Worley, Jr. was in charge of the USDA Fiber Laboratory and ran measurements on fiber length, fiber strength, and micronaire. P. R. Ewald was in charge of the USDA Fiber Quality Laboratory and ran the miniature spinning tests (Landstreet, et al., 1959, 1962) for yarn strength determinations. This was one of our best tests because yarn strength embraced all fiber parameters. Really, Phil Ewald was in charge of both laboratories because he was in charge of operational funds. Bush Landstreet (Landstreet, et al., 1959, 1962) was at the Spinning laboratory before I came to Florence; however, he had retired (or quit) to form his own company, Star Lab. Several reviews (Perkins, et al., 1984, Perkins, et al, 1992, Ramey, H. H., 1980) are helpful in understanding fiber and yarn measurements in cotton.

When I came to Florence, cotton breeding was under the Cotton Branch of the Cotton and Other Fiber Crops, USDA. The chain of command was as follows:

B. M. Waddle--Chief of the Cotton Branch
J. B. Pate--Assistant Chief Cotton Branch
H. R. Carns--Investigations Leader Physiology
Tom Kerr--Investigations Leader for Fiber Quality
C. F. Lewis--Investigations Leader for Breeding

John Pressley--Investigations Leader Pathology

When Tom Kerr retired in 1970, H. H. Ramey resigned from Cotton Incorporated and moved to Beltsville as Tom's replacement as Investigations Leader for Fiber Quality.

Black Friday hit us again in 1972 with a major overhaul of the organization of USDA. Business offices were decentralized from the Washington area and cotton research became a part of the Agricultural Research Service (ARS) with business headquarters in the Southern Regional Office, New Orleans, LA. C. F. Lewis, Staff Scientist, became the Director of Cotton Breeding Research, and remained at Beltsville, MD. H. H. Ramey was transferred to the Cotton Fiber and Spinning Laboratories, Knoxville, TN. Harry Carnes became Staff Scientist at the USDA Plant Physiology Institute, Beltsville, MD. Jim Pate went to Phoenix, AZ as Assistant Area Director. Billy Waddle and John Turner retired and moved to Arizona and Texas, respectively.

In a few years, the four Regional Business Offices were closed and 12 Area Offices were opened. It didn't make much difference to researchers in the field. You just had to deal with a different Area Director and send mail to a different address. Individual projects were approved by a Research Leader and research funds were sent to the Location Leader for distribution. When this system was instituted, Cuttino Harrell held both positions which was the ideal situation. When Cuttino retired there was no one for me to direct; therefore, I always had an Entomologist or Soils and Water Scientist for a Research Leader. You can spend a lot of time explaining why you need more that one research assistant, why you have to do things a certain way to insure genetic purity, and why a plot cotton picker is just as important as some expensive laboratory apparatus like an electron microscope.

I was most fortunate that the Research Leaders generally left me alone. I ran a big breeding program and we got good results that they were looking for. I also got excellent support from the Superintendent of the Pee Dee Experiment Station, Dr. John Pitner. We had an ideal cooperative arrangement whereby the SC Agricultural Experiment Station bought the fertilizer and prepared the land for planting; furnished farm equipment; bought insecticides and controlled insect pests; and furnished necessary help for operating cotton pickers and gins under my supervision.

During one of the periods when Congress failed to pass a budget for government operations, everyone who was not declared essential was sent home. All USDA personnel at Florence were declared non-essential. I had about 30 acres of cotton to harvest, the weather was perfect, state personnel were standing by to help, and I intended to operate the cotton picker. The Research Leader told me that I could not pick cotton and gave me a number of reasons why it was not feasible. I told him that at 1:00 o'clock, when the State employees returned from lunch, the picker would run. He left in a huff and came back in about 15 minutes and said it was alright to pick because the Area Director had declared my research assistants and me essential workers. USDA went back to work the next day and my research assistants were more than a little upset because they didn't get the afternoon off.

Continuation Of Breeding At Florence

The intermating of PD germplasm lines (Culp et. al., 1979) and the crossing (essentially intermating) of the PD germplasm lines with Atlas, Mo-Del, Delcot 277, TH 149 and related material (Table 6) has been most successful in the simultaneous improvement of lint yield and fiber strength. The early developed PD germplasm lines [(3) FJA, (4) FTA, (5) AC, (6) PD 2164, (7) PD 2165, (8) Atlas, (9) Coker 421, (10) PD 4398, (11) PD 4381, and commercial cultivars (1) 'Coker 201' and (2) Auburn 56] fall on, or very close to the regression line established between lint yield and yarn strength in the basic PD germplasm pool (Figure 4). These data suggest that selection for higher lint yields demanded by cotton growers has resulted in germplasm lines with reduced fiber strength. The correlation coefficient (r=-0.94) between lint yield and yarn strength in the basic PD germplasm pool illustrates the problems faced by breeders in attempting to increase lint yield and fiber strength simultaneously in upland cotton.

In the cross (essentially intermating) of PD 2165 x PD 4381 (AC.FJAXAC.G) (Culp and Harrell, 1977) several outstanding progenies, PD 0109, PD 0111, and PD 0113 (Culp and Harrell, 1980a), performed above expectations for yield and fiber strength based on deviations from regression (Figure 4). In this cross, extra fiber strength genes came entirely from the PD germplasm pool. Auburn 56 (Smith, 1964) does not exhibit extra strength genes because its yarn strength is 98% of that of Coker 201, and it has not imparted extra fiber strength in other crosses with commercial cultivars of *G. hirsutum* L. Instead, Auburn 56 contributed extra factors for yield and resistance to the fusarium wilt-rootknot nematode complex caused by Fusarium oxysporium Schlect. F. vasinfectum (Atk.) Snyd. & Hans. And Meloidogyne spp.

In two other crosses (Harrell et al., 1974), PD 2164 x Coker 421 and PD 4398 x Coker 421, several superior progenies were produced and germplasm line PD 9241 (H:FTA.0)(later became commercial cultivar 'SC-1')(Culp and Harrell, 1979c), PD 9223 (H:AC.FJA), and PD 9232 (H:AC.FJA) were developed and released. All three breeding lines performed above expectations for yield and quality based on the deviations from regression (Figure 4). Coker 421 combined successfully with many PD lines such as AC.D, AC.FJA, FTA.0, and TH 149. Over the past 20 years, no cultivar outside the PD germplasm pool with extra fiber strength has combined with the PD germplasm lines and given such a series of outstanding selections (Harrell et al. 1974). PD 4398, from Atlas, and Mo-Del or Delcot 277, which are closely related to the PD germplasm, only mimics our success with Coker 421. We suggest that Coker 421 extra strength genes must be similar to those that went into the PD germplasm pool because it combined so well with PD and other triple-hybrid-related lines (Culp, 1992).

The association between lint yield and fiber strength in the PD germplasm pool may be best explained by linkage as suggested by Miller and Rawlings (1967) and Meredith and Bridge (1971). Al-Jibouri et al. (1958) suggested that the genetic correlations between lint yield and fiber strength are probably caused by linkage, pleiotropism, or both. More recently, Scholl and Miller (1976) presented data suggesting that pleiotropic effects also may be important in explaining this genetic relationship. The correlation coefficients between lint yield and yarn strength of selected progenies after crossing (essentially intermating) in the PD material have been changed from highly significantly negative (-0.93) to positive (but not significant) (Table 6). Initially, line F was the first major improvement in a high yielding cotton with superior fiber strength of triple hybrid origin (Culp and Harrell, 1980b), but selection for high yield invariably resulted in reduced fiber strength. Intermatings with related germplasm lines such as A and T (FTA selections) did very little to alleviate the adverse association (r=0.92). Correlation coefficients between lint yield and fiber strength were significantly reduced in the AC material and the intermating of AC lines with material from the high fiber strength germplasm pool (Table 6). Although the negative correlations between lint yield and yarn strength of superior progenies from the AC.FJA and AC.G crosses were reduced, the mean of these lines did not deviate significantly from regression (PD 2164, PD 2165, and PD 4381 in Figure 4). Culp and Harrell (1973) have reported only two improved breeding lines with extra fiber strength resulting from numerous selections within selfed populations of cotton (Figure 5). They concluded that these improvements probably resulted from outcrossing because of drastic plant changes in the new selections. The correlation between lint yield and yarn strength in Earlistaple 808 (first cycle of selection) was –0.90 (Table 7), compared with –0.58 for Earlistaple-7 selection (second cycle of selection) which gave hope of improving lint yield and fiber strength simultaneously in Upland cotton. Unfortunately, one or more cycles of selection in line F, PD 2165, and PD 4381 (excluding PD 4381-54 and its progenies), produced no significant breeding improvements or major changes in the correlations between lint yield and yarn strength (Table 7). Additional intermating (AC.FJA x AC.G, or x AC.W, or x AC.D or x AC.V, or x H) further reduced the correlations between lint yield and fiber strength and produced superior offspring with both high lint yield and increased fiber strength (Table 6).

Therefore, we have reached a point in cotton breeding whereby progress in improving lint yield and fiber strength can be made by simultaneously selecting superior plants with and without extra fiber strength genes, in segregating populations from crosses between PD lines and commercial cultivars (Culp, et al. 1979a). Culp et al. (1979b) also have developed for the first time an insect-resistant germplasm line with extra fiber strength without prior selection for improved fiber quality. These results support a recent change in the lint yield-fiber strength relationship in this germplasm pool of upland cotton.

With the change in the association between lint yield and fiber strength, we expected greater compatibility between PD germplasm and commercial cultivars. Crosses have been made with Auburn 56 (G), Coker 303 (W), Dixie King (D) (Culp and Harrell, 1977), Coker 421 (H), Atlas (0), TH 149, and Coker 310 (V) (Harrell, et al., 1974). PD germplasm lines that contain the germplasm of these cultivars (Tables 6 and 7) produce high lint yields with improved fiber strength and all show a reduction in the negative lint yield-fiber strength relationship.

After additional testing, PD 9241 produced superior yields when compared in replicated yield trials with other PD germplasm lines and was released in 1975 as SC-1 (Culp and Harrell, 1979c), the first southeastern cultivar with extra fiber strength from Beasley's (1940) Triple Hybrid. In 10 tests at the Pee Dee Research and Education Center at Florence, SC, in 1970, 1971, and 1972 (Harrell et al. 1974), SC-1 produced a significantly higher mean yield than Coker 201 (a popular South Carolina cultivar) and PD2165 (the high quality check) (Table 8). Fibers of SC-1 were stronger than those of Coker 201, but weaker than those of PD2165. Fibers of SC-1 were also finer than the checks, longer than Coker 201, but equal in length to PD 2165. Yarn tenacity of SC-1 was significantly stronger than that of Coker 201 and equal to that of PD 2165. Fiber elongation was significantly higher than that of both checks. In fact, SC-1 has the highest E1 of any PD germplasm lines and suggests that a change in fiber diameter or perimeter may have occurred in the cross.

When tested at Blackville, Clemson, and Florence, SC in 1974, 1975, and 1976 (Harrell et al. 1974), SC-1 produced yields comparable with those of the two most popular South Carolina cultivars, Coker 201 and Coker 310 (Table 9). Additional testing throughout the Southeast suggested that SC-1 was not widely adapted and was highly susceptible to the fusarium wilt-rootknot nematode complex. Fibers of SC-1 were shorter than those of Coker 310, but longer than those of Coker 201. Micronaire of SC-1 was equal to that of Coker 201, while E1 and yarn tenacity were significantly higher than those of the two check cultivars.

Using a half-diallel, Green and Culp (1990a) showed that SC-1 contributed both yield and yarn strength improvements to its progenies. These data provide additional evidence that unfavorable linkages in the lint yield-fiber strength relationship have been broken and favorable recombinations have been found.

Additional intermating with outcrosses to the commercial cultivars, Auburn 56 (G) and Dixie King (D) produced a superior germplasm line, PD 4548 (Culp et al. 1985a). This germplasm line was developed from the cross of PD 4381 (AC.G x PD 8623 (H:AC.D). After additional testing, germplasm line PD 4548 was released in 1984 under the name of PD-1, a replacement for SC-1 (Culp, et al. 1985b). When compared with southeastern cultivars and checks in 10 tests on the PD Research and Education Center, Florence, SC in 1975, 1976, and 1977 (Table 10), PD-1 produced comparable yield to that of SC-1 and superior yields to those of the other commercial cultivars and checks (Culp, 1981). Fiber length of PD-1 was equal to that of SC-1 and Coker 310; however, fibers of PD-1 were coarser than those of SC-1. Fiber strength of PD-1 was significantly higher than that of all cultivars and checks, which also equated into a significantly higher yarn tenacity. When tested in the Official South Carolina Cultivar Trials at Blackville and Florence, SC in 1980, 1981, and 1981 (Table 11), PD-1 produced yields equivalent to those of SC-1, but higher than those of the other cultivars and checks. Fibers were coarser than those of SC-1, but equal in length and strength. In the 1979 Regional High Quality and the 1981 and 1982 Eastern Regional Tests grown in Alabama, Georgia, North Carolina and South Carolina (Table 12), PD-1 produced superior yields to those of Coker 201 and Acala SJ-5. Fibers of PD-1 were coarser than those of Acala SJ-5, but equal in fineness to Coker 310. No significant differences were noted in fiber length of cultivars. Yarn tenacity of PD-1 was superior to that of Coker 310 and approached that of Acala SJ-5.

Additional intermating and selection in the PD germplasm with an outcross to Coker 201 resulted in the simultaneous improvement of lint yield and fiber strength (Culp, et al. 1985b). The superior germplasm line, PD 6208, was developed from the cross, PD 9363 (R.FJA:AC.FJA) x PD 9240 (H:FTA.O). Breeding line PD 6208 was released in 1987 as PD-3, a replacement for PD-1 (Figure 6)(Culp, et al. 1988). In the 1981, 1983, and 1985 Regional High Quality Tests (Table 13), PD-3 produced lint yields equivalent to those of McNair 235 and Stoneville 213 and superior to those of the high quality check, Acala SJ-5. Yields of this magnitude suggested that PD-3 had the broadest adaptability of all PD germplasm tested to date and was well received by producers (McClintic, 1989). A major problem is planting seed production, distribution and marketing by State agencies. Moreover, fibers of PD-3 were equal in length to those of Acala SJ-5; however, they were weaker and coarser, but produced yarn tenacity that approached that of Acala SJ-5. Fiber properties of PD-3 were also superior to those of the check cultivars, McNair 235 or Stoneville 213.

In the 1982, 1983, 1984, and 1985 Official South Carolina cultivar trials at Blackville and Florence (Table 14), PD-3 produced a significantly higher yield than that of PD-1 and McNair 235, while fiber strength and yarn tenacity were equivalent to that of PD-1. These data suggest that we have been successful in the simultaneous improvement of lint yield and fiber strength in the PD program.

Of the PD cultivars released today, PD-3 has the broadest adaptability of high fiber strength cottons. In the 1987, 1988, and 1989 Eastern Regional Test grown in Alabama, Georgia, North Carolina, South Carolina, and Tennessee (Table 15), PD-3 produced yields equivalent to those of the adapted southeastern cultivars. Fibers of PD-3 were shorter in length than those of Coker 315 and Acala 1517-75, the cultivars with the longest fibers in the test. Fiber length of PD-3 was equivalent or superior to that of the other cultivars tested. Fiber strength of PD-3 was less than that of Acala 1517-75, equal to that of ‘Deltapine 90’, and superior to that of the other cultivars tested. Fibers of PD-3 were coarser than those of Acala 1517-75, but equal or superior to those of the other cultivars tested. Yarn tenacity of PD-3 was less than Acala 1517-75, but superior to that of the other cultivars.

Yarn tenacity is considered our best measure of fiber quality of a cultivar or germplasm line because it reflects all the fiber properties in one measure. Stelometer readings have been considered the best measure of fiber strength. In the 1987 Eastern Regional tests (Table 16), fiber strength was measured with the Stelometer and three different HVI systems. Stelometer readings failed to separate the superiority of PD-3 for superior yarn tenacity over Deltapine 90. All HVI systems failed to reflect the relationship between yarn and fiber strength accurately; however, HVI measures are helpful in placing plant segregates into classes of fiber tenacity. Comparisons of measures from fibergraph and HVI suggest that either is a good measure of fiber length (Table 17) and fiber fineness (Table 18); however, stelometer is a more accurate measure of fiber strength (Table 19). Green et al. (1990b) recently released 11 germplasm lines (Figure 6) from crosses with PD germplasms and southeastern and Delta cultivars. These lines apparently have high yield potential and extra fiber strength under short- and full-season conditions. Four of these PD germplasm lines produced comparable or superior lint yields to those of PD-3 under a short-season production system (Table 20). One of these lines, PD 5582 may have improved fiber strength and yarn tenacity. Five of these germplasm lines produced maximum yields under a full-season production system (Table 21) and several of them may have higher yield potential than that of PD-3. Two germplasm lines produced superior yields under short- and full-season production systems (Table 22). One of these lines may have superior fiber strength and yarn tenacity. Additional testing will be required to determine the performance of this material.

It is evident that PD germplasm is much more compatible with Southeastern and Delta cultivars (Green and Culp 1990a). These data support our hypothesis that unfavorable linkages between lint yield and fiber strength must have been broken through intermating and selection.

Lloyd May, who replaced Cindy Green, at the Pee Dee Experiment Station, further tested the above germplasm lines and found that they were often equal in quality and yield to that of PD 3, but not superior. Therefore, he saw no reason to release any of them as a replacement for PD 3, but decided to breed for additional progress in the simultaneous improvement of yield and quality in the Pee Dee germplasm.

Deussen (1987) gave the desired cotton fiber properties for rotary and other new spinning systems (Table 23). The major change is a reduction or micronaire from the present premium range of 3.5 to 4.9 to 2.7 to 3.5. If germplasm with such a micronaire were available, the proposed change would result in a significant reduction in yield, which Deussen suggests should be compensated for by textile manufacturers. If such a breeding accomplishment occurs, I doubt that it would be practical in southeastern cotton production. After the usual wettings of the fiber by occasional to frequent rains, cottons with fibers in the upper premium range have the ability to fluff and dry more easily. Cottons with micronaires in the lower end of the premium range frequently fail to fluff and dry, resulting in excessive rot, hard lock condition, and reductions in yield.

I have attended a number of Breeder-Spinner Conferences; however, I have never been told just what spinners want in regard to fiber quality. John Gannaway reported that they let him know what they wanted all the time, but I think he was busy listening to Frank Webber. Unfortunately, at the Breeder-Spinner Conferences, the spinners went off with their group to get tanked up while we breeders socialized among ourselves.

Probably, Mr. Ernest Carpenter of Greenwood Mills gave the best description of what mills want as follows: "They want fibers long as a rope, strong as steel, fine as silk, and cheap as hell". I am not sure that these desires have changed greatly. Meredith (1980) ran a survey on program emphasis of both private and public breeders and the results are given in Table 24. There is no doubt that breeding for high yield is highest on both lists. Cotton producers must have high yields to make money and mills must buy as cheaply as possible to compete in the world market. After the emphasis on yield, breeding for earliness, disease resistance, and insect resistance follow in that order. Breeding for fiber quality is fourth place in importance. Webb (1983) summarized what breeders were doing to meet the mill's needs with the breeder's capabilities.

Genetic Gain In Lint Yield And Fiber Quality

Yield and fiber quality comparisons of modern over obsolete cultivars and PD germplasm lines have been used to measure genetic gains in these characters and to establish a base for estimating future breeding accomplishments. Bridge et al. (1971) reported that genetic gain in lint yield improvements averaged 10.2 kg/ha/yr in 1968 and 1969 in the Mississippi Delta (Figure 7). Hoskinson and Stewart (1977) compared 'Deltapine A' and 'Carolina Dell' with four modern cultivars in Tennessee in the mid-1970's and found that both obsolete cultivars produced significantly less lint and matured later than the lowest yielding modern cultivar. Using their data and regressing lint yield on the approximate year that each cultivar was released, Culp and Green (1992) estimated genetic gain at 7.2 kg/ha/yr in yield improvement of modern over obsolete cultivars. Bassett and Hyer (1985) estimated genetic gain in lint yield in the 50-year-old Acala cotton program of California at 8.0 kg/ha/yr. They also found that fiber strength has steadily increased throughout the period and micronaire has remained in a relatively narrow, but desirable range since the release of 'Acala 4-42' in 1949. Bridge and Meredith (1983) reran tests in the Mississippi Delta in 1978 and 1979 with the addition of several new improved cultivars and estimated genetic gain in lint yield improvement at 9.5 kg/ha/yr (Figure 8). Culp and Green (1992) evaluated 11 commercial cultivars and 18 germplasm lines of cotton, 12 modern and 1 obsolete, in two tests each year over the three year period of 1979, 1980, and 198l at Florence, SC, to determine what genetic improvements the new cultivars and germplasm lines had over the old ones.

SC-1 (Culp and Harrell, 1979c), the first PD cultivar with extra fiber strength, produced significantly more lint than that of all other PD germplasm lines tested. The average yield of SC-1 was equivalent to that of McNair 235, the highest yielding currently grown southeastern cultivar in our tests. A regression analysis of all the lint yield data on all cultivars and PD germplasm lines showed that lint yields increased at the rate of 9.2 kg/ha/yr. When Earlistaple 7 is selected as the representative of the oldest obsolete cultivar tested and Acala SJ-5 and Paymaster, which are not adapted to this region of production, are eliminated from the analyses, lint yields have increased at the rate of 10.2 kg/ha/yr (Figure 9). These data are in excellent agreement with those of Bridge et al. (1971) and Bridge and Meredith (1983) of 10.2 and 9.5 kg/ha/yr in cultivar improvement, respectively, in Mississippi.

A regression analysis of the average yields of all the PD germplasm lines by the year tested (F5 generation) shows that lint yields have increased at the rate of 13.8 kg/ha/yr (Figure 10). If we exclude PD 4461 or line Q (Culp and Harrell, 1979b), a breeding line with fiber strength genes from *G. barbadense* L. rather than triple hybrid origin (Culp and Harrell, 1973) (Figure 11), a more accurate rate of increase in yield of 15.1 kg/ha/yr is obtained. This rate of increase is higher than that found with current vs. obsolete cultivars; however, it is within the range of yield increases due to breeding of 5 to 17% within seven major breeding firms over a 15-year period (Turner, et al., 1976). A regression analysis of the average yields of related PD germplasm on the year developed, showed that lint yields have increased more dramatically at the rate of 20.6 kg/ha/yr (Y=-299.2 +20.6x). Thus, greater progress may have been made in the simultaneous improvement of lint yield and fiber quality in the PD germplasm than that measured in conventional Upland cotton improvement programs.

In the early stages of this study, plants with superior lint yield potential and extra fiber strength were rare occurrences. Lint yield and fiber strength of thousands of selections (Culp, et al., 1979) were measured over a 5-year period before line F was found (Culp and Harrell, 1980b). Outstanding lines A, J, N, and T were developed after an additional 1 to 5 years of similar work. Selections of superior and rare plants became more frequent in PD 2165 (AC,FJA) and PD 4381 (AC,G) when genetic linkages were broken and the association between lint yield and fiber strength were reduced. Approximately 1 in 30 to 1 in 50 superior F2 plants with high yield potential and extra fiber strength were found in these two populations (Table 9). Rare plants occurred in a ratio of about 1:300. With additional crossing (essentially intermating) the frequency of superior plants increased to 1 in 15 and rare plants to 1 in 40.

Our data indicate that linkage is the major cause of the negative association between lint yield and fiber strength in upland cotton. We have been successful in breaking these linkages through modified intermating and selection. Breeding progress in improving lint yield and fiber strength simultaneously in cotton is highly dependent upon the occurrence of favorable recombinations. Hanson (1959) proposed that an effective procedure for breaking up linkage blocks and increasing genetic recombinations is to utilize four or more parents for one to four cycles of intermating. Since initial crosses in the PD material were made in 1946 (Culp and Harrell, 1974), we did not set out to test Hanson's theory, but our data are supportive of it. Other breeding methods (Culp and Harrell, 1973) have been tried numerous times but none have produced superior progenies in the PD breeding program.

Cotton Breeding In Alabama

Ware (1937) listed H. B. Tisdale (Federal and State) and J. B. 'Jimmy' Dick as (Federal) cotton breeders at Auburn in 1936. I have no record of their accomplishments. Mr. Dick mentioned that he bred cotton for Coker's Pedigreed Seed Company at Coker, AL (I hope I didn't dream this) before he moved to Stoneville, MS as Director of the Cotton Breeding Program at the Delta Branch Experiment Station. Mr. Dick was under orders (as we all were) from Billy Waddle, Cotton Division Branch Chief, USDA not to make Coker and Stoneville Pedigreed Seed Companies and Delta and Pine Land Company irate by competing (with Public funds) in cultivar development. Our purpose was to develop germplasm that might be used by commercial companies for cotton improvement.

In 1936, A. L. 'AL' Smith was listed (Ware, 1937), along with W. W. Ballard, as Federal breeders at Experiment GA. Smith was also listed as cotton breeder in disease resistance. H. A. Peacock told me in a recent telephone conversation that Ballad and Smith had a nursery at Experiment that was infested with the Fusarium Wilt and Root Knot Nematode complex. Ballard and Smith used this area to select the original plants of 'Empire' (Ballard, 1950) and 'Auburn 56' (Smith, 1964) out of 'Cook 307-6'. Raymond Shepherd told me that after Smith moved to Auburn, he developed the Fusarium Wilt Nursery at Tallassee, AL where cotton breeders across the U.S. tested their cultivars and germplasm for reaction to these pathogens.

Smith (1964) is noted for the development of the fusarium wilt resistant cultivar, Auburn 56. This cultivar was widely grown in areas where the fusarium wilt-rootknot nematode complex reduced yield. Auburn 56 was widely used in germplasm and cultivar development. While surveying a pine forest on his farm near Tallassee, Smith suffered a heart attack and died. A. J. 'Al' Kappelman, USDA Plant Pathologist, was hired in 1966 as Smith's replacement and he conducted the Fusarium Wilt Nursery, which was a great service to all U.S. plant breeders. He also conducted research on the management of this pathogen in cotton production.

Raymond Shepherd was hired as the USDA plant breeder at Auburn University in 1965. He was primarily responsible for developing nematode resistant cottons. He developed and published methods for screening for nematodes, primarily root-knot, and released the first germplasm line that is essentially immune to this pathogen. He found that if cottons are resistant to nematodes, fusarium wilt is a minor problem because the pathogen has no passage into the cotton plant. Shepherd has released a large number of germplasm lines with useful characters that also possess resistance to the fusarium wilt-rootknot nematode complex. Shepherd retired in 1990.

After Kappelman retired in the mid 1980's, Wylie Johnson, a state employee, took over the Fusarium Wilt Nursery at Tallassee and is now in charge of cotton testing in Alabama.

Cotton Breeding In Georgia

College Experiment Station, Athens

Several early researchers stationed at The University of Georgia were involved in cotton breeding. None of them produced germplasm lines or commercial cultivars and their activities have been listed with coworkers at other breeding locations.

There is no doubt that J. B. Weaver is the most well known cotton breeder from Athens. He wants to be known as the *Father of Hybrid Cotton* if he can just get one of several of his systems of production to work successfully in making the hybrid. Even though he has been retired for several years, I noted that he had another new hybrid (JB-?) in 1997 tests in South Carolina. When I was visiting the cotton breeding program at Multan, Pakistan and was taken to a model farm, Mr. Bokhari farm owner, asked immediately how his good friend, Dr. Weaver, was doing. He even wanted me to take an 8 x 12 rug to J.B., and J. B. didn't like it because I didn't cart it half way around the world for him. Everywhere I went in the People's Republic of China, inquiries about J. B. were made. The people looked pleasant; therefore, I assumed that they were not mad with him. In China and Pakistan, hybrid seed were being made by hand for commercial production. In all cases, I thought that they could have picked better parents and I could not see heterosis for yield in the hand made hybrids they were growing. I believe that J.B. should have instructed them to test a large number of hand pollinated hybrids to find the superior parents before they began making hybrid seed by hand.

Researchers were also busy attempting to use Vesta Meyer's *G. harknessii* male sterile cytoplasm that had been transferred to germplasm lines of Weaver's that he had given to them. From what I remember and read, they had just about as much success as Dr. Weaver. Dr. Weaver has released a number of germplasm lines along with the cultivar being sold as Sure Grow 1001.

<u>Georgia Experiment Station, Experiment</u>

Shortly after the establishment of the Georgia Experiment Station at Experiment, GA in 1889, Gustave Speth made one of the first systematic and continuous attempts to improve cotton by hybridization. A dozen or more promising breeding lines were developed from Sea Island x Upland crosses; however, all of these failed to reach cultivar status. (Dr. Ware (1937) reported that to date (1936) all efforts to improve cotton through interspecific hybridization of Sea Island x Upland had failed). In 1893, H. N. Starnes (succeeded Speth) made several crosses between Upland cultivars, but did not continue the experimentation long enough to develop improved cultivars. About this same time, J. M. Kimbrough used mass selection for a decade or more to improve the cultivar, Jones Improved. Early in the selection period, the stock of the re-selected cultivar was introduced as Jones Re-improved. After1898, it was known as 'Schley'.

R. J. H. DeLoach, Botanist and Pathologist, made crosses among several Uplands between 1906 and 1908. Out of one cross between 'Cook Improved' and 'Columbia' he developed the cultivar, 'Sunbeam', which was high-yielding and had large bolls, staple of about 2.54 cm (1 inch), and some resistance to diseases. From 1912 to 1914 at Athens, Loy E. Rast made further selections in Sunbeam that resulted in the new cultivar, 'College No. 1'. From 1914 to 1920 inclusive, this was the earliest and highest producing cultivar out of some 40 tested. It soon became popular in some sections of the state where cotton wilt was not a serious problem, and because of its earliness was also a favorite for a while in a few sections after the boll weevil became serious. From 1915 to 1936, the Georgia College of Agriculture maintained the cultivar by continuous selection. In 1926, R. R. Childs began the selfing of strain and carried this method through 1933. This led to a cultivar with much more uniform staple length, which in 1936 averaged 2.54 to 2.58 cm (1 to 1 1/16 in).

Ware (1937) listed four cotton breeders in Georgia in 1936 and all of them were stationed at Experiment. R. P. Bledsoe and G. A. Hale were Georgia State Cotton Breeders. W. W. Ballard and A. L. 'Al' Smith were Federal Cotton Breeders and Smith had responsibility of breeding for disease resistance. From the pedigrees of cultivars, W. W. Ballard began his work on the development of Empire, and A. L. Smith began similar development of Auburn 56 before he moved to Auburn, AL. Empire (Ballard 1950) was developed in 1944 from the cross of Stoneville 2 and Cook 307-6. This cultivar was widely grown throughout the Southeast and used extensively in cultivar development. Tony Peacock told me that Ballard and Smith developed a nursery at Experiment infested with rootknot nematodes and fusarium wilt. Selections of Empire growing in this diseased nursery produced Empire WR in 1950. Parker (1995) reported that there were five cotton breeders in Georgia in 1950. These breeders were W. W. Ballard and B. S. Hawkins at Experiment. T. J. Stafford at the College Experiment Station, Athens, and J. H. Turner, Jr. and J. G. Jenkins at Tifton. I am sure that Barney Hawkins was involved in the development of Empire; however, Ballard has always been given credit for this accomplishment. Ballard left the USDA in the late 1950's to join Estes Seed Company where Empire WR-61 was their bread-and-butter cotton.

Ballard and his wife stopped by to see Cuttino shortly after I came to Florence. We were working in the breeding nursery when this long Lincoln drove up. Ballard visited for a few minutes and wanted to take us to lunch. Cuttino declined graciously, but when they were gone he said, "I rode with him once, and I said then, never again".

H. A. Peacock replaced Ballard as the USDA cotton breeder at Experiment in 1958. Peacock and Hawkins did some excellent research on heterosis for lint yield, inheritance of characters in the cotton plant and agronomic studies to improve cotton production.

The cotton work at Experiment was closed out in 1973. Tony moved seed stocks, office furniture, gins, cleaners, and farm equipment to the Pee Dee Station at Florence, SC and planned to join Cuttino and me in the cotton breeding there. However, he was offered a position as Director of the Florida Experiment Station at Jay, FL and moved there instead of South Carolina. Tony has grown yield tests of Pee Dee material at Jay, FL for me, Dr. C. C. Green and Dr. O. L. May since 1974. He has been actively involved with testing of cotton cultivars for the area and agronomic studies to improve yield. Tony retired as Director of the Experiment Station at Jay in 1996.

Coastal Plain Experiment Station, Tifton

John H. Turner, Jr., the first cotton breeder at the Coastal Plain Experiment Station (CPES), was employed 19 September 1936 (Parker, 1995). Turner (1942) released 'Tifton Station 21', the first cotton cultivar bred at CPES. This short staple cultivar, developed from an individual plant selection out of 'Wannamaker's Dixie Triumph', was superior in staple length, yield and resistance to the fusarium wilt-rootknot nematode complex. The average data for three years for this cultivar were: 558 pounds of lint per acre, 38% lint, and 2.7.8 mm (1 3/32 in) staple length.

Turner (1948) opened the box for cotton yield in Georgia with the release of 'Pandora', meaning all gifted. Pandora was developed from the cross of Tifton Station 21 X Tifton Station C. Tifton Station C (Turner, 1952) was also developed from an early maturing single plant selection at Tifton. (Seed of Station C were never multiplied for seed distribution because its fibers were so poor that mills would not accept it). John wrote that observers say that Pandora "squats down" at squaring and has a compact plant type that distinguishes it from other cultivars. Pandora was among the best available cultivars in yield and was grown extensively in South Georgia. It was soon apparent that an earlier maturing cultivar was needed for commercial production.

To meet the demand for earlier maturing cultivars, Turner (1952) developed 'Early Fluff' from the cross of Tifton Station C X Empire. This cultivar was early maturing and produced excellent yields. Dramatic changes in cotton production were occurring with the introduction of organic insecticides for insect control. Moreover, Beasley's Triple Hybrid material, as a new source of extra-fiber strength, was a breeder's challenge.

Turner crossed the triple hybrid material with Pandora and Early Fluff (Figure 12 and Figure 13) and took this material with him when he moved to Shafter, CA in 1952. This material became the basis of the California Acala Program (Figure 12) and the Missouri Cotton Program initiated by Dr. Sappenfield (Figure 13). Julian Jenkins also used the material (Figure 14) to continue the Georgia Triple Hybrid Program.

J. G. Jenkins, the second cotton breeder at CPES, began work as the USDA Sea Island cotton specialist on 6 July 1938 (Parker, 1995). His responsibility was to develop a superior Sea Island (*G. barbadence* L.) cultivar to revive Sea Island production in the Coastal areas of Georgia, Florida, and South Carolina where the crop was abandoned because of its destruction by the boll weevil in 1922. Culp and Harrell (1974) reported that the Sea Island work was moved to Tifton, GA from Johns Island, SC in 1946. My good friend Julian Jenkins was a colorful character. In fact, Julian operated in technicolor most of the time. I first met Julian in the company of Tom Kerr and Cuttino Harrell on a visit to the Coastal Plain Station in August 1968. My first remark, when we went to the cotton field was: "What is wrong with this cotton? There are no bolls on the upper half of the plants". Julian explained very simply (if he could in his low country brogue, being born and raised at Rockville, SC) that he quit spraying for boll weevils in late July and they destroyed the top crop of cotton. He liked this arrangement because he could pick his crosses, gin the material, and be the first to enter his material in the Winter Nursery at Iguala, Mexico. Also, he was always one of the first to get his seed of advanced generations in the spring. This arrangement would bias the yield of late cultivars in yield trials, but this was of little concern to Julian. He was more interested in equaling or beating the major Coker cultivar in production. At one of the Cotton Improvement Conferences, he cornered Henry Webb and remarked, "Henry, daumn it!, I just got to where I could beat Coker 100 and you had to come out with Coker 201."

It was at this meeting that Julian also cornered Tom Richmond and began to talk about his sailboat racing days at the Charleston Yacht Club Regatta. Tom had a hard time understanding Julian's Charleston brogue and finally said, "Ah!, Julian, you don't remember anything about sailboating". Julian replied, "Well! I know enough not to let Harry Carns pull up the keel board and sink the boat." Tom understood that remark and walked away smiling.

Julian was a remarkable plant breeder who learned the plant breeding trade in the cotton field. He graduated from Rockville High School (or somewhere on Johns Island). He loved to talk about his experiences working on the oilrigs in Southern California. You did not want to talk about the heat or gnats at Tifton, Ga. because he would recount stories that were far worse. When Julian returned from the Southwest, his brother, Willie, helped him to get a job as Sea Island cotton breeder, along with John Turner at the Coastal Plain Experiment Station. Hob Ramey thinks that Julian went to Clemson several years, but Cuttino said he was a high school graduate. Ramey believes that Julian was one of the plant breeders trained by Mr. Cook. In a recent telephone conversation with J. A. Lee, I remarked that Julian was an excellent cotton breeder, but had very little formal training. Josh remarked, " Oh Hell! You didn't need a degree to practice the art of plant breeding; you just needed the degree to get the job." There is no doubt that Julian knew plant breeding methods and had developed a keen eye for selecting outstanding plants from segregating populations that could be advanced to superior cultivars.

On our visits to Tifton, Julian always hauled us around in his air conditioned Buick. (As most of you 'old timers' remember, government cars were not air conditioned, and if you ever were in Tifton in August, air conditioning was appreciated). Julian picked up Tom Kerr, Cuttino Harrell, and me at the motel and journeyed to his home for a drink before dinner. Julian got out the 12-ounce water glasses, a fifth of bourbon, a tray of ice, and a bushel of goodies to nibble on. All this time, he was explaining to us that he thought that two drinks per night were enough for anybody. Everybody was allowed to mix his own drink, and since it was after 5:00 o'clock, Julian led the way. His idea of a good drink was 10-ounces of bourbon and three ice cubes to cut the edge. I must admit that although Tom Kerr loved bourbon, none of us cared for such a strong drink, much less two.

Cuttino asked Julian what his doctor thought of him drinking bourbon with the health problems he had accumulated at the age of 78. "Oh!" he said, "my doctor didn't think it was a good idea to imbibe alcoholic drinks, so I found one that thought it was the thing to do. Now, everybody is happy".

During dinner, a terrible storm with very heavy rains occurred and continued through the night. Julian was late picking us up the next morning because he ran out of gas. Cuttino asked him how he ran out of gas when he had ½ tank when he let us out. "Oh!" He said, "It was raining so hard when I got home, I grabbed a newspaper to throw over my head, slammed the door, and ran inside. When I got ready to come to work this morning, the key was on, but the motor had stopped. I had to call AAA to get the car started after they brought some gas.

It was so wet the next day that we stayed in the office and reviewed Julian's work and research results. Cuttino asked, "Julian, how did you get such high lint percentages this year?" Julian replied, "Well, you folks fussed so much about how low they were last year, I threw the boll samples in the greenhouse about three weeks before I ginned them, and that helped a lot."

Cuttino and I complained about the troubles we were having finding the desirable combinations of characters in plant selections. Julian remarked, "Hell! Boys, you should try working on that 'Daumn' Sea Island cotton again if you want something difficult. Cuttino agreed that he had a good point.

We had been trying to get Julian to grow yield tests at several locations so that he could make valid comparisons of yield between cultivars and germplasm lines. This year he had grown three very good tests and had excellent data for cultivar comparisons. We had all bragged about his good tests and how useful the data was going to be in decision making. As we were leaving for home, Julian ran out to the car and exclaimed, "You fellows can't leave until you help me decide which test I'm going to use and which ones I throw away." Tom just bellowed, "Drive! Drive!"

After moving to the Coastal Plain Station, Julian decided that the best way to increase the yield of Sea Island cotton was to increase lint percentage. I don't know how he did it, but he produced an experimental Sea Island germplasm line (labeled V) that we used in the development of line Q (Pee Dee 4461)(Culp and Harrell, 1979b)(Figure 11) that had an average lint percentage of 39, 6% higher than any other Sea Island cultivars. I do not know of any other cotton breeder that has had this kind of success in improving the lint percentage of Sea Island cotton.

In 1941, south Georgia farmers planted some 16,000 acres of Sea Island cotton because it was needed in the war effort (World War 11, 1939-1945) for fabric in barrage balloons, parachutes, parachute shrouds, machine gun cartridge belts, and other uses (Parker, 1995). The Commodity Credit Corporation (CCC) provided price support ranging from 52 to 59 cents per pound for grade 1 with staple length varying from 38.1 to 44.5 mm (1 ½ to 1 3/4 in) and above. Jenkins (1942) wrote a production bulletin (No. 33), *Growing of Sea Island cotton in the Coastal Plains of Georgia*. He covered some 10 important points to consider, but most important, he emphasized that you are growing a specialty crop and should treat it as such. When the CCC support price for Sea Island cotton was dropped at the end of World War 11, Sea Island cotton production was discontinued.

In 1946, 'Sealand 542,' an extra-long staple cultivar, developed from the cross of Bleak Hall (Sea Island cultivar) backcrossed five times to Coker Wilds (extra-long staple upland) was released jointly by the USDA at the Pee Dee Experiment Station, Florence, SC and CPSE, Tifton, GA. In 1949, a report (Parker, 1995) indicated that 197 bales of Sealand were produced on 357 acres in Berrien County, GA.

Jenkins (1953) released 'Coastland', a new long staple cotton for the Southeast. This cultivar was developed from an intra-specific cross of three *G. barbadense* cottons. Parker (1995) reported that the last mention of Sea Island cotton in Georgia occurred in 1959 when Coastland-RN was released by Jenkins.

At this time, the extra-long staple cotton needs of the textile industry were being met by the new Pima cotton industry of the Southwest that had developed from the production of outstanding Pima cultivars developed by Feaster and Turcotte (1962). The development of extra long staple upland was curtailed and Jenkins (Parker, 1995) continued Turner's work of intergrating the extra-fiber strength of triple hybrid material to upland cotton in Georgia.

Although Jenkins had very little training in genetics and plant breeding, he knew that to get favorable genetic recombinations for selection out of the mass of worthless material, you must make hybridizations and grow out large populations of segregating material (Figure 14). John Turner had taken an F2 selection from the cross of ‘Pandora’ X ‘Florida Green Seed’ and crossed it to ‘Early Fluff’. An F2 selection from this cross combination was crossed to AHA 6-1-4. AHA 6-1-4 (Culp and Harrell, 1974), a California germplasm line with extra fiber strength, was derived from crosses involving Acala types and the primitive Hopi (American Indians) cultigens. An F2 selection from this cross was hybridized with an F4 selection of TH 458 by Turner before he left for California. Jenkins maintained this population by bulk breeding until the F6 generation when a large number of productive lines were selected, grown in isolation, and allowed to self and intermate at random until the F10 generation. Also in 1954, an F6 selection was crossed with ‘Empire’, and the F1 planted in a second intermating block. Open pollinated seed were planted each year and strong selection pressure was applied for yield. The two populations were kept separate except for some crossing between outstanding plants in both populations that were kept in the mix. In 1960, several outstanding Atlas germplasm lines were selected from both groups. In 1961, AC 239 and CE 260 from the Florence program were introduced into the Atlas material to improve lint percentage (Figure 14). Selections after intermating produced Atlas 261 and Atlas 352 and related material. From this material two mixes produced two cultivars, ‘Atlas 66’ and ‘Atlas 67’ that had excellent fiber strength, but produced slightly lower yields (15%) than commercial southeastern cultivars under production. Textile manufacturers were not willing to pay a premium for extra fiber strength; therefore, the cultivars were grown on only a few acres in Georgia in the late 1960’s. Julian retired from USDA in 1965 and was employed by the Georgia Cotton Commodity until 1972.

With the departure of John Turner for Shafter, CA in 1952, W. W. Bradford finished his PhD at Texas A&M College and replaced John H. Turner, Jr. as upland cotton breeder at CPES, Tifton (Parker, 1995). Bradford remained at Tifton only five years before moving to Delta Pine and Land Company at Scott, MS in 1957.

Shelby H. Baker was employed to replace W. W. Bradford in cotton breeding and production in 1967. Before this move, Coker’s Pedigreed Seed Company, Hartsville, SC had employed Shelby. He has developed, released, and registered a number of germplasm lines that show improvements in resistance to the fusarium wilt-rootknot nematode complex and insect resistance.

‘Tifcot 56’, a cultivar developed from the cross of Coker 310 x Pee Dee 4381 [(Pee Dee 4381 was developed from Auburn 56 x AC 349 (Figure 3)] with improved fiber quality and early maturity was developed, released, and registered in 1985. In 1990, he released ‘Georgia King,’ a high yielding, high quality, medium-full season cultivar with very high fiber strength. Georgia King was developed from the cross of Tifcot 56 X McNair 235. McNair 235 was developed from the cross of Coker 310 X Pee Dee 2165. The pedigree of Pee Dee 2165 is given in Figure 3. Tifcot 56 and Georgia King were exclusively licensed to commercial seed companies to assure their availability to farmers; however, the seed companies have failed to produce adequate planting seed for distribution. Georgia King has led yield tests in Georgia and other southeastern states and would be widely planted if seed were available.

Cotton Breeding In Tennessee

Cotton breeding work at the Tennessee Agricultural Experiment Station in cooperation with the USDA was begun soon after 1900 by S. M. Bain. Bain developed the cultivar ‘Trice’, and the seed stocks were maintained under his supervision for many years by farmers who would take the necessary precautions to produce pure seed. After Bain, J. F. Bridger of Bells TN preserved, grew, and distributed seed of Trice until the early 1930.

Shortly after this period, Newman I. Hancock and S. H. Essary began the process of improving the Trice cultivar and purifying the seed stocks. They developed ‘Trice 5’, ‘Trice 25’, ‘Trice 5-42’, and ‘Trice 25-1-45. These researchers also made selections in ‘Acala 5’ and ‘Acala 8’.

Ware (1937) listed N. I. Hancock, State cotton breeder, and D. M. Simpson, Federal cotton breeder, at Knoxville, TN in 1936. Simpson developed the cultivars ‘Hancock’ and ‘Pope’. We were observing cultivars in the Florence Yield Tests with “Simp” when we came upon Pope. Cuttino remarked that Pope was bad to lay down. “Simp” didn’t bat an eye as he replied that Pope was just tired from carrying such a big load of bolls. Pope was never an important cultivar for production in the Southeast. J. B. Weaver was of the opinion that it made a good parent for hybrids because the F2 generation from such a cross produces almost as much lint as the F1. Pope is not listed in Ramey’s (1966) diagrams of cultivar; neither is it reported (Calhoun et al., 1997) as part of the germplasm of any present day cultivar.

Simpson did some valuable research on measuring natural outcrossing in cotton and determining the practicality of using heterosis in cotton by producing seed in areas of high outcrossing. When Simpson retired, Marivale was moved to Knoxville to take his place. Marivale did some excellent work at the USDA fiber Laboratory and his wife was most helpful in computerizing the Laboratory. “Ed” Duncan, operated the Knoxville station for a few years until he was moved to Iguala, Mexico to operate the Winter Cotton Nursery. James B. Pate, whose work on Other Fiber Crops in Florida was closed out, replaced him. In 1965, Billy M. Waddle pulled “Jim” into Beltsville as his Assistant Chief of the Cotton Branch. Norman Justis, who had served as a plant breeder at the Delta Branch Experiment Station, Stoneville, MS with J. B. Dick and coworkers, replaced Pate. Norman remained at Knoxville only a few years until he could find a position close to home in MO. With the resignation of Justis, the Knoxville Station was closed because the location was out of the cotton growing area.

Distribution Of PD Germplasm

It is often difficult to trace the use of germplasm by other cotton breeders. PD germplasm has been requested for its yield potential and extra fiber strength genes and shipped to cotton researchers around the world. David Burns of McNair Seed Company developed McNair 220 and McNair 235 from the cross of Coker 201 x PD 2165. Bridge and Chism (1978) developed DES 56 from the cross of Stoneville 213 x PD 2164. PD 2164 and PD 2165 (Figure 3) were sister germplasm lines developed from the cross of AC 239 x FJA 348 (Culp and Harrell,1979a). The major selection criteria in the development of McNair 235 and DES 56 were high yield potential and early maturity. Fiber length and micronaire were selected within acceptable limits; however, fiber strength was allowed to fall at random. Comparison of lint yields and percentage seed cotton harvested at first pick of both cultivars with the parents in tests conducted by Culp and Green (1992) and Bridge and Meredith (1983), respectively, suggested that significant progress was made in the improvement of both characters. It may be deducted from these data that these improvements in lint yield and earliness must be due to the introduction of new genes for yield and earliness from the PD germplasm through hybridization and selection. These superior characteristics must have been transferred to Deltapine 50, because Keith Jones developed this outstanding cultivar (planted to over one million acres across the cotton belt for several years) from the cross of DES 56 x Deltapine 16. Other cultivars developed that contain PD germplasm are (A) Deltapine 20, (B) DES 119 and related material, (C) Coker 139, and (D) Georgia King.

Meredith (1992) has used PD germplasm in his efforts to develop high yielding cottons with extra fiber strength, primarily by backcrossing and selection. MD 51 ne is a BC2F2 selection from the cross of MD 6511 x Deltapine 90. MD 6511 was a BC5 selection from the cross of Deltapine 16 x FTA 263-20. In the Regional High Quality Test, this cultivar was superior to PD-3 in fiber and yarn tenacity, and approached that of the high quality check, Acala 1517-75. It also produced significantly more lint than Deltapine Acala 90, when backcrossing was used to maintain yield potential in the developing germplasm.

May, et al. (1995) determined the genetic diversity of 126 cultivars and cluster analysis revealed that 48 Southeastern , U.S. and Mississippi Delta cultivars fell into Group 1. The mean coefficient of parentage was 0.20, indicating a degree of relationship near that of cultivars derived from crosses with a common parent. They suggest that the 17 cultivars in this cluster released between 1987 and 1990 show an alarming trend toward erosion of the genetic base. Maybe this accounts for Tom Kerr's supposition that seed of all southeastern cultivars were bulked and redistributed, Henry Webb would find Coker 315, Bill Manning would select Stoneville 213, and Early Ewing would choose Deltapine 16 within a couple of years.

Bowman, et al. (1996) found that Pee Dee germplasm lines had made a contribution to the pedigrees of 34 of 260 cultivars released between 1970 and 1990 in their study. Calhoun, et al. (1997) listed 356 cultivars release between 1970 and 1995, and a quick check indicated that the same 34 plus 21 more had some degree of Pee Dee germplasm in their pedigree. The Pee Dee Program (USDA-ARS & S. C. AES) was one of 16 of the most influential Cotton Improvement Programs during the period of 1970-1990.
It is evident that the Pee Dee lines discussed above that have contributed germplasm to commercial cultivars of importance were developed in the late 1960's and 70's (Figure 3)(Culp and Harrell, 1974). In a telephone conversation with Dr. Cindy Green, she indicated that the contributions from PD-3 are just beginning to appear. A number of researchers are having success in using the recently developed Pee Dee germplasm to develop high yielding cultivars with extra fiber strength. In the development of Deltapine 5305, she used PD-3 X Ering 92 (?) as the basic cross. Several selections from crosses between germplasm lines, released by Green and Culp (1990b), and Deltapine material, are in first year seed increases and appear promising for cultivar release. Don Keim recently developed Deltapine 5111 from the cross of PD-3 X Deltapine 50 that appears promising. Shelby Baker at CPES, Tifton, GA has used Pee Dee 6208 (PD-3) in a number of crosses, and one appears to have cultivar potential for the near future. Similar crosses have been made by Dr. Lloyd May. PD 94042 developed from the cross of 'Jimian 8' X PD-3-8 produced excellent yields in Georgia and South Carolina. It is apparently too late for maximum production in North Carolina.

When I was invited as a guest lecturer (Culp, 1985) to the Peoples' Republic of China, a number of producers wanted to know the value of giving the Chinese our production and cultivar secrets. I tried to explain that this was an exchange of ideas and material. I brought back three Chinese cultivars and tested them for yield and fiber quality in three tests at Florence, SC in 1986 (Culp and Moore, 1987). Yields varied significantly among tests (Table 25) because of the extremely dry growing conditions of 1986 when rainfall measured 7.62 cm (3 in.) from 1 April until 3 August. The two Chinese cultivars, Ering 92 and Jimian 8—used in crosses by Green and May—produced lint yields equivalent to those of PD-3 and Coker 315 (Table 25). Both cultivars had shorter (Table 26) and weak (Table 27) fibers when compared with PD-3 and Coker 315. Yarn tenacity (Table 27) was also significantly lower than the stronger US check cultivars.

It was evident from these studies that the Chinese researchers have spent their major emphasis during the past few years on increasing lint yield at the expense of fiber quality. I suggested earlier that these Chinese cultivars might carry extra genes for lint yield not found in US cottons. Research by Green and May indicate that this might be the case.

I hope that the PD germplasm has made, and will continue to make a significant contribution to US cotton production. This could be the reward for the efforts of the late Tom Kerr to keep the program going when many administrators wanted to close the work. I'd also like to know that the long, hot and cold hours spent in the field by the (late) Willie Jenkins, (late) Cuttino Harrell, Cindy Green, Lloyd May, and myself were not in vain.

References

Anonymous. 1960. Notice of the naming and release of a noncommercial breeding stock of cotton, C6-5. Calif. Agri. Exp. Stn. and USDA Memo. 2 p.

Anonymous. 1967. Notice of naming and release of two noncommercial breeding stocks of cotton, TH 149-8 and TH 149-20. N. C. Agr. Exp. Sta. And USDA Memo. 2p.

Al-jibouri, H. A., P. A. Miller, and H. F. Robinson. 1958. Genotypic and environmental variances and covariances in an upland cotton cross of interspecific orgin. Agron. J. 50:633-636.

Baines, E. 1835. History of the cotton manufacture in Great Britian. Fisher, Fisher, and Jackson. London.

Ballard, W. W. 1950. Breeding methods used in the development of Empire cotton. Proc. Second Cotton Imp. Conf. Pp. 1-9.

Bassett, D. M., and A. H. Hyer. 1985. Acala cotton in California: 60 years of varietal improvement. P. 76 In J. M. Brown (ed) Proc. Beltwide Cotton Prod. Conf., New Orleans, La, 6-11 Jan. Natl. Cotton Coun. Am., Memphis, TN.

Beasley, J. O. 1940. The origin of American *Gossypium* species. Am. Nat. 75:285-286.

Bowman, D. T., O. L. May, and D. S, Calhoun. 1996. Genetic base of upland cotton cultivars released between 1970 and 1990. Crop Sci. 36:57-581.

Bridge, R. R., and J. F. Chism. 1978. Registration of DES 56 cotton. Crop Sci. 18:524.

Bridge, R. R., W. R. Meredith, Jr., and J. F. Chism. 1971. Comparative performance of obsolete varieties and current varieties of upland cotton. Crop Sci. 11:29-32.

Bridge, R. R., W. R. Meredith, Jr. 1983. Comparative performance of obsolete and current cotton Cultivars II. Crop Sci. 23:949-952.

Calhoun, D. S., D. T. Bowman, and O.L. May. 1997. Pedigrees of Upland and Pima cotton cultivars released between 1970 and 1995. MAFES, MSU Bull 1069.

Culp, T. W. 1981. Lint yield and fiber quality improvements in PD lines of upland cotton. S. C. Agric. Exp. Stn. Tech. Bull. 1081.

Culp, T. W. 1982. The present state of the art and science of cotton breeding for fiber quality. p. 99-110. In J. M. Brown (ed) Proc. Beltwide Cotton Prod. Res. Conf. Los Vegas, NV. 3-7 January. Natl. Cotton Coun. Am., Memphis, TN.

Culp, T. W. 1985. Lectures presented to Chinese researchers at the Cotton Research Institute, Anyang, PRC. NTIS PB. 86-120409

Culp, T. W. 1992. Simultaneous improvement of lint yield and fiber quality in upland cotton. p. 227. In C. R. Benedict (ed) Cotton Fiber Cellulose: Structure, Function & Utilization Conf., 28-31 October. Savannah, GA. Nat'l. Cotton, Counc., Cotton Inc., and USDA, ARS.

Culp, T. W. 1993. Genetic contributions to yield in cotton. P. 321-360 In G. A Slafer (ed). Genetic Improvement of Field Crops. Marcel Dekker, Inc. 20 Madison, Ave. New York, NY.

Culp, T. W., and C. C. Green. 1992. Comparative performance of obsolete and current cultivars and PD germplasm lines of cotton with extra fiber strength. Crop Sci. 32:35-41.

Culp, T. W., and D. C. Harrell. 1973. Breeding methods for improving yield and fiber quality of upland cotton (*Gossypium hirsutum* L.). Crop Sci. 13:686-689.

Culp, T. W., and D. C. Harrell. 1974. Breeding quality cotton at the Pee Dee Experiment Station, Florence, S. C. USDA Publ. ARS-S-30.

Culp, T. W., and D. C. Harrell. 1975. Influence of lint percentage, boll size, and seed size on lint yield of upland cotton with high fiber strength. Crop Sci. 15:741-746.

Culp, T. W., and D. C. Harrell. 1977. Yield and fiber quality improvements in upland cotton (*Gossypium hirsutum* L.). S. C. Agric. Exp. Stn. Tech. Bull. 1061.

Culp, T. W., and D. C. Harrell. 1979a. Registration of Pee Dee 0259 and Pee Dee 2165 germplasm lines of cotton. Crop Sci. 19:418.

Culp, T. W., and D. C. Harrell. 1979b. Registration of Pee Dee 4461 cotton. Crop Sci. 19:752.

Culp, T. W., and D. C. Harrell. 1979c. Registration of SC-1 cotton. Crop Sci. 19:410.

Culp, T. W., and D. C. Harrell. 1980a. Registration of medium staple cotton germplasm. Crop Sci. 20:290.

Culp, T. W., and D. C. Harrell. 1980b. Registration of extra-long staple cotton Germplasm. Crop. Sci. 20:289.

Culp, T. W., D. C. Harrell, and T. Kerr. 1979. Some genetic implications in the transfer of high fiber strength genes to upland cotton. Crop Sci. 19:481-484.

Culp, T. W., and R. F. Moore. 1987. Performance of Chinese and U. S. cottons. p.115-116. In J. M. Brown (ed) Proc. Beltwide Cotton Conf. Dallas, TX. Nat'l. Cotton Counc., Memphis TN.

Culp, T. W., R, F. Moore, and J. B. Pitner. 1985a. Registration of PD-1 cotton. Crop Sci. 25:198

Culp, T. W., R. F. Moore, and J. B. Pitner. 1985b. Simultaneous improvement of lint yield and fiber strength in cotton. S. C. Agric. Exp. Stn. Tech. Bull. 1090.

Culp, T. W., R. F. Moore, L. H. Harvey, and J. B. Pitner. 1988. Registration of 'PD-3' cotton. Crop Sci. 28:190.

Duessen, H. 1987. New textile processing and technology and its impact on fiber quality need. P. 47-53 In J. M. Brown (ed) Proc. Beltwide Cotton Prod. Conf. Dallas, TX. 4-8 January. Nat'l. Cotton Coun. Am., Memphis, TN.

Feaster, C. V., and E. L. Turcotte. 1962. Genetic basis for varietal improvement of Pima cotton. U.S.D.A. Publ. ARS 34-31.

Faerber, C. 1995. Future demands on cotton fiber quality in the textile industry. P. 1449 In D. A. Richer and J. Armour (eds) Beltwide Cotton Conf., San Antonio, TX. 4-7 January. Nat'l Cotton Counc., Memphis, TN.

Fryxell, P. A. 1969. A classification of *Gossypium* (Malnaceae). Taxon. 18:585-591.

Green, C. C., and T. W. Culp. 1990a. Potential for the simultaneous improvement of yield, fiber quality, and yarn strength strength in upland cotton. Crop Sci. 30:66-69.

Green, C. C., and T. W. Culp. 1990b. Selection for maturity differences and improved yield stability in Pee Dee germplasm lines. P. 81-82 In J. M. Brown (ed) Proc. Beltwide Cotton Prod. Res. Conf., Las Vegas, NV, 9-14 January. Nat'l. Cotton Counc. Am., Memphis, TN.

Hanson, W. D. 1959. The breakup of initial linkage blocks under selected mating systems. Genetics 44:857-868.

Harrell, D. C. 1966. Cotton breeding and improvement investigations. Annu. Rep. Crops Res. Div. and S. C. Agric. Exp. Stn. 68 pp.

Harrell, D.C., W. E. Vaught, and J. B. Blanton. 1963. Cotton breeding and improvement investigations. Annu. Rep. Crops Res. Div. And S. C. Agric. Exp. Stn. 58 pp.

Harrell, D. C., T. W. Culp, W. E. Vaught, and J. B. Blanton. 1974. Recent breeding progress in improving lint yield and fiber quality in PD lines of upland cotton (*Gossypium hirsutum* L.). S. C. Agric. Exp. Stn. Tech. Bull. 1052.

Harrell, D. C., and T. W. Culp. 1979. Registration of Pee Dee 4381 germplasm line of cotton. Crop Sci. 19:418.

Hoskinson, P. E., and J. M. Stewart. 1977. Field performance of two obsolete cotton cultivars. p. 78-79 In J. M. Brown (ed) Proc. Beltwide Cotton Prod. Res. Conf., Atlanta, GA, 10-12 January. Nat'l. Cotton Counc. Am., Memphis, TN.

Jenkins, J. G. 1942. Growing of Sea Island cotton in the Coastal Plain Georgia. Ga. Coastal Plain Exp. Stn. Bull. 33.

Jenkins, J. G. 1948. Sea Island cotton breeding. Ga. Coastal Plain Exp. Stn. Bull. 16-1

Jenkins, J. G. 1953. Coastland - A new long staple cotton for the Southeast. Ga. Coastal Plain Exp. Stn. Bull. 53:1-24.

Landstreet, C. B., P. R. Ewald, and T. Kerr (1959) A miniature spinning test for cotton. Textile Res. J. 29:701-706.

Landstreet, C. B., P. R. Ewald, and H. Hutchens (1962) The 50-gram spinning test: its development and use in cotton quality evaluation. Textile Res. J. 32:655-669.

May, O. L., D. T. Bowman, and D. S. Calhoun. 1995. Genetic diversity of U.S. Upland cotton cultivars released between 1980 and 1990. Crop Sci. 35:1570-1574.

McClintic, D. 1989. PD-3 cotton wins high praise. The Furrow, Southern Cotton Edition, Deere & Co., John Deere Road, Moline, IL. p. 18.

Meredith, W. R., Jr. 1992. Improving fiber strength through genetics and breeding. P.289-302. In C. R. Benedict (ed) Cotton Fiber Cellulose: Structure, Function & Utilization Conf., 28-31 October, Savannah, GA. Nat'l. Cotton Counc., Cotton Inc., and USDA.

Meredith, W. R., Jr. 1980. Use of insect resistant germplasm in reducing the cost of production in the 1980's. Proc. Beltwide Cotton Conf. (J. M. Brown, ed), St. Louis, MO, 6-10 Janurary. Nat'l Cotton Counc. Am., Memphis TN.

Meredith, W. R., Jr., and R. R. Bridge. 1971. Breakup of linkage blocks in cotton, *Gossypium hirsutum* L. Crop Sci. 11:695-698.

Miller, P. A. and J. O. Rawlings. 1967. Breakup of initial linkage blocks through intermating in a cotton breeding program. Crop Sci. 7:199-204.

Parker, M. 1995. Cotton research. In M. Bass, M. Parker (eds) History of the Costal Plain Exp. Stn. Tifton, GA.

Perkins, H. H., D. E. Ethridge, and C. K. Bragg (1984) Fiber. In R. J. Kohel, C. F. Lewis (ed) Cotton, Agron. Monogram 24, ASA CSSA SSSA. Madison, WI.

Ramey, H. H. 1966. Historical review of cotton variety development. Proc. 18th Cotton Impr. Conf. P. 310-326.

Ramey, H. H. 1980. Fiber crops. P.35-59 In C. S. Hoveland (ed) Crop Quality, Storage, and Utilization. Amer. Soc. Agron. And Crop. Sci. Soc. Amer.

Scherer, J. A. B. 1916. Cotton as a world power. Frederick A. Stokes Co. Philadelphia, PA.

Scholl, R. L., and P. A. Miller. 1976. Genetic association between yield and fiber strength in upland cotton. Crop Sci. 16:780-783.

Smith, A. L. 1964. Registration of Auburn 56 cotton. Crop Sci. 4:445-446.

Turner, J. H., Jr. 1942. 'Tifton Station 21', A new cotton for South Georgia. Ga. Coastal Plain Exp. Stn. Mimeo. 15.

Turner, J.H., Jr. 1948. Introducing Pandora cotton for the Georgia Coastal Plain. Ga. Coastal Plain Exp. Stn. Circ. 12.

Turner, J. H., Jr. 1952. Upland cotton breeding for the Coastal Plains Area. Ga. Coastal Plain Exp. Stn. Tech. Mimo. 6.

Turner, J. H., H. H. Ramey, and S. Worley, Jr., 1976. Trends for yield and quality in cotton breeding since 1960. (Abstract) p.107 In J. M. Brown (ed) Proc. Beltwide Cotton Prod. Res. Conf., Las Vegas, NV, 5-7 January, Nat'l. Cotton Coun. Am., Memphis, TN.

Ware, J. O. 1937. Plant breeding and the cotton industry. P. 65 In G. Hambridge and E. N. Bressman (eds) 1936 Year Book of Agri. US Gov. Printing Office, Washington, D.C.

Ware, J. O. and D. C. Harrell, 1963. Inheritance of fineness of lint in upland cotton. Crop Sci. 31:163-165.

Webb, H. W. 1983. Highlights of the 1982 Cotton Breeder-User Seminar: Technological changes in fiber processing and in plant breeding relating to mill needs and breeder capabilities. Proc. Beltwide Cotton Prod. Res. Conf., Nat'l. Cotton Council, pp 19-22

Webb, R. W. 1936. New facts on strength of cotton start breeding for fine short staple. Ofc. of Inf. USDA. Press Release. Table 1. List of state station and federal field workers in cotton breeding and genetics in the United States (Ware, 199377).

Table 1. List of state and federal field workers in cotton breeding and genetics in the United States. (Ware, 199377).
[Asterisks denote: (*) Federal; (**) State and Federal]

State	Post Office	Name of Worker
Alabama	Auburn	H.B. Tisdale ** (cotton breeding)
	......do	J.B. Dick (cotton breeding)
Arizona	Tucson	W.E. Bryan (cotton breeding)
	.....do	E.H. Pressley (cotton breeding)
	Sacaton	C.J. King* (cotton breeding)
	.....do	R.H. Peebles* (Egyptian cotton breeding and genetics)
	.....do	H.J. Fulton* (Egyptian cotton breeding and genetics)
Arkansas	Fayetteville . . .	L.M. Humphrey (cotton breeding and genetics)
	.....do	Landis S. Bennett* (cotton breeding and genetics)
California	Riverside	J.M. Webber* (cotton genetics and cytology)
	Shafter	G.J. Harrison* (cotton breeding and genetics)
Georgia	Experiment . . .	R.P. Bledsoe (cotton breeding)
	.....do	G.A. Hale (cotton breeding)
	.....do	W.W. Ballard* (cotton breeding)
	.....do	A.L. Smith * (cotton breeding in disease resistance)
Louisiana	Baton Rouge . .	H. B. Brown (cotton breeding and genetics)
	.....do	John R. Cotton* (cotton breeding and genetics)
Mississippi	State College . .	J. Fred O'Kelly (cotton breeding and genetics)
	Delta Branch Experiment Sta., Stoneville	W.E. Ayres (cotton breeding
	.....do	H.A. York (cotton breeding)
	.....do	J.W. Neely* (cotton genetics and breeding)
New Mexico	State College . .	G.N. Stroman (cotton breeding and genetics)
	.....do	A.R. Leding* (cotton breeding)
North Carolina . .	Raleigh	J.H. Moore (cotton breeding in reference to fiber
	.....do	P.H. Kime** (cotton breeding)
Oklahoma	Stillwater	L.L. Ligon* (cotton breeding and genetics)
South Carolina . .	Pee Dee Branch Sta., Florence	W.H. Jenkins* (cotton breeding and genetics

Tennessee	Knoxville	Newman I. Hancock (cotton breeding)
	.....do	D.M. Simpson* (cotton breeding)
Texas	College Station	D.T. Killough (cotton breeding and genetics)
	.....do	G.T. McNess (cotton breeding)
	Substation No. 3, Angleton	R.H. Stansel (cotton breeding)
	Substation No. 1, Beeville	R.A. Hall (cotton breeding)
	Substation No. 12, Chillicothe	J.R. Quinby (cotton breeding)
	Substation No. 6, Denton	P.B. Dunkle (cotton breeding)
	Substation No. 8, Lubbock	D.L. Jones (cotton breeding)
	Substation No. 11, Nacogdoches	H.F. Morris (cotton breeding)
	College Station	T.R. Richmond* (cotton genetics and breeding)
	U.S. Field Stat, Greenville	H.C. McNamara* (cotton breeding)
	.....do	D.R. Hooton* (cotton breeding)

Table 2. Yields of Sea Island and Meade Cottons by USDA at James Island, SC (Cooke and Doyle).

Year	Sea Island (45 mm)	Meade (41 mm)
	---------------------------kg ha---------------------------	
1923	77	286
1924	97	333
1925	168	227
1926	122	259

Table 3. Lint yields, boll, fiber, and spinning properties of ‘Sealand 542’, ‘Earlistaple 7’, and ‘Coker 100 A’ grown at Florence, SC, from 1956 through 1960. (Culp and Harrell, 1974)

	Lint yield			Boll
Varieties	lb/acre	% ‘Coker 100 A’	Lint %	size (g)
Coker 100 A	844a	100	38.0a	7.07a
Earlistaple 7	666b	79	33.7b	6.92a
Sealand 542	547c	65	31.4c	6.98a

	Length, in[2]		T[1]	Micro-	Yarn
Varieties	UHM	Mean	gf/tex[3]	naire[4]	strength[5]
Coker 100 A	1.15a	1.01a	18.1a	4.55a	117a
Earlistaple 7	1.37b	1.14b	22.0b	4.10b	146b
Sealand 542	1.39b	1.14b	22.6b	3.84b	152c

[1]Measurements having a letter in common are not significantly different at the 0.05 level of probability.
[2]Data available for 1956, 1957, 1958, and 1961 only.
[3]Data available for 1956, 1957, and 1958 only.
[4]Data available for 1958 and 1960 only.
[5]Skein strength of 27-tex yarn.

Table 4. Lint yield, lint percentage, fiber properties, and yarn strength of 6 extra-long staple cotton cultivars grown at Tempe, AZ, 1960 (Feaster and Turcotte, 1962).

Cultivar	Lint Yield	Lint	UHM	Mean	T_1	Micronaire	22’s
	kg/ha	%	mm	mm	kNm/kg	reading	kNm/kg
Pima	314	25.1	38.1	32.0	269	3.77	167
SxP	485	27.3	37.6	32.2	282	3.61	178
Amsak	440	27.4	38.1	32.5	302	3.56	190
Pima 32	480	26.7	37.6	31.2	301	3.49	183
Pima S-1	528	31.5	35.3	30.5	299	3.77	183
Pima S-2	728	32.9	35.3	30.2	306	3.80	183
LSD .05	59	0.5	0.05	00.8	08	0.15	07
LSD .01	81	0.7	0.08	01.0	10	0.20	10
C.V. (%)	10.0	1.5	1.3	1.9	2.2	3.4	2.2

Table 5. Fiber and spinning properties of strains from the cross combinations NA, FJA, and AC tested at Florence, SC, from 1958 to 1963 (Culp and Harrell, 1974).

	Lint	Length, in		gf/tex	Yarn
Strain	%	UHM	Mean	T[1]	strength[2]
NA	34.6a	1.37a	1.17a	27.70a	161a
FJA	37.6b	1.26b	1.10b	24.70b	153b
AC	38.9b	1.17c	1.02c	23.18c	148c

[1]Measurments having a letter in common are not significantly different at the 0.05 level of probability.
[2]Skein strength of 27-tex yarn.

Table 6. Correlation coefficients between lint yield and yarn strength in a series of crosses (essentially intermatings) involving triple hybrid ancestry and *G. barbadense* L. introgression of similar material crossed with southeastern cultivars (Culp et al., 1979).

Populations	No. selections	r	r^2
F	14	-0.928	0.86
FTA	18	-0.918	0.84
AC	11	-0.765	0.58
AC.FJA	39	-0.488	0.24
AC.G	28	-0.613	0.38
AC.FJA x			
AC.G	6	0.217	0.05
AC.W	9	-0.249	0.06
AC.D	12	0.045	0.002
AC.V	4	0.448	0.20
H	7	0.436	0.19
AC.?	31	0.162	0.03

Table 7. Correlation coefficients between lint yield and yarn strength after several cycles of selection within four PD breeding lines (Culp et al., 1979).

	Selections					
	Cycle 1		Cycle 2		Cycle 3	
Populations	No.	r	No.	r	No.	r
Earlistaple	11	-0.899	24	-0.578	--	--
Line F	5	-0.946	9	-0.921	--	--
Pee Dee 2165 (AC.FJA)	11	-0.478	10	-0.605	29	-0.49
Pee Dee 4381 (AC.G)	9	-0.479	19	-0.593	--	--

Table 8. Lint yields, fiber properties, and yarn tenacity of three cultivars evaluated in 10 tests in South Carolina in 1970, 1971, and 1972 (Culp, 1992).

		Fiber				
Cultivar	Lint yield	S.L. 2.5%	Strength T_1	Elongation E_1	Micro-naire	Yarn tenacity
	kg/ha	mm	g/tex	%	unit	g/tex
SC-1	1318 a	30.5 a	20.86 b	7.9 a	4.48 b	136 a
Coker 201	1232 b	29.7 b	18.50 c	7.3 b	4.63 a	119 b
PD 2165	1011 c	30.2 a	21.38 a	6.3 c	4.67 a	135 a

Table 9. Lint yields, fiber properties, and yarn tenacity of three cultivars evaluated in the Official South Carolina Test at Blackville, Clemson, and Florence in 1974, 1975, and 1976 (Culp, 1992).

		Fiber				
Cultivar	Lint yield	S.L. 2.5%	Strength T_1	Elongation E_1	Micro-naire	Yarn tenacity
	kg/ha	mm	g/tex	%	unit	g/tex
SC-1	889	29.0	24.0	7.7	4.2	116
Coker 310	829	29.5	22.8	6.9	4.0	105
Coker 201	809	27.9	21.4	7.0	4.2	97

Table 10. Lint yields, fiber properties, and yarn tenacity of five cultivars or germplasm lines evaluated in 10 tests in South Carolina in 1975, 1976, and 1977 (Culp, 1992).

			Fiber				
Cultivar	Lint yield	Lint	S.L. 2.5%	Strength T_1	Elongation E_1	Micro-naire	Yarn tenacity
	kg/ha	%	mm	g/tex	%	unit	g/tex
PD-1	1007a	42.2a	30.0b	22.6a	6.4d	4.8b	146a
SC-1	989ab	39.5b	29.6bc	21.0c	7.5a	4.7c	136c
Coker 310	898bc	39.3bc	30.5a	19.7d	7.1b	4.8b	124d
Coker 201	843c	39.0c	29.1c	18.6e	6.8c	4.9a	119e
PD 2165	756d	38.2d	29.7bc	21.5b	6.3d	4.8b	140b

Table 11. Lint yield and fiber properties of PD-1 and five other cultivars grown in the 1980, 1981, and 1982 Official South Carolina Cultivar Trials at Blackville and Florence, SC (Culp, 1992).

			Fiber			
Cultivar	Lint yield	Gin turnout	S.L. 2.5%	T_1	E_1	Micro-naire
	kg/ha	%	mm	g/tex	%	unit
PD-1	1380	40.0	29.0	25.2	6.1	4.50
SC-1	1344	38.3	29.0	25.8	6.9	4.07
McNair 235	1333	38.4	28.2	23.7	6.2	4.53
Coker 315	1329	39.3	29.0	23.9	6.4	4.33
St 825	1234	37.9	28.2	21.4	6.0	4.60
DPL 26	1186	39.7	28.2	23.2	6.9	4.55
Average	1294	38.5	28.6	23.7	6.5	4.47
LSD (0.05)	45	0.4	--	--	--	--
CV (%)	7.6	1.8	--	--	--	--

Table 12. Lint yields, fiber properties, and yarn tenacity of PD-1 and two cultivars grown in Alabama, Georgia, North Carolina, and South Carolina in the 1979 Regional High Quality and the 1981 and 1982 Eastern Regional Test (Culp, 1992).

			Fiber		
Cultivar	Lint yield	Lint	Span length 2.5%	Micro-naire	Yarn tenacity
	kg/ha	%	mm	unit	g/tex
PD-1	1023	41.2	30.0	4.9	154
Coker 310	984	39.6	29.5	4.9	141
Acala SJ-5	453	38.0	29.5	4.4	157

Table 13. Lint yields, fiber properties, and yarn tenacity of PD-3 and check cultivars grown in the 1981, 1983, and 1985 Regional High Quality Tests (Culp, 1992).

			Fiber				
Cultivar	Lint yield	Lint	S.L. 2.5%	Strength T_1	Elongation E_1	Micro-naire	Yarn tenacity
	kg/ha	%	mm	g/tex	%	unit	g/tex
PD-3	1074a	40.1a	29.0a	21.7b	5.9a	4.6b	163a
McN 235	1138a	39.2b	28.4b	20.3c	5.7a	4.6b	147b
St 213	1089a	38.8b	28.2b	19.1d	6.2a	4.7a	134c
SJ-5	786b	37.8c	29.0a	23.2a	5.9a	4.3c	168a

Table 14. Lint yields, fiber properties, and yarn tenacity of PD-3 and check cultivars grown in the Official South Carolina Cultivar Trials at Blackville and Florence in 1982, 1983, 1984, and 1985 (Culp, 1992).

			Fiber				
Cultivar	Lint yield	Gin turn	S.L. 2.5%	T_1	E_1	Micro-naire	Yarn tenacity
	kg/ha	%	mm	g/tex	%	unit	g/tex
PD-3	1418a	41.6	28.4	25.3	6.0	4.2	120
PD-1	1318b	40.9	29.0	25.1	5.9	4.2	118
C 315	1388a	41.2	29.2	24.6	6.0	4.2	110
McN 235	1317b	39.1	28.2	23.6	6.1	4.2	108

Table 15. Lint yields, fiber properties, and yarn tenacity of PD-3 and selected cultivars grown in the 1987, 1988, and 1989 Eastern Regional Cultivar Tests (Culp, 1992).

		Fiber				
Cultivar	Lint yield	S.L. 2.5%	T_1	E_1	Micro-naire	Yarn tenacity
	kg/ha	mm	g/tex	%	unit	g/tex
KC 380	1163a	28.4b	19.2d	6.9b	4.7d	111d
PD-3	1123a	28.4b	21.6b	6.7b	4.5bc	130b
DPL 50	1108a	28.4b	18.5de	8.7a	4.6cd	107d
McN 235	1108a	27.7c	19.6cd	7.0b	4.4b	117c
DPL 90	1108a	27.9c	21.2b	7.1b	4.7d	121c
C 315	1083a	29.0a	20.2c	6.8b	4.5bc	120c
PM 145	915b	26.4d	19.2d	7.0b	4.5bc	109d
1517-75	692c	29.0a	24.0a	6.9b	4.0a	138a

Table 16. Yarn tenacity, stelometer, and HVI measures (g/tex) on selected cultivars in the 1987 Eastern Regional Test (Culp, 1992).

				HVI	
Cultivar	Yarn tenacity	Stelo-meter	SL-1	SL-2	MC-1
1517-75	147a	24.9a	25.9a	32.7a	32.0a
PD-3	135b	21.6b	24.9a	30.5b	28.3bc
DPL90	126c	20.8bc	25.1a	30.0bc	30.3ab
Coker 315	124cd	19.6cd	22.4b	28.0bcd	27.0cd
McN 235	121cd	19.3cd	23.1b	29.0bcd	27.0cd
KC 380	114e	19.2d	22.2b	25.8e	26.5cd
DPL 50	109e	18.4d	20.6c	24.3e	27.5c
Paym. 145	109e	18.9d	22.1b	28.3bcd	25.0d

SLl-1 = Starlab (calibrated to USDA Int. Std.)
SL-2 = AMS-Memphis (calibrated to USDA SL-HVI std.)
MC-1 = AMS-Memphis (calibrated to USDA MC-HVI std.l)

Table 17. Comparison of 2.5% span length measured by the Fibergraph and HVI in the Eastern Regional Tests (Culp, 1992).

	Fibergraph			HVI		
Cultivar	1987	1988	1989	1987	1988	1989
Coker 315	28.7a	29.0ab	29.2a	28.4a	29.0a	29.2a
Ac 1517-75	28.4ab	29.5a	29.0ab	27.9ac	28.4ab	28.7a
PD-3	28.2ac	28.4ad	28.7ab	27.9ac	28.2ac	28.2a
DPL50	27.9bd	28.7bc	29.0ab	27.4bc	27.9cd	28.2a
KC 380	27.7cd	28.4bd	29.0ab	27.2cd	28.4ab	28.4a
McNair 235	27.4d	27.4e	28.4b	27.2cd	27.4cd	27.9a
DPL 90	27.4d	27.7de	28.4b	26.9d	27.2d	28.2a
Paym 145	26.2e	26.4f	26.9c	25.6e	26.2e	26.4a

Table 18. Comparison of micronaire readings measured by Fibergraph and HVI in the Eastern Regional Tests (Culp, 1992).

	Fibergraph			HVI		
Cultivar	1987	1988	1989	1987	1988	1989
1517-75	4.0a	4.0a	4.0a	4.1a	4.0a	4.0a
Mc 235	4.3b	4.5b	4.4b	4.4ab	4.2ab	4.3b
C 315	4.4bc	4.7b	4.4b	4.4ab	4.3ab	4.4b
Pay 145	4.5bc	4.5b	4.4b	4.6bc	4.4b	4.3b
PD-3	4.5bc	4.6b	4.4b	4.5bc	4.4b	4.5bc
DPL 50	4.6c	4.6b	4.4b	4.5bc	4.6cd	4.4b
DPL 90	4.6c	4.7b	4.7bc	4.5bc	4.6cd	4.8cd
KC 380	4.6c	4.6b	4.8c	4.8c	4.8d	5.0d

Table 19. Comparison of T_1 strength (g/tex) measured by HVI and Stelometer in the Eastern Regional Tests (Culp, 1992).

	Fibergraph			HVI		
Cultivar	1987	1988	1989	1987	1988	1989
1517-75	24.9a	23.9a	23.1a	25.9a	24.3a	30.4a
PD-3	21.5b	21.6b	21.6b	24.9a	21.8bc	27.7b
DPL 90	21.6b	20.8bc	21.3b	25.1a	22.0b	26.8b
Coker 315	20.6c	19.6cd	20.3c	22.4b	20.7cde	25.5cd
McN 235	20.1c	19.3cd	19.3d	23.1b	20.5def	25.2de
KC 380	19.6cd	19.2d	18.7d	22.2b	19.1g	24.0e
DPL 50	18.9d	18.4d	18.2e	20.6c	18.9g	23.8e
Paym.145	192.d	18.9d	19.6cd	22.1b	19.6fg	24.8d

Table 20. Lint yields, fiber properties, and yarn tenacity of four PD germplasm lines of cotton at Florence, SC in 1987, 1988, and 1989 (Culp, 1992).

Germplasm line or cul.	Lint yield	Fiber S.L. 2.5%	Fiber T1	Fiber Micronaire	Yarn tenacity
	kg/ha	mm	g/tex	units	g/tex
PD 5286	884	28.4	22.9	4.7	137
PD 5529	851	29.5	23.3	4.5	140
PD 5576	969	29.0	22.2	4.8	138
PD 5582	987	29.2	22.2	4.7	137
PD-3	901	29.2	23.0	4.7	139
LSD (P=0.05)	69	0.3	0.5	0.1	2.1
CV (%)	16	1.8	3.5	4.2	4.6

Table 21. Lint yields, fiber properties, and yarn tenacity of five germplasm lines of cotton at Florence, SC in 1987, 1988, and 1989 (Culp, 1992).

Germplasm line or cul.	Lint yield	Fiber S.L. 2.5%	Fiber T1	Fiber Micronaire	Yarn tenacity
	kg/ha	mm	g/tex	units	g/tex
PD 5246	1028	27.7	22.2	5.0	129
PD 5256	939	28.7	22.9	4.9	138
PD 5358	1015	28.7	22.5	4.9	138
PD 5377	922	28.2	23.0	4.7	138
PD 5380	958	28.7	22.9	4.8	136
PD-3	965	28.2	22.7	5.0	136
LSD (P=0.05)	69	0.01	0.5	0.1	2.7
CV (%)	12	1.73	4.0	3.2	3.6

Table 22. Lint yields, fiber properties, and yarn tenacity of two PD germplasm lines of cotton at Florence, SC in 1987, 1988, and 1989 (Culp, 1992).

Germplasm line or cul.	Lint yield Full season	Lint yield Short season	Fiber S.L. 2.5%	Fiber T1	Fiber Micro-naire	Yarn tenacity
	kg/ha	kg/ha	mm	g/tex	units	g/tex
PD 5363	960	975	29.0	23.0	4.7	143
PD 5472	1020	1043	28.7	22.4	4.7	139
PD-3	965	902	28.7	22.4	4.9	138
LSD (P=0.05)	69	69	NS	0.5	0.1	2.3
CV (%)	12	16	2.0	4.7	4.0	3.8

Table 23. Desired cotton fiber properties for rotor spinning and other new spinning systems (Deussen, 1987).

Property	Measurement
Micronaire	2.7 to 3.5
% mature fibers	72% to 88% or more
Maturity ratio	0.8 to 1.0 or better
Fineness	100 to 150 mtex
Strength	25 to 30 g/tex (T1 stelometer)
Elongation	7% or more
Length	1 to 1 1/8 inches (25 to 29 mm)
Uniformity ratio	45% or better
Shirley N.L.C.	Less than 1.5%
Microdust content	Minimal

Table 24. Rank of 10 breeding objectives in 1979 (Meredith, 1980).

Objective	Priority[1] Private[2]	Priority[1] State[3]	Priority[1] Weighted average
Lint yield	5.0	4.6	4.8
Earliness	4.4	4.8	4.6
Lint quality	3.4	3.9	3.7
Disease res.	4.4	3.9	4.1
Insect res.	3.6	4.2	4.0
Harvestability	3.3	3.1	3.2
Seed, planting	3.4	2.1	2.6
Seed, nutrients	2.8	2.0	2.3
Seed yield	1.9	1.4	1.6
Herbicide tol.	1.5	1.6	1.5

[1]Meredith, 1980
[2] Priority rating: 1 = very low; 5 = very high
[3] Nine private and 11 state breeders

Table 25. Lint yields of three U.S. and three Chinese cotton cultivars grown in three tests at Florence, SC in 1986 (Culp and Moore, 1987).

Cultivar	Lint yields (kg/ha) Test 1	Test 2	Test 3	Average
PD-3	865 a[1]	1086 ab	884 a	945 ab
Coker 315	842 ab	983 bc	888 a	905 abc
Deltapine 50	804 ab	933 c	821 a	852 bc
Jimian 8	832 ab	1159 a	874 a	955 a
Ering 92	914 a	1073 ab	871 a	953 a
86-1	697 b	941 c	834 a	824 c

[1]Means followed by the same letter within a column do not differ significantly at the 0.05 level.

Table 26. Fiber length of three U.S. and three Chinese cultivars grown in three tests at Florence, SC in 1986 (Culp and Moore, 1987).

Cultivar	Fiber length (mm) 50% SL	Fiber length (mm) 2.5% SL	UR
PD-3	1.47 a[1]	30.0 a	49 a
Coker 315	1.47 a	30.2 a	49 a
Deltapine 50	1.42 b	29.2 b	49 a
Jimian 8	1.32 c	26.7 d	49 a
Ering 92	1.42 b	29.2 b	49 a
86-1	1.35 c	28.2 c	48 a

[1]Means followed by the same letter within a column do not differ significantly at the 0.05 level.

Table 27. Fiber strength, elongation, micronaire, and yarn tenacity of three U.S. and three Chinese cultivars grown in three tests in Florence, SC in 1986 (Culp and Moore, 1987).

Cultivar	Strength (T_1) mN/tex	Elongation (E_1) %	Micronaire reading	Yarn tenacity mH/tex
PD-3	227 a[1]	5.4 b	5.2 b	152 a
Coker 315	205 b	5.8 b	5.0 b	141 b
Deltapine 50	200 c	8.1 ab	5.2 b	124 c
Jimian 8	181 e	7.6 ab	5.8 a	118 d
Ering 92	181 e	8.5 a	5.0 b	122 c
86-1	187 d	7.2 b	4.6 c	128 c

[1]Means followed by the same letter within a column do not differ significantly at the 0.05 level.

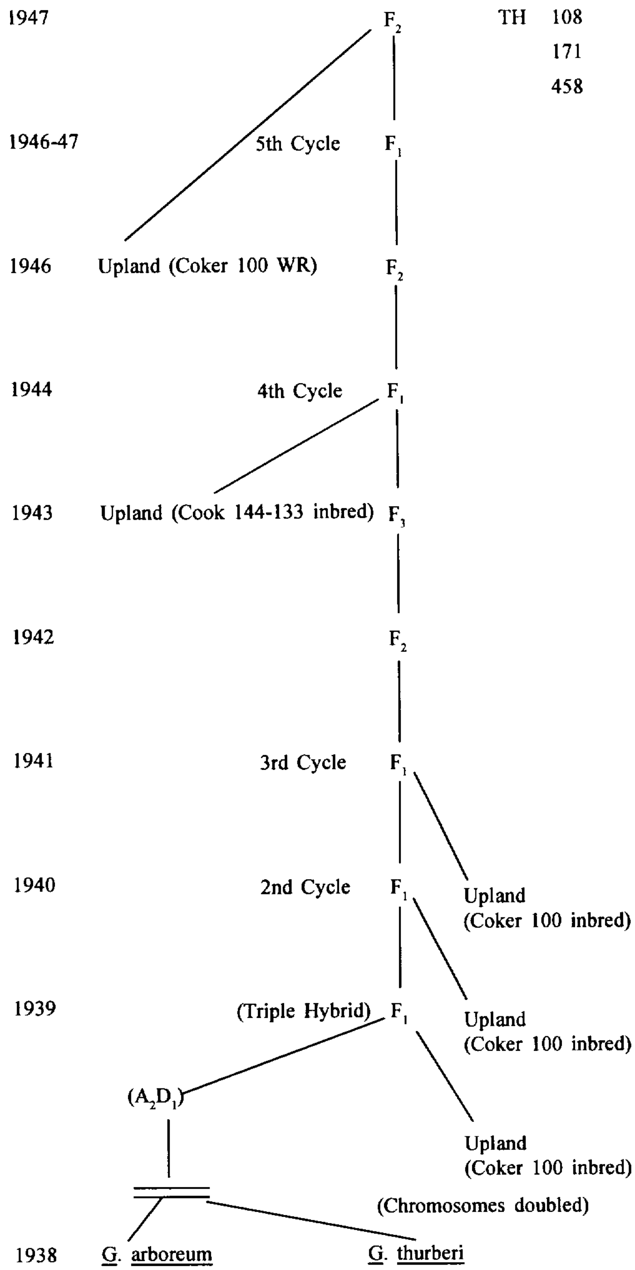

Figure 1. Pedigree of the Raleigh Triple Hybrid Strength lines, 1938 through 1974 [Kerr, unpublished data (Culp, 1982)}.

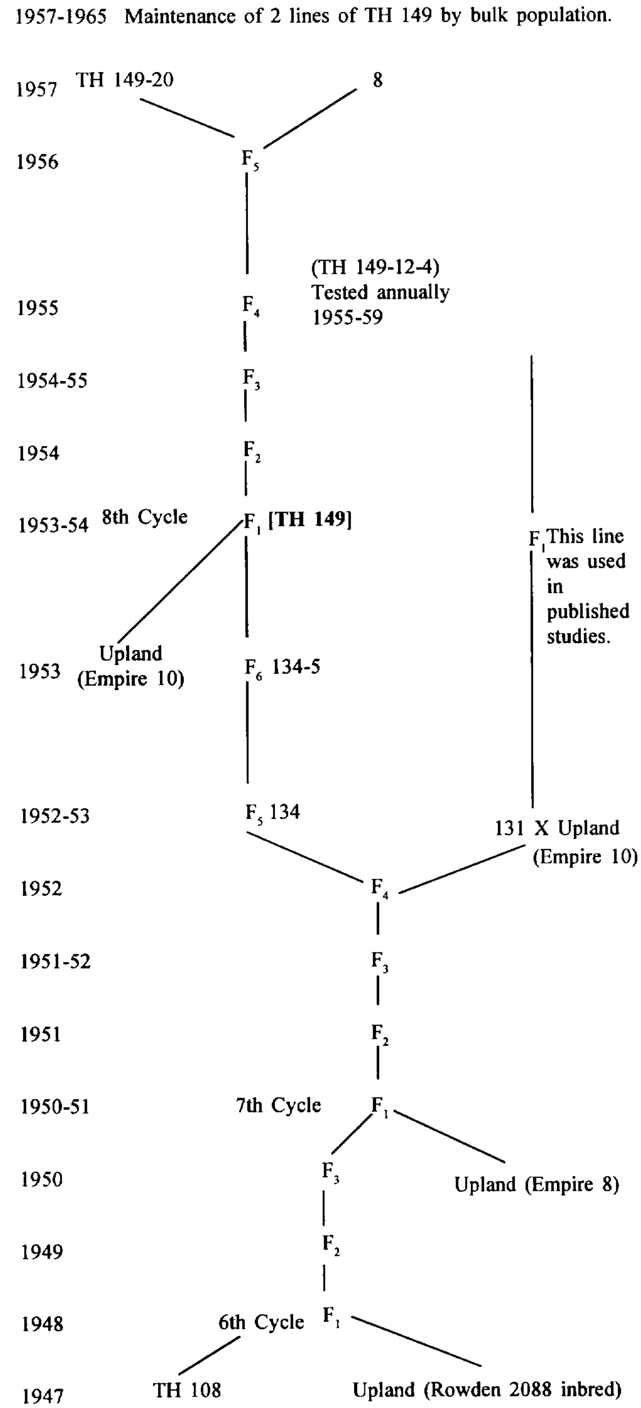

Figure 2. Pedgree of TH149 (Raleigh Triple Hybrid lines) [Kerr unpublished data (Culp, 1982)].

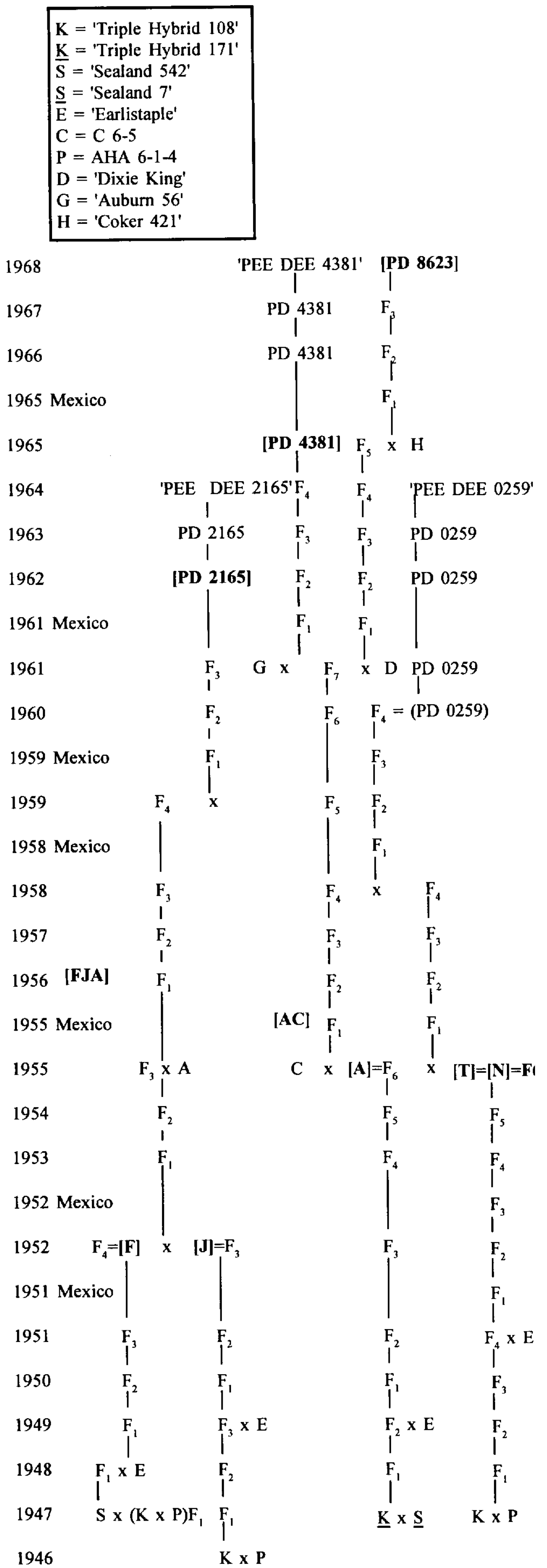

Figure 3. Pedigree of breeding stocks developed in the PD breeding program at florence, SC, from 1946 to 1968 with Beasleys Triple Hybrid *G. arboreum* L. X *G. thurberi* Tod. X *g. hirsutum* L. (Culp and Harrell, 1974)

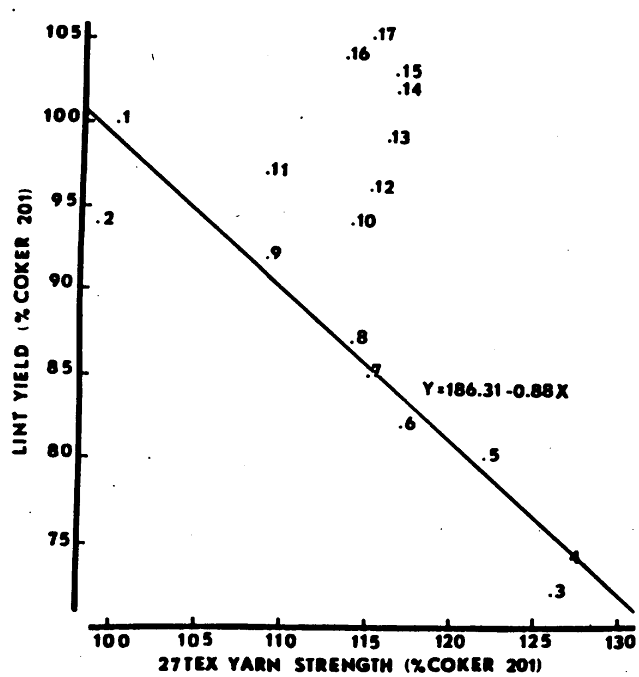

Figure 4. Lint yield and yarn strength of PD breeding lines from intercrosses within the Pee Dee germplasm pool and outcrosses with southeastern Cultivars. Numbers are as follows: (1) Coker 201, (2) Auburn 56, (3) FJA, (4) FTA, (5) AC, (6) PD2164, (7)PD2165, (8) Atlas, (9) Coker421, (10) PD4398, (11) PD4381, (12) PD0109, (13) PD9232, (14) PD9223, (15)PD0111, (16) PD0113, (17) PD9214. (Culp et al., 1979)

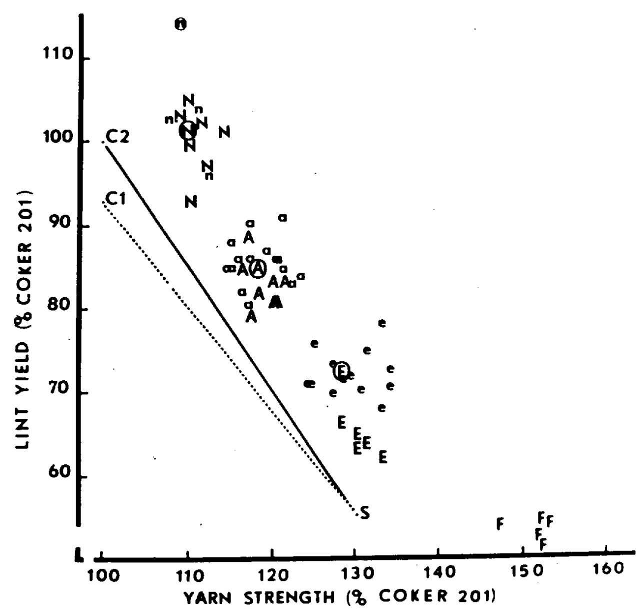

Figure 5. Lint yeild and yarn strength (expressed as a percentage of Coker 201) of strains from three Pee Dee lines in the first and second cycles of selection on the Pee Dee Experiment Station, Florence, SC., from 1954 through 1971. F = line F (DPSE 330); E = first cycle selections of Earlistaple; Ⓔ = Earlistaple-7; Ⓐ = original selecgtion of Pee Dee 2165; N and n = first and second cycle selections of Pee Dee 4381, respectively; Ⓝ = original selection of Pee Dee 4381; ⓝ = Pee Dee 4381-54; C1 = coker 100 A; C2 = Coker 201; and S = Sealand 542. (Culp and Harrell, 1973)

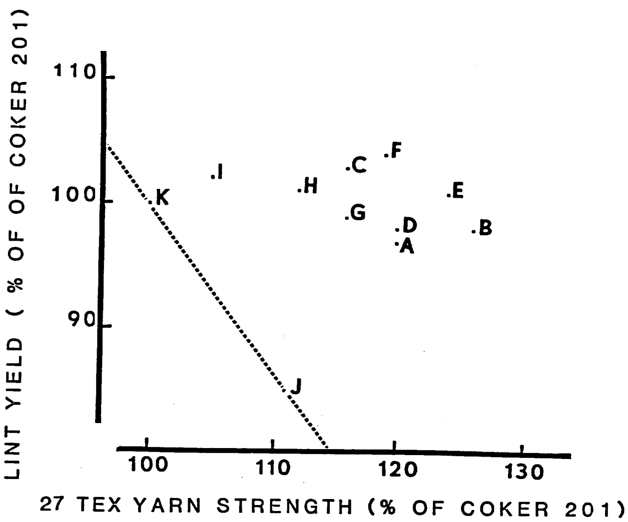

Figure 6. Lint yield and yarn strength of seven OD germplasm lines tested at Florence, S.C., from 1978 through 1981. Germplasm lines and checks were as follows: (A) PD 6044, (B) PD 6132, (C) PD 6142, (D) PD 6179, (E) PD 6186, (F) PD6208, (G) PD 6992, (H) SC-1, (I) Coker 310, (J) PD 2165, and (K) /cijer 201. (Culp et al., 1985)

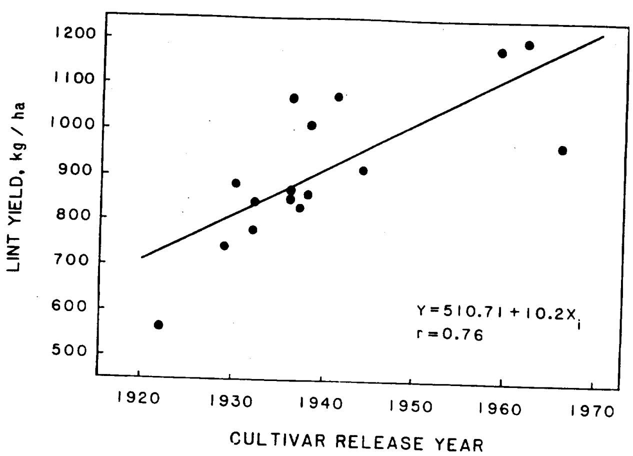

Figure 7. Average yield of obsolete vs modern Cultivars of cotton grown at Stoneville MS, in 1967 and 1968. (Bridge et al., 1971)

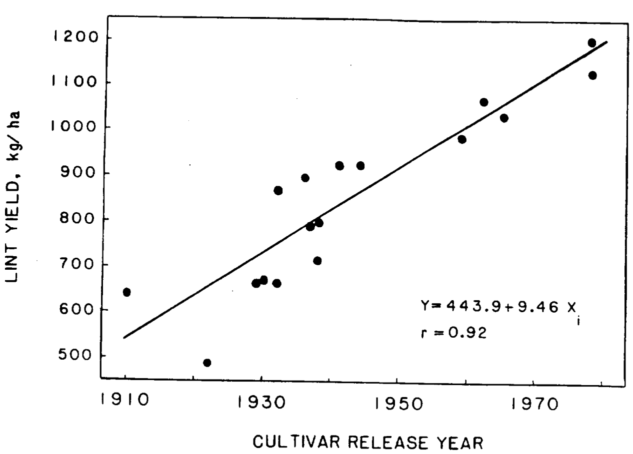

Figure 8. Average yield of obsolete vs modern Cultivars of cotton grown at Stoneville, MS, in 1978 and 1979. (Bridge et al., 1983)

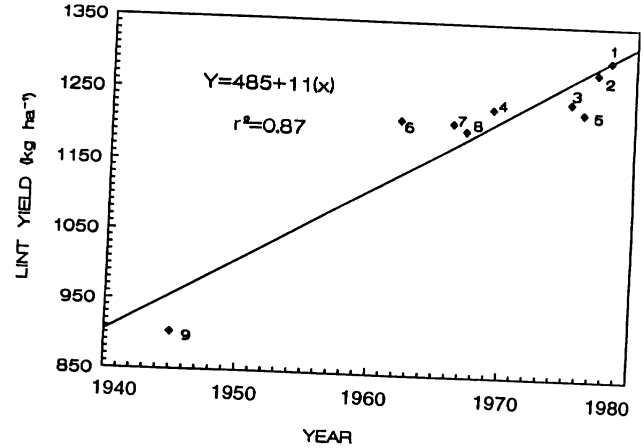

Figure 9. Regression of current and obsolete cultivars (1 = NcNair 235, 2 = SC-1, 3 = Coker 304, 4 = Coker 310, 5 = Ncnair 220, 6 = Stoneville 213, 7 = Coker 201, 8 = Deltapine 16, 9 = Earlistaple 7) of cotton grown at the Pee Dee Rsearch and Education Center, Florence, South Caroline, in 1979, 1980 and 1981. (Culp et al., 1992)

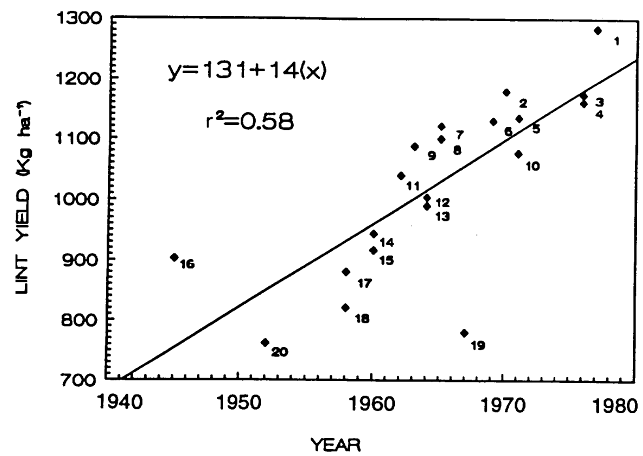

Figure 10. Regression of current and obsolete PD germplasm lines and cultivars [1 = SC-1 (H:FTA.0), 2 = PD9223 (H:AC.FJA), 3 = PD875 (Q/M X DSR.6-56, 4 = PD695 (Q:AC.NA), 5 = PD013 (AC.G:AC.FJA), 6 = PD 8619 (Q X M), 7 = PD4381 (AC.G), 8 = PD4398 (FTA.O), 9 = PD2165 (AC.FJA), 10 = PD0111 (AC.G:AC.FJA), 11 = AC241, 12 = PD3246 (AC.FTA), 13 = PD3249 (AC.FTA), 14 = CE260, 15 = AC235, 16 = Earlistaple 7, 17 = FTA, 18 = FJA, 19 = PD4461 (Q, Culp and Harrell [20]), 20 = Line F] of cotton grown at the Pee Dee Research and Education Center, Florence, South Carolina, in 1979, 1980, 1981. Letters represent the germplasm lines and breeding stocks as follows: A = KSE (Hybrid 313), C = C6-5, E = Earlistaple, F = KPSE (Hybrid 330), G = Auburn 56, H = Coker 421, J = KPE (Hybrid 363), K = triple hybrid, M = MODEL, N = KPE (Hybrid 482), o = Atlas, P = AHA 6-1-4, S = Sealand, and T = KPE (Hybrid 304). (Culp et al., 1992)

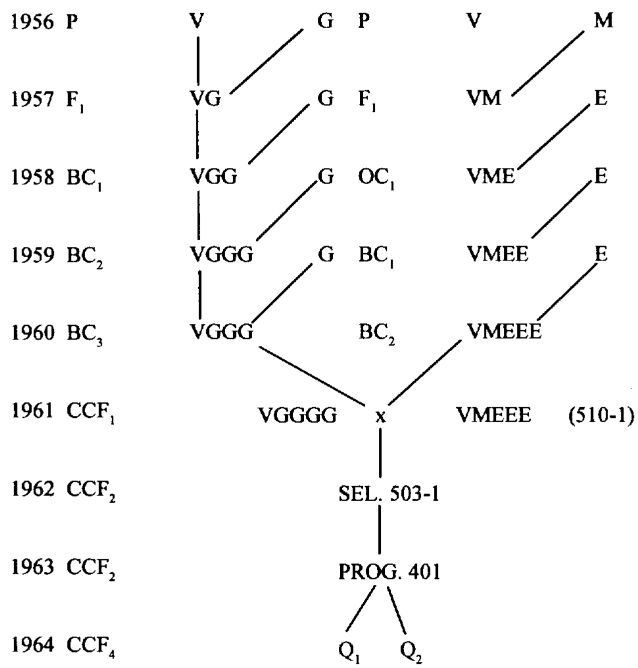

Figure 11. Pedigree of the Q lines derived by backcrossing and composite crossing. Sumbols are as follows: E = Earlistaple; G = Auburn 56; M = coker 100 Wilt; V = Experimental *G. barbadense* strain with high lint percentage (developed by J.G. Jenkins); P = parents; BC = backcross; OC = outcross; and CC = composite cross (Culp and Harrell, 1973).

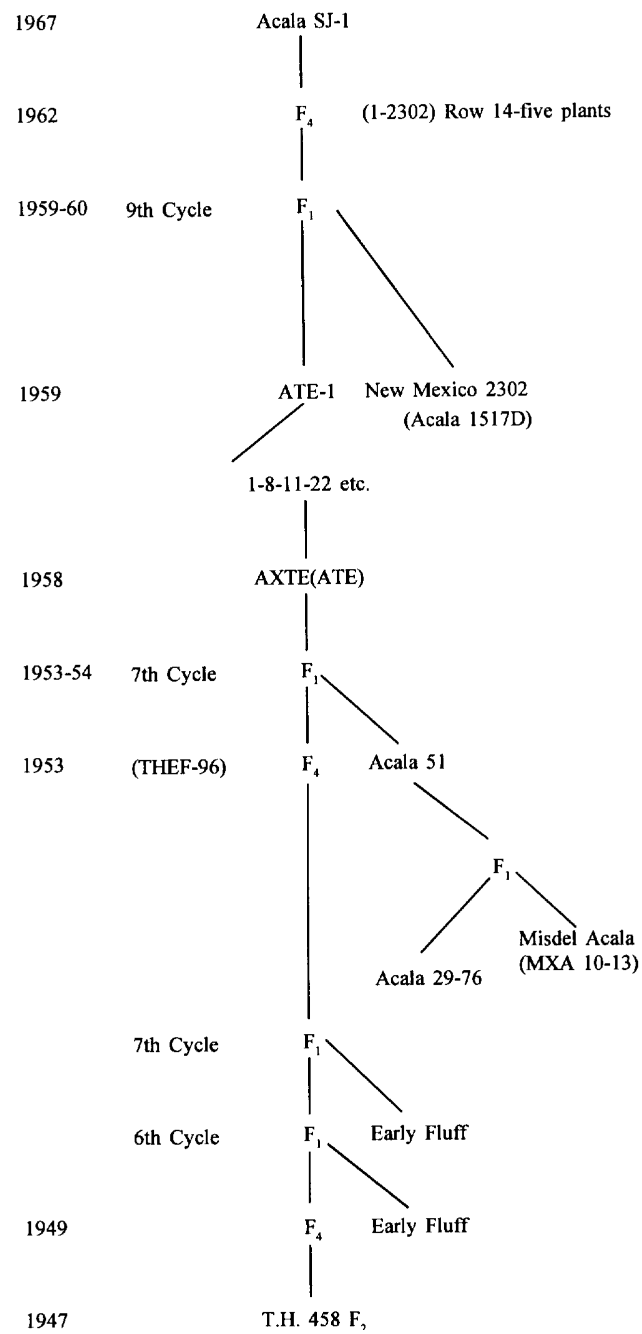

Figure 12. Pedigree of Acala SJ-1 at Shafter, CA [Kerr, unpublished data (Culp, 1982)].

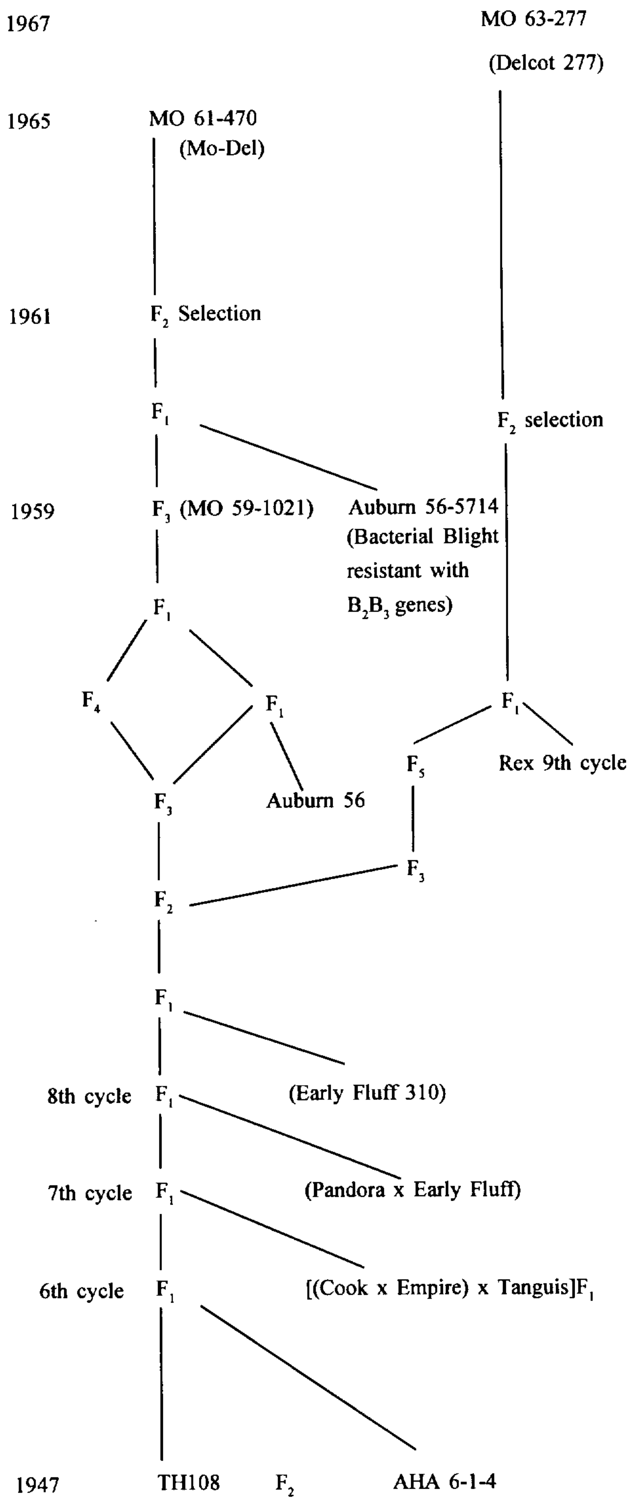

Figure 13. Missour Triple Hybrid germplams lines [Kerr, unpublished data (Culp, 1981)].

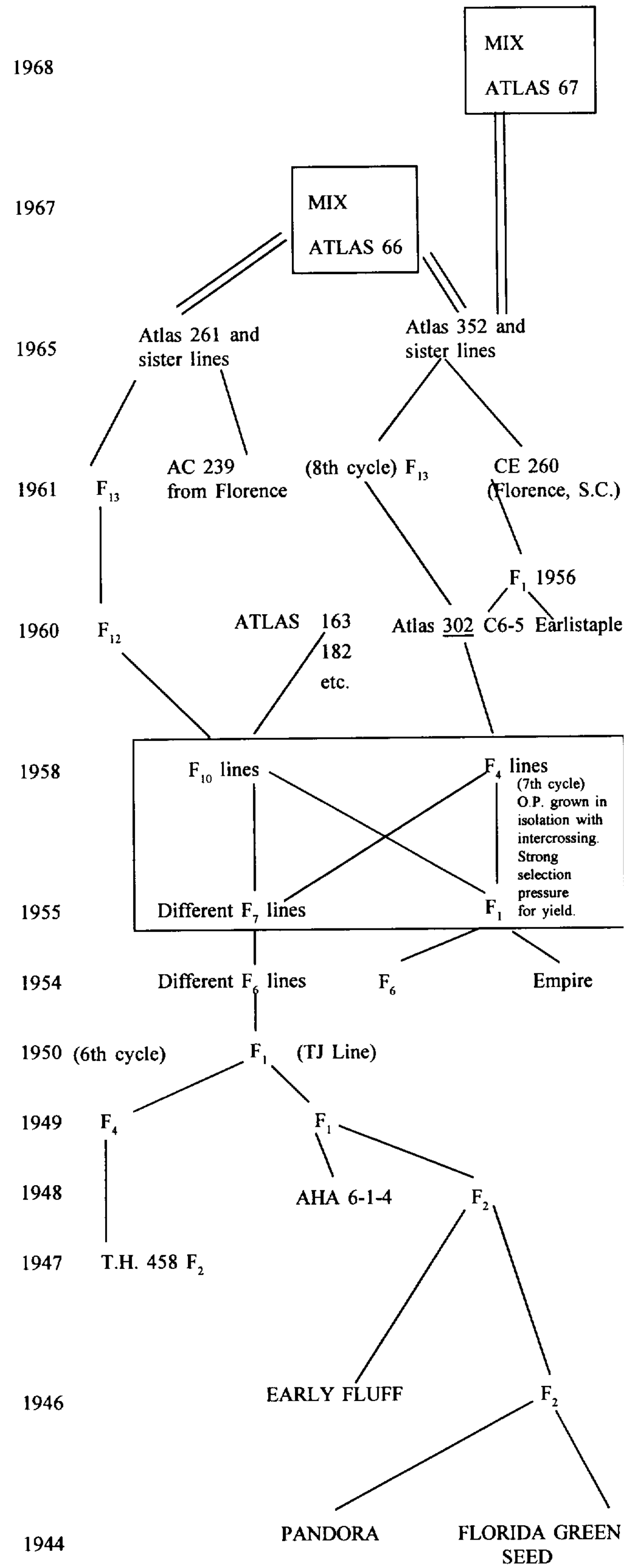

Figure 14. Pedigree of Atlas lines at Tifton, CA, [kerr, unpublished data (Culp, 1982)].