PUBLIC BREEDING EFFORTS IN THE MID-SOUTH--HOST PLANT RESISTANCE

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Abstract

Cotton breeding research on host plant resistance to the Fusarium wilt-nematode disease complex, to root-knot and reniform nematodes and to key insect pests (bollworm-budworm, boll weevils, plant bugs), and on how open-canopy traits affected boll rot, earliness, insects and yield are reviewed and discussed, especially as it related to the Louisiana Agricultural Experiment Station and the time frame of 1950 to 1990.

Introduction

Most aspects of genetic improvement of cotton are of interest to me, but I've been most fascinated by opportunities for genetic improvements in host plant resistance (HPR) to cotton pests -- the subject of this presentation. My primary goal, however, was not so much in finding resistance per se, as it was in combining HPR with improved agronomic traits so that its use in cotton production was enhanced.

When we combines traits from various sources, sometimes the plant forgets to yield, especially if frego bract and glabrous are in the package. At a field day at Bossier City during the early 1980s, my good friend and coworker, David Caldwell, searched my plots for such a plant. He found and took with him a tall, rangy plant with few bolls, then pulled all off but one or two. He set the plant out of sight at the stop where he was to talk about cotton varieties and breeding. When he came to the breeding part of his presentation, David held up this near-barren plant, pointing out to the large crowd in attendance that this unique plant came from Dr. Jones' plots and represented his more recent efforts in cotton breeding. David said that since the plant had the traits for red leaf, okra leaf, frego bract, glabrous, nectariless, high glanding and was on a wilt-nematode resistant background, it was resistance to boll weevil, bollworm, budworm, plant bugs, white-fly, boll rot, Fusarium wilt, root-knot nematode, and to YIELD. Then he added, "Dr. Jones will breed anything". This, of course, I DENY!!

Someone said that "Experience is what you get looking for something else". I do admit to making lots of crosses and looking at lots of different breeding populations over the years in pursuit of my cotton breeding goals. I hope that's what David was inferring.

Stories such as the above, and the mislabeling and defruiting of some of my strains by others have made it difficult for some of my efforts to GET RESPECT. For example, in the 1970 Regional High Quality Test, I entered a strain which I labeled "LA-DASS", denoting its origin and parentage ((Dp. 15 x AHA) x Stardel) x Stv. 7A). But, Brad Waddle couldn't resist moving the hyphen to make it read "LAD-ASS". Immediately, Bob Bridge and Tom Culp took up the torch and before the year was out, everyone knew this strain as LAD-ASS, LED-ASS or LARD-ASS. Though it topped the test as an average of locations, like Rodney Dangerfield, it never "GOT RESPECT".

Still, I think we made some contributions to cotton improvement during this anniversary period, and I will attempt to enumerate and discuss some that relate to HPR.

First, I want to thank Dr. Steve Calhoun for inviting me to this forum and Drs. Joe Schwer and Ed Lubbers of Mycogen for sponsoring me. Secondly, I wish to acknowledge some excellent scientists and research team members with whom I worked. I was fortunate to have had two outstanding cotton scientists as mentors to get me started properly. They were Dr. M. T. Henderson, a superb scientist and teacher, and the late Ferd Self, an excellent field agronomist and cotton breeder who was totally dedicated to quality improvement of both fiber and seed. Early on, I enjoyed the cooperation of Drs. Dale Newsom, W. J. Martin, D. C. Neal, and Wray Birchfield on our nematode-wilt research. That lead to a joint HPR research project with Dr. Newsom on cotton boll weevil, and later, with equal satisfaction, to joint research projects for HPR to major insect pests with Dr. Dan Clower, Dr. Jerry Graves, Gene Burris and other entomologists. Fortunately, we had excellent cooperation with Agr. Exp. Stn. scientists at Alexandria, Bossier City, St. Joseph, and Winnsboro. The friendly support and cooperation of David Caldwell, Cotton Breeder, Dr. C. W. Kennedy, Cotton Physiologist, and Wilbur Aguillard, Cotton Fiber Laboratory, were of both value and pleasure. During the 1950s and early 1960s, we had the good services of Drs. Warren Meadows, Smith Worley, and K. W. Tipton. Then followed several excellent, dedicated Associates who were an integral part of our research efforts and accomplishments. They were, in order of service, Dr. John Andries, A. J. Major, Jr., Dr. M. R. Milam, J. W. Brand, Kenneth Quibedeaux, Dr. D. T. Bowman, Alphonce Coco, Dr. S. J. Stringer, Dr. J. P. Beasley, and Ivan Dickson. Numerous Graduate Students, Student Workers, and Staff were likewise very valuable contributors. Also I was blessed to have had two good scientists, in the persons of Dr. Steve Calhoun and later Dr. Gerald Myers, to assume leadership of the LSU Cotton Genetics/Breeding Program following my retirement. The research program I was a part of for 40 years passed into very capable hands.

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Discussion

Fusarium Wilt-Nematode Complex

When Atkinson (1892) identified the causal organism for Fusarium wilt, he noted that root-knot nematodes increased the severity of the disease. Still, the full importance of nematode to Fusarium wilt infestation was not fully understood and appreciated until the 1950s. Nematicide experiments (A. L. Smith, 1948; Newsom and Martin, 1953) gave added emphasis to nematodes as predisposing agents for the wilt fungus, because incidence of wilt was reduced, along with populations of nematodes, by soil treatment with ethylene dibromide, a chemical not considered to have fungicidal activity.

Many parasitic nematodes species occurr in association with Fusarium wilt. Were all species important as predisposing agents to this disease complex -- if not, which ones were? These were some of the questions that were addressed in the 1950s that helped our understanding of this disease complex. I remember it being a very exiting research topic at the time with rapid developing new insights to an old problem.. Small groups of interested researchers would meet in someone's hotel room during the cotton meetings as informal work groups to report and discuss their research findings on the subject matter.

The sting nematode, (*Belonolaimus longicaudatus* Rau) was the first species proven to be involved in the wilt-nematode complex. Holdeman and Graham (1954) used pure cultures of sting nematode (with *Vs* without) in combination with the Fusarium wilt fungus (with *Vs* without) to prove the association. Similarly, Martin, Newsom and Jones (1956) proved involvement of the root-knot nematode (*Meloidogyne incognita* (Kofoid & White) Chitwood) in the disease complex. Root-knot, alone, was shown to cause severe injury to cotton plants and, in combination with the wilt fungus, to significantly increase the incidence of wilt for both wilt-susceptible and wilt-resistant genotypes, compared with effects of the wilt fungus alone. These authors also showed that pure cultures of nematodes of the genera *Trichodorus*, *Tylenchorhynchus* and *Helicotylenchus*, though parasitic on cotton, were not pathogenic nor did they have any effects on the incidence of Fusarium wilt. The elimination of these and other genera as predisposing agents helped in clarifying which nematodes <u>were</u> and which <u>were not</u> important contributors to the disease complex.

In 1952, the reniform nematode (*Rotylenchus reniformis* Linford & Oliveira) was found in high numbers and in near-pure populations in the cotton wilt plots at LSU Perkins Road Agronomy Farm. Subsequent studies proved this nematode capable of reproducing to extra high numbers (increasing from 1,000 to 49,000 larvae/pint of soil in only two months) and was highly pathogenic on cotton. It increased the incidence of wilt for wilt-susceptible genotypes but, unlike root-knot and sting, it had little or no effect on the incidence of wilt-resistant types. It reduced yield by 25 to 50% (even more for wilt-susceptible cultivars), delayed maturity, reduced plant and boll size and , in some years, lint percentage (Jones et al., 1959; Birchfield and Jones, 1961).

The reniform nematode is quite resistant to desiccation, making it easily spread from field to field on farm equipment (Birchfield and Martin, 1970). This fact may explain, in part, its rapid spread. Distribution of the reniform nematode in 35 years has increased from a few known infected acres in LA, GA and AL (Birchfield and Jones, 1961) to 1.5 million acres in 11 states from TX to NC (Overstreet and McGalley, 1997. Thus far, it does not occur in the three states west of Texas. It may already exceed root-knot in importance as a pest of cotton in the eastern part of the US Cotton Belt and continues to spread at an alarming rate.

Resistance to Root-Knot Nematode

When we began screening for root-knot resistance in 1952, it was by far the more important nematode on cotton in the state, region, and country. We searched the literature, visited with Dr. Al Smith, and got seed of 64 entries for screening in a heavily root-knot infested field on LSU Entomology-Horticulture Farm. The more promising entries were further screened at Baton Rouge, Natchitoches and in the greenhouse in later years. Mexican Wild Jack Jones (National Seed Storage Entry #28672) and Clevewilt 6 (SA#245) emerged as the more resistant of the entries studied. Plants were classified for degree of root galling, averaged over reps and tests and reported in Table 1 as a percentage of Deltapine 15, the common check in all tests, (Jones et al., 1958).

Up until this study, Dr. Al Smith (whom we all looked for leadership on this subject) gave emphasis to Cook 307 and Auburn 56 as the more important upland sources of resistance and to *G. barbadense* var. *darwinii* as the highest known level of resistance to root-knot.

Thus, our comprehensive study turned out to be an important reference on screening and genetics of resistance to root-knot, but because of where it was published, it was largely lost from the literature -- more Rodney Dangerfield syndrome. Still, I know the study had a major impact on the Louisiana and Alabama cotton breeding programs, and, indirectly, the breeding programs in other states and countries.

History of Mexican Wild Jack Jones

For the record and because of its importance as a source of root-knot resistance, a review of the history of Wild Mexican Jack Jones is hereby given. Seed of this entry was collected by Mr. J. L. Stulb, a New Orleans Cotton Merchant, from the interior of Mexico while on a hunting expedition (exact location now unknown). Mr. Stulb was impressed with the plant's prolificness of bolls and thought it may have genetic value for our cotton industry. A nice bouquet of bolls of this and another plant (glabrous), collected somewhere on the coast of the Yucatan Peninsula, were hand delivered by Mr. Stulb to Ferd Self in early spring of 1951. Ferd planted seed of both entries in his nursery that spring, but since both were late to emerge (hard seed) and photoperiodic, he lost interest. As a long shot and somewhat as an afterthought, I added both of Stulb's entries to our 1952 root-knot screening study. Fortunately, the one collected from the interior of Mexico proved to be quite resistant. Plants were stubbed and moved to the greenhouse and used in making crosses and seed production.

Dr. Al Smith, on learning of our results, requested seed of Mexican Wild and Clevewilt 6 for confirmation studies. (I probably sent the seed to Al labeled as Mexican Wild and he added Jack Jones to its name to distinguish it from other primitive *G. hirsutum* cottons from Mexico. Dr Shepherd entered the strain in the national germplasm collection, probably as labeled by Smith). Dr. Smith had the foresight to crossed Mexican Wild Jack Jones with Clevewilt 6-8 and selected for resistance within F2 and F4 generations in fields heavily infested with root-knot.(Shepherd, 1974), but regrettably, Al died ca. 1963 before completing the study.

Fortunately for cotton breeding, Dr. Raymond Shepherd took over leadership of the root-knot research program at Auburn. Through careful research, he recognized and exploited transgressive segregation in this cross which culminated in the release of Aub. 623 RNR, a strain with resistance approaching that of immunity and significantly greater than either parent alone. Since then, Dr. Shepherd released several agronomically enhanced breeding lines with resistance to root-knot comparable to Aub. 623 RNR. These including, among others, Aub. 634 RNR, M-240 RNR, and M-725 RNR (Shepherd, 1982; Shepherd et al., 1989). These new releases are important contributions because they are agronomically enhanced sources of near-immunity to this pest.

Breeding Studies With Clevewilt 6

Because Clevewilt 6 was similar in resistance to Mexican Wild Jack Jones and superior to this strain agronomically, we chose to concentrate on the cross of Deltapine 15 X Clevewilt 6 for breeding and genetic studies. The genetic study (F2 and F3) indicated that resistance to root-knot was a quantitative trait in which the parents differed by an estimate of two pairs of genes (Jones et al., 1958). Early breeding and yield testing was accomplished on root-knot infested soil at Natchitoches, Cheneyville, and St. Joseph and on reniform infested soil at Baton Rouge. Promising strains were also kindly evaluated for root-knot resistance at Tallassee, by Dr. Smith (Jones and Tipton, 1962). Strains from this cross were originally referred to by the "LA DC" prefix but later as "Bayou".

Bayou had good root-knot and Fusarium wilt resistance. Average root-knot larvae populations in field plots of Bayou, Auburn 56, and Deltapine Smoothleaf are given as an average of 5 replications and 7 sampling dates over 2 years at St. Joseph (Figure 1). Greenhouse studies confirmed resistance of Bayou and Auburn 56, with both having significantly fewer egg-mases/cm of root and eggs/egg-mass than Deltapine Smooth (Jones and Birchfield, 1967). Bayou had higher lint percentage, was more resistant to lodging, and had better fiber quality than Auburn 56. Furthermore, it was generally superior in yield to Auburn 56 and other cultivars on root-knot infested soils in the lower Mid-South Region, but it did not quite measure-up in yield with the better adapted but susceptible cultivars on non-problem soils (Jones and Birchfield, 1967). Since most infected fields are only partly affected, we believed it was important that resistant cultivars should yield comparable with adapted, susceptible cultivars on soils where the disease is not a problem. So, we continued with our germplasm enhancement studies.

One strain, Bayou 7769, had unusually high fiber strength in addition to its root-knot resistance. It was crossed with Deltapine 16 in 1971 as a continuing effort in germplasm enhancement of wilt-rootknot resistance. This cross yielded, among others, LA 434-RKR and LA 453-RKR. These high fiber quality, root-knot resistant strains performed well in the Regional High Quality Tests during the 1980-82 period. Several selections from LA 434 RKR (LA RN 4-4, LA RN 909, LA RN 910, and LA RN 1032) were found to have low levels of resistance to the reniform nematode plus moderate resistance to the root-knot, and were released as nematode resistant germplasm (Jones et al., 1988).

Stoneville LA 887 and Paymaster H1560 Cultivars

These cultivars are a culmination of 36 years of germplasm enhancement for resistance to the Fusarium wilt root-knot nematode disease. They originated as sister F5 lines from a cross made in 1980 between LA 434 RKR and DES 11-9, an experimental strain from Dr. Bob Bridge. (A selection from DES 11-9 was later released by Dr. Bridge as 'DES 119', Bridge, 1986). Stoneville 'LA 887' was tested as La 830887 (or LA 887), and Paymaster 'H1560' was tested as LA 830909 (or LA 909).). They were first yield tested in 1987, and both were top yielding entries in the 1989 Regional High Quality Test. These cultivars combine moderate resistance to root-knot with high yielding ability, good fiber quality, medium-early maturity, high lint percentage, and broad adaptation. 'LA 887' was released in 1990 with exclusive marketing rights contracted with Stoneville Pedigreed Seed Company (Jones et al., 1991). 'H1560' was released in 1995 with exclusive marketing rights contracted with Jacob Hartz Seeds (now Paymaster).

Stoneville LA 887 was the first cultivar to combine resistance to the Fusarium wilt root-knot disease complex with truly top-yielding performance over a wide area of the belt, including non-root-knot infested soil. For several years after LA 887 was released (1990-94), 3-, 4-, and 5-

year averages of all official state experiment station yield trials showed Stoneville LA 887 to be the top-yielding cultivar as an average of all tests in each of the following four regions:

1. Louisiana (Figure 2)
2. Mid-South Region (Figure 3)
3. Southeast Region (Figure 4)
4. Eastern 10-State Region (Figure 5)

More recent averages usually find Stv. LA 887 below the newer cultivars (Stv. 474, SG 125, PM H1215, PM H1220, and PM H1244) but above many popular cultivars. PM H1560 has not been tested as extensively as Stv. LA 887, and I have not summarized its beltwide yield performance sufficiently to compare it with Stv. LA 887, but in Louisiana, average yield of the former is comparable with the latter.

The quality of fiber of Stv. LA 887 is illustrated by data from the 1996 National Cotton Variety Tests (Rayburn, 1997) and summarized in Table 2. Four cultivars, Stv LA 887, SG 125, PM HS26, and Acala Maxxa, were national standards in 1996, and as such were tested across the belt and extensively evaluated for fiber quality and spinning performance. Stv LA 887 was superior to SG 125 and PM HS26 for most quality measurements, averaging about intermediate between SG 125 and Acala Maxxa for yarn strength, fiber strength, micronaire, and fiber perimeter.

Resistance to Reniform Nematode

LA RB 15702 was the first germplasm of cotton found to be resistant to the reniform nematode (Jones, 1973). Results from a 6-replicated greenhouse screening study of selected lines from my cotton nursery showed LA RB 15702 (derived from Robbins' Okra X Bayou) to have a significantly lower mean egg-mass index than the two checks, Deltapine 15 and Stoneville 213. A report of these findings was made at the 1973 S-77 Meeting at Fayetteville, AR and its low-level resistance (ca 50% reproduction level of Deltapine 16) was later confirmed by Yik & Birchfield (1984) and Beasley (1985). Other sources of low-level resistance to this nematode in upland cotton are:

- Aub 80-180, Aub 612 RNR, Aub 634 RNR (Beasley, 1985; Muhammad and Jones, 1990)
- LA RN 4-4, LA RN 909, LA RN 910, LA RN 1032 (Beasley, 1985; Jones et al., 1988; Muhammad and Jones, 1990)
- N220-1-91, N222-1-91, N320-2-91, N419-1-91 (Cook et al., 1997)

Yik (1981), a Ph.D. student under Dr. W. Birchfield, was the first scientist to make an extensive search for resistance to reniform in *Gossypium* and related genera. The work, reported by Yik and Birchfield (1984) showed enormous variation within Gossypium from immunity (*G. longicalyx*), to highly resistant (*G. somalense*; *G. stocksii* ;*G. barbadense*, T-110; *G. arboreum*, P.I.41895 & 417891), to resistant (*G. herbaceum*, P.I.408775 & P.I.408778; *G. arboreum*, CB3839 & P.I.417887, *G. raimondi* Ulbr.#9, *G. hirsutum* race marie galante T-893, T-903, & T-874) to moderate resistant (*G. herbaceum* P.I. 408782, P.I. 408780; *G. arboreum* P.I. 417892; *G. thurberi* - Sonoita, AZ; *G. anomalum* #35; and *G. hirsutum*, Upland, LA RB 15702) to highly susceptible with 600% (*G. trilobum*) and 700% (*G. thurberi*) of the egg production of the Deltapine 15 check. They found low-level resistance (relative to Deltapine 15) in the following *G. hirsutum* entries: T-020, T-069, LA Mexican Smooth 15158, T-016, T-037, Kapas Parao, and T-050 (Yik and Birchfield ,1984). A confirmation study confirmed the immunity of *G. longicalyx*, the near immunity of *G. somalense*, and showed that resistance of T-110 and T-893 was due to a reduction in both number of eggs/eggmass and eggmass/per cm of root, compared with the Deltapine 15 check (Yik, 1981).

Other cotton genotypes reported to be resistance to reniform are T-176, T-026, T-019 and Shepherd's root-knot resistant, day-neutral converted form of these entries (Beasley, 1985). Carter (1982) reported *G. arboreum* 'Nanking' C.P. 1402 to be resistant. Later, Stewart and Robbins (1996) screened about half of the Asiatic collection and reported some entries to be highly resistant, with 5% or less of the reproduction level in the upland checks. Robinson et al. (1997) reported two accessions of *G. barbadense* (T-1347 and T-1348), collected from high elevations in Veracruz, Mexico, to be resistance to reniform.

Thus, we now have a bonanza list of sources of resistance to this important pest. Some sources are expected to be more difficult to transfer into upland than others; some are already in *G. hirsutum* and just need combining with agronomically enhanced upland germplasm. The high level of resistance in T. 110, though a *G. barbadense*, should not be particularly difficult to transfer into upland germplasm.

Because this nematode reproduces to such high numbers by first bloom, the level of resistance may need to be 15 to 30% of the reproduction level of Deltapine 15 in order to confer a meaningful level of field resistance. The T-110, T-893, and T-903 accessions have this level of resistance and offer much promise as resistant parent.

Dr. Cook and his coworkers in Texas reported progress by intercrossing low-level-resistance upland strains and selecting for resistance on reniform infested soil. It is important that this good work be continued. Muhammad and Jones (1990) studied inheritance of resistance to reniform in two low-level-resistant upland strains (LA RN 910 and Aub 612 RNR) in crosses with Deltapine 41 (susceptible). They found evidence of different genetic systems governing resistance and suggested that crossing the two resistant parents may lead to increased resistance. However, they cautioned that the general lack of additive effects implied difficulty in breeding for resistance using these lines.

Dr. Stewart and coworkers in Arkansas are exploring ways of transferring reniform resistance from *G. arboreum* into upland. This approach appears promising and hopefully will be vigorously pursued. But, I submit the problem is so serious to our cotton industry that it justifies a long-term commitment by other breeders as well.

Open Canopy Cottons

Our studies with leaf shape were motivated by the hypothesis that opening-up the leaf canopy would increase sunlight penetration and air movement and lower relative humidity within the canopy, making the micro-environment less favorable for boll rot development. Genes for five leaf shapes are members of an allelic series, and all show absence of dominance. They range from the narrow, willow-like leaf of super okra to the broad, shallow lobes of normal; okra is intermediate but skewed toward super okra while sea island and sub okra are intermediate but skewed toward normal. Sea island and sub okra have identical phenotypes and may be controlled by the same gene. I transferred sea island leaf into upland during the 1960s, and Bill Sappenfield found sub okra leaf as a segregate in his breeding material that had both triple hybrid and *G. barbadense* in its background. Sappenfield called it sub okra because it reminded him of the leaf shape phenotype transferred to upland from *G. thurberi* by John Green, (since lost). Meredith developed isolines and made several important studies of leaf shape using Sappenfield's sub okra, and it was through Meredith that I obtained seed for our studies.

We developed near-isogenic populations with different leaf shapes on several variety backgrounds and studied them over multiple locations and years over intervals of three decades. Meredith and coworkers at Mississippi reported on several excellent isogenic studies during the 1980s.

Results of these leaf shape studies are summarized as follows:

- Boll rot - Super okra reduced losses from boll rot by about 55% and okra about 40% of the losses of normal leaf. No effect on boll rot was detected for sea island (Jones, 1972, 1982).
- Earliness - Cut-out and harvest dates were usually reduced by 10-14 days for super okra leaf and 5-7 days for okra leaf compared with normal leaf isolines. Sea island and sub okra leaf isolines had little if any effect (Jones, 1972, 1982).
- Yield - Super okra yielded about 8% less than normal leaf as an average of environments, but it produced positive gains over normal under rank growth environments. Okra produced yields about 5% higher than normal leaf as an average of environments; seldom did it yield significantly less than normal, and under rank environments, it yielded considerably more. Sea island (studied in only Stv 213-613 background) yielded similar to normal leaf, while sub okra (studied in only MD-11 background) yielded 3 to 5% higher than normal (Jones, 1972, 1982; Jones et al., 1988).
- More recently, Gumbo 500 Sub (BC6 from Meredith) was compared with Gumbo 500 (okra) over 3 years (1987-89) at 3 locations in Louisiana. Gumbo 500 Sub outyielded Gumbo 500 Okra by an average of 10% (Jones, et al, unpublished). Several leaf shape isogenic studies conducted at Stoneville, MS showed super okra to yield less, okra to yield about the same, and sub okra to yield about 5% more than normal leaf (Meredith, 1984; Meredith and Wells, 1987). We had earlier concluded that okra lead was the optimum leaf shape for cotton in the lower Mid-South Region, but more recent data suggest sub okra may be the optimum shape.
- Banded-wing whitefly - Screening studies for resistance to this pest (*Trialeurodes abutilonea*, Haldeman) showed that okra and super okra disrupted colonization of this insect and substantially reduced number of pupa and eggs per sq. in. compared with related normal leaf genotypes. Furthermore, their effects were cumulative with the resistance of smooth leaf, giving increased resistance over either trait alone. Sea island leaf had non-detectable effects on this pest. (Jones, et al., 1975)
- Spray penetration - Okra leaf significantly increased spray penetration (purple dye) within the mid-plant canopy by 40 to 100 % compared with normal leaf (Jones, et al., 1987).
- Microclimate - Okra and super okra significantly increased sunlight penetration which lowered relative humidity, increased soil surface temperature, promoted drying of soil surface, and increased mortality of immature boll weevil (under dry conditions) compared with normal leaf isolines (Reddy, 1974; Jones, 1972, 1982).

Open Canopy Cultivars

'Gumbo', an okra leaf cultivar, and 'Pronto', a super okra leaf cultivar, were released in 1976 by LA Agr. Exp. Stn. (Jones, 1976). I believe these to be the first upland open-canopy cultivars released in the USA and perhaps the world. Gumbo is a composite of four selected strains, two from the Stoneville 7A background (BC 6) and two from the Stoneville 213 background (BC5). Pronto is a composite of four selected strains, all from the Stoneville 7A background (BC6). These cultivars were earlier (especially Pronto) than most normal-leaf cultivars and Gumbo was competitive in yield and fiber quality with adapted normal-leaf cultivars at the time of release.

'Gumbo 500' is a wilt resistant okra leaf cultivar with improved yield and quality of fiber , and was released in 1981 as a replacement for Gumbo (Jones et al., 1981). Gumbo 500 is a composite of three sister strains from the cross of LA Okra 3 X 'Deltapine 25'. LA Okra 3 is an experimental open-canopy strain of the Deltapine Smoothleaf background (BC6). Gumbo 500 was superior in earliness and yield to Stoneville 213 and Deltapine 61 and for a while competed well with the cultivars of its time.

Bollworm-Budworm Complex

Our source for HG germplasm traces to a strain obtained from Dr. Lukefahr labeled "GT 5A-10-15-2-XG15" that we crossed with 'Stoneville 213'. I remember it was awful looking germplasm from an agronomic point of view, and I might would have abandoned the entire F2 population but for the encouragement and appeal of Dr. Lukefahr to make at least a few selections. I followed his advice and selected/stubbed ca 30 plants which were moved to the greenhouse and bioassayed with live larvae. Some of the more resistant plants were then crossed with advanced breeding lines of Bayou related germplasm. Populations from these crosses were intercrossed for 4 years in a semi-isolated plots (30 to 50% outcrossing). Individual plants were selected in 1973 on the basis of high density of glands on calyx lobes (GOCL), only guessing at its effectiveness as a selection procedure until hearing Sappenfield's et al. paper in 1974.

I, independently, observed variation for density of GOCL during the summer of 1973. HG lines (Class 4) were glanded over the entire calyx lobes (sepals) while normal upland cultivars (Class 2) were glanded on lower calyx but lobes were free of glands; some segregating lines had plants intermediate (Class 3) with glands on lower calyx plus margin of calyx lobes; reduced glanded plants were Class 1 and glandless plants were Class 0. I classified all plants in my small HG nursery (Classes 2, 3, or 4) and had a few progeny row samples analyzed for flower-bud gossypol. My observations were too small to be conclusive, but since they were in agreement with the comprehensive and conclusive data of Sappenfield et al. (1974), I immediately accepted their findings and began using GOCL as the primary selection criteria for worm resistance in our HG germplasm. GOCL was augmented by a few cycles of selection based on fresh-square and/or lyophilized-square-powder bioassay. Later, GOCL was augmented by progeny row evaluation under heavy worm pressure but with control of other insects. This combination was effective.

Boll rot can be quite severe at Baton Rouge, and it soon became apparent to us that large glanded lines with rugate bolls suffered severely from boll rot. Types with small glands were non-rugate and did not rot as badly as large gland types. Furthermore, if GOCL were dense, they gave comparable levels of worm resistance as the large gland types. Thus, because of selection against boll rot, our HG strains tended to have small, dense glands over calyx lobes and carpel walls, and with square gossypol below the 1.25% then generally accepted as the minimum required level for field resistance to bollworm-budworm. Consistent with our field observations, Parrott et al. (1989) showed that frequency of GOCL was more important to worm resistance than gland size and total square gossypol.

Bollworm-Budworm Resistant Germplasm Release

Major progress resulted from the 1977 cross of two LA HG lines from the early intercrossing program: LA HG 83-1-1480-1546 X LA HG 157-18838-1394-1497. Three germplasm lines from this cross (LA HG-063, LA HG-065 and LA HG-660) were released in 1987 (Jones, et al., 1988). These lines averaged ca. 50 to 60% of the worm-damaged fruit and live larvae observed on Stoneville 213. Mean yield of these lines significantly exceeded Stoneville 213 under. worm pressure and equaled the check when worm damage was below threshold (Jones et al., 1987).

Releases Of Cultivars 'H1215', 'H1220', and 'H1244'

Further enhancement occurred when Miscot T8-27 was crossed with LA HG-063 in 1985. Miscot T8-27 is an early maturing, strain developed and released by Bourland and Bridge (1988). F2 plants exhibiting GOCL from this cross were harvested in bulk (1986) and grown in Mexico for a generation advance. Superior F4 plants with GOCL were selected and progeny tested in 1988. Selected strains (F6) were yield tested beginning in 1989. Three strains (LA 870206, LA 870210, and LA 870222) showed superior performance and were released as cultivars in 1994 by the Louisiana Agricultural Experiment Station under the names of 'H1215', 'H1220', and 'H1244', respectively, through a contractual arrangement for exclusive marketing rights with Jacob Hartz Seed (now Paymaster). Hartz tested the strains (option) in beltwide state yield trials in 1992 as HX1406, HX1410 and HX1422, respectively, and in 1993 under the name of HX1206, HX1220 and HX1244, respectively (Calhoun et al. 1997a, 1997b, 1997c).

These cultivars, first with the HG trait, combine a low to moderate level of bollworm-budworm resistance with early maturity, high yield potential, good quality of fiber, high lint percentage, and generally good adaptation across the Mid-South Region.

Phloem Wilt

A new disease hit these HG cultivars during early summer of 1995 in the southern Mid-South Region. Also hit was Stoneville 132 which is genetically related through Miscot T8-27. Symptoms of the disease are: wilted plants with copper or bronze colored leaves, necrosis or discoloration of phloem tissue, reduced root system, and shedding of fruit (bolls too old to shed become soft or dry-up); plants frequently remain alive but stunted, and may slowly recover and begin to fruit in late season. Plants begin to succumb at early boll set and continue throughout the summer. Symptoms are worse under low plant populations such as at ends of row, edges of skips, skip-row plantings, etc.

The disease has been referred to as Copper Top Wilt, Bronze Wilt, and Phloem Necrosis. I am suggesting that "Phloem Necrosis" or "Phloem Wilt" is more descriptive. Several things may cause bronzing and/or wilting of leaves and loss of fruit, including Fusarium and Verticillium wilt and potash deficiency. Fusarium and Verticillum wilt cause discoloration of xylem tissue, not the phloem. Discoloration of phloem tissue is unique to this malady. The causal organism is unknown. Bell et al (1997) implied the disease may be the same as Agrobacterium root rot, but since the symptoms attributed to Agrobacterium root rot did not coincide with symptoms described above, especially in regard to phloem necrosis, they may, in fact, be different diseases.

The Phloem Wilt (necrosis) is under genetic control. Most cotton genotypes are immune. Only a narrow germplasm base, related to Miscot T8-27, are affected. The disease shows complete dominance for susceptibility, and frequently exhibits low penetrance. Disease incidence was light in 1997, but several fields had damaging levels in 1995 and 1996. The disease has the capability of causing severe damage, and selection for immunity should be practiced in segregating generations when susceptible germplasm are used in crosses.

Multiple Pest Resistance

Because cotton growers have multiple pests that they must control, cotton breeders must develop multiple HPR to these key pests if plant resistance to insects is to have much of an impact on pesticide usage. For example, in the lower Mid-South Region, resistance to the boll weevil, bollworm-budworm and plant bugs are needed. Frego bract and red stem confer an important and cumulative level of resistance (nonpreference) to boll weevil, but frego bract increases sensitivity to plant bugs (Jones, 1972; Jones et al., 1978). Combining frego bract with nectariless helped to ameliorate the problem, but did not completely solved it (Jones et al., 1983, 1984). Furthermore, opportunities exist for utilizing important levels of resistance/nonpreference to boll weevils from certain primitive *G. hirsutum* race stocks (Lukefahr and Vieiera, 1986; Jones et al., 1987; McCarty and Jones, 1989) and for increasing preference differential among cottons to weevils for improving effectiveness of trap plantings (Jones et al, 1987).

Progress was made in combining multiple insect-resistant traits in agronomically enhanced germplasm (Jones et al., 1989) but further improvements are needed to make these cottons commercial acceptable. Perhaps the greatest progress was made with LA 850075 FHG and LA 850082 FN, which were released as germplasm lines (Calhoun et al., 1994). LA 850075 FHG combines frego bract with HG to give boll weevil and bollworm-budworm resistance, along with good fiber and yield potential, but it is in need of nectariless to reduce its plant bug sensitivity (Jones et al., 1989; Calhoun et al., 1992). LA 850082 FN combines frego bract with nectariless, resistance to bollworm-budworm, early maturity, and high yield potential in Louisiana and Mississippi (Jones et al., 1989; Calhoun et al., 1992; Jenkins and McCarty, 1994), but need further agronomic and fiber improvement.

Since bollworm-budworm resistance of LA 850082 FN is due to either the "X" factor from T-254 or the "Q-factor" from PD 695, it is interesting to speculate that its level of resistance may be increased further if it was combined with the resistant factor (s) from HG.

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Table 1. Root-knot index of selected cotton genotypes expressed as per cent of check (Dp. 15); average of three or more tests over years and locations.

Strain/Variety	**No. Tests**	**Root Galling (% of Check)**
Mexican Wild Jack Jones	3	45.1
Clevewilt 6	5	46.4
Clevewilt 3	3	58.6
Sikes 38-6	3	64.5
Auburn 56	3	69.5
Coker 4 in 1	3	70.5
Wannamaker Early Wilt	3	76.5
Coker 100 Wilt	3	85.9
Plains	3	92.2
Deltapine 15 (Check)	3-5	100.0

Source: Jones, Wright, and Newsom (1958).

Table 2. Selected fiber (HVI) and spinning traits, average of all tests (n=19-21) in common, National Cotton Variety Test, 1996.

Trait	LA 887	SG 125	HS-26	Maxxa
Yarn tenacity (mN/tex)	125	111	118	141
2.5% SL, HVI (in.)	1.13	1.12	1.06	1.14
Strength, HVI (g/tex)	29.8	25.4	29.4	32.1
Elongation, HVI (%)	10.0	10.1	10.2	9.7
Micronaire, HVI (unit)	4.3	4.7	4.6	4.0
Weight, Arealo. (mg/in)	4.2	4.5	4.6	3.7
Perimeter, Arealo. (micr.)	49.1	51.0	51.3	47.3

Source: Raburn (1997)

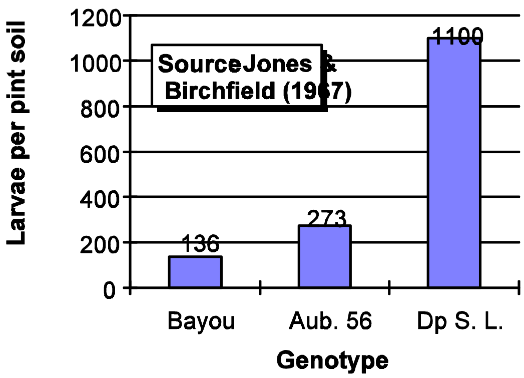

Figure 1. Relative resistance to root-knot as measured by larvae population, field plots, St. Joseph, LA, avg. 5 reps and 7 sampling dates, 1965-66

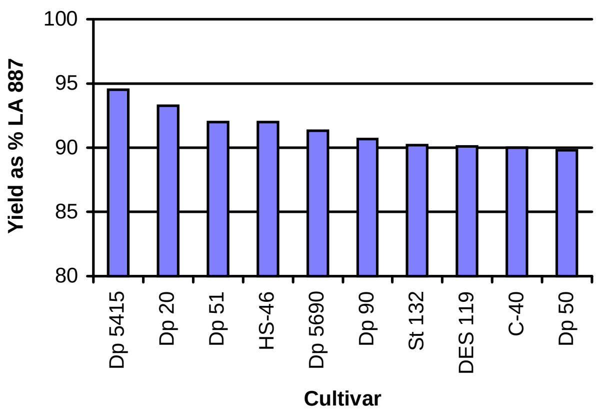

Figure 2. Four-year mean lint yield of cotton cultivars in Louisiana as a % of LA 887; average of all state yield trials (totaling 22 to 28) in which the test cultivar was compared with LA 887 (1991-94).

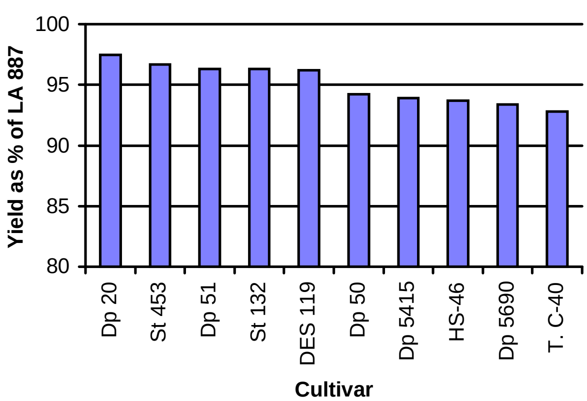

Figure 3. Four-year mean lint yield of cotton cultivars in the 5-state Mid-South Region as a % of LA 887; average of all state yield trials (totaling 82 to 112) in LA, MS, AR, TN, MO in which the test cultivar was compared with LA 887 (1991-94).

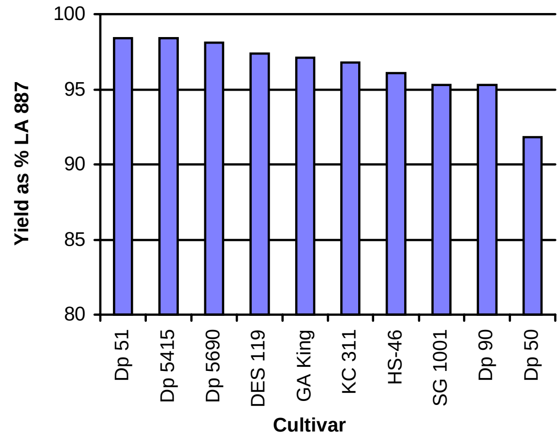

Figure 4. Four-year mean lint yield of cotton cultivars in the 4-state Southeast Region as a % of LA 887; average. of all state yield trials (totaling 79 to 83) in NC, SC, GA, AL in which the test cultivar was compared with LA 887 (1991-94).

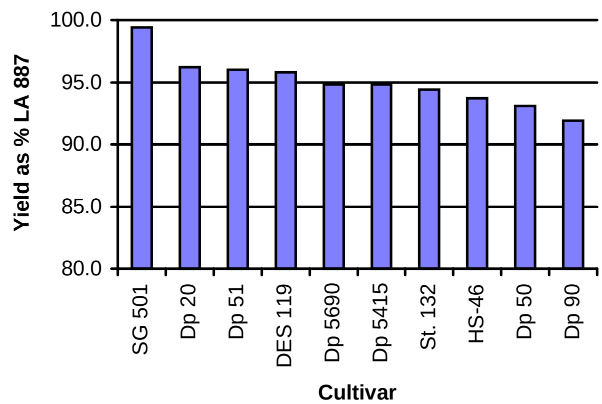

Figure 5. Four-year mean lint yield of cotton cultivars as a % of LA 887 for all tests in common with this check over the 10-state area from south-central TX to NC, totaling 139 to 225 tests in common (1991-94.)