ESTIMATION OF CURRENT COTTONSEED-FIBER RATIOS, SEED INDICES, AND SEED TISSUES AND COMPOSITIONAL PROPERTIES

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Abstract

Because of the sustained efforts to breed cotton for increased fiber yield, several seed/fiber compositional properties have likely shifted over the decades. Conversations with breeders, ginners, and oil processers have identified a number of concerns, including reduced seed size, weaker hulls, greater levels of fiber contamination, and reduced kernel protein levels—all of which directly affects the economic value of the current processing practice and the value of the seed for direct feeding to dairy cows. To better understand these changes, a series of field cotton varieties was collected from areas around Stoneville, MS; Lubbock, TX; and Las Cruces, NM. The samples were ginned and cleaned to determine seed-to-fiber ratio, weighed to give seed index, and hand-dissected to determine the proportions of linter, hull, and kernel. Kernels were then analyzed for gossypol, oil, and protein. Results from the first two years of study (2014 and 2015) indicated that the average seed/fiber ratio was 1.44 ± 0.10 (range: 1.28–1.60, as is basis) and has declined compared with published data from the 1930s and 1940s. Seed indices averaged 9.90 ± 1.11 g (range: 8.46–11.8 g, as is basis) and showed a similar decline compared with early published varietal data. Seed tissue proportions have changed less, although a decrease in the percentage of linters was apparent. A third year of study is in progress.

Introduction

Over many decades, sustained plant breeding efforts have resulted in steadily increased cotton yields. These efforts, however, have come with consequences for the seed, and a number of complaints and problems are being voiced by ginners and oil processors regarding changes in seed quality. Weaker hulls, smaller seed size, and reduced protein levels have all been discussed.

Weak seed is a problem for both the fiber and seed processors, as hull fragments can contaminant the fiber making it more difficult to clean. Weaker hulls lead to more damaged seed, which are then more prone to moisture uptake and degradation of the oil during storage, causing a direct loss of extractable oil and oil refining problems. Small seed size is a concern for ginners, as the seed is usually taken as the payment for ginning. In addition to the direct economic loss, small seed size results in additional ginning losses, as more seed exit the gin stand with the gin motes or in the fiber cleaning operations. Small seed size also affects the oil processor's ability to recover the linters and dehull the seed. Low protein levels force crushing plants to reduce the addition of hulls to the kernel tissue during oil extraction, making it more costly to ensure a standard 41% protein level in the defatted meal product.

Values for these seed properties were frequently obtained in the early years of studying seed quality and oil processing, and a number of these studies can be found discussed in chapters in A.E. Bailey's book "Cottonseed and Cottonseed Products" (see e.g., chapters by Lund, 1948; Tharp, 1948). However, since this publication, few studies have focused on these properties, although the expectations are that some of these values have undergone substantial shifts with continued breeding. To try to better understand the magnitude of these differences, this study was undertaken to derive values comparable to commercial operations on current varieties and to compare these values with those discussed in the early literature.

Methods

Several varieties of field cotton were collected with the help of the ARS cotton gin laboratories located in Stoneville, MS, Lubbock, TX, and Las Cruces, NM. Three pound samples of each variety were ginned on a 10-saw laboratory-scale gin, and the fiber and seed fractions were collected and weighed. Moisture was determined on both fractions by standard oven methods. The ginned fiber was cleaned on a Shirley fiber cleaner with two passes. Seed-to-fiber ratio was determined after correcting for the trash level determined by the cleaner, and the seed index (gram weight of 100 seed) was determined by weighing.

To determine the percentage of linter (short unginnable fibers), hull, and kernel tissues, white fuzzy seed was analyzed for linter content by AOCS method Aa 7-55, which uses a modest acid treatment followed by agitation to brush the linters free of the seed. The procedure determines the linter content by weight difference, then back corrects the moisture to an 8% level (typical of fiber and linter moisture levels at ambient conditions). White fuzzy seed was hand cut to separate kernels from the hull plus linter fraction and both fraction were weighed. The hull fraction was then determined by difference.

Protein and moisture levels were measured on the hull–linter and kernel fractions. Oil, protein, gossypol, and moisture contents were measured on the kernel tissue. The hull–linters fraction was ground with a Wiley laboratory mill, and kernels were chopped with a Braun hand-held food chopper, both to pass a 20 mesh sieve.

Gossypol was measured by HPLC with the AOCS Recommended Practice Ba 8-99, and protein was determined by combustion with a LECO FP-538 nitrogen analyzer. Both measurements were made on an as is basis, and the moisture level was used to calculate values on a moisture free basis. Oil was determined after freeze-drying the ground kernel tissue, as dry tissue improves the extractability of the oil. The oil was extracted with a Foss Soxtec analyzer (15 min immersion cycle and 3 hr extraction cycle with petroleum ether). The kernel moisture level was then used to back calculate the results to an as is basis. Seed gossypol and oil levels were based on the kernel results, and seed protein was calculated from the protein measured for both the hull–linter and kernel tissues.

All analyses were conducted on triplicate sub-samples (replicates) of each variety as received. Most analytical determinations were made in duplicate, with the average result taken as the value for the replicate. Seed index was averaged on triplicate 100 seed weight determination for each replicate. All results were obtained both on an as is basis and on a moisture free basis. Values reported below are on an as is basis.

Results

For the 2014 season, eleven field cotton samples were analyzed. One *Gossypium barbadense* variety (DP340) was included. One *G. hirsutum* variety, STV5458, was collected from two locations. All were grown under irrigated conditions. In 2015, thirteen samples were analyzed. Three of the samples were grown in dryland conditions, the others were grown under irrigation. STV4946 and DP1044 were grown in two locations. When evaluated by year, little difference was observed in the average values or ranges of most evaluated properties, suggesting that the populations were sufficient to generate representative results.

The seed/fiber ratio from the two year population varied from 1.23 to 1.60 with an average value of 1.44 ± 0.12. This represents a marked decrease from values that can be calculated from fiber and seed production records complied by the Depts. of Agriculture and Commerce from 1930 to 1946 as reported by Lund (1948), which averaged 1.74, and the 1.8 value noted by Thornton (1932). The average value is also lower that the value of 1.5 that is often cited in current literature (e.g.; Dowd, 2015). The change appears to be due to more than simply increased fiber yield. Smaller seed were also apparent with an average seed index of 9.9 ± 1.2 g. This compares with varietal averages between 11 and 12 g in early studies (Garner et al., 1914; Fraps, 1916; Tharp, 1948), indicating that a ~10-20% reduction in seed size has occurred over the past 70 years of breeding. For comparison, DP555, which has a notoriously small seed size causing a number of ginning and processing difficulties, has a seed index of about 7.0 (Dowd, unpublished results).

The STV5458 variety in 2014 showed marked property differences between the Lubbock and Stoneville locations. Given that this variety was developed for the Delta region, it might be expected that productivity of this variety would be lower in Lubbock, which was realized with a lower seed-to-fiber ratio and dramatically smaller seed index (Table 1). Also, given the almost 30% drop in seed size and the smaller 8% reduction in seed/fiber ratio, it is also apparent that this variety must have also yielded considerably less fiber in Lubbock.

Table 1. Seed index (100 seed weight) and seed-to-fiber ratio for cotton samples grown in 2014 and 2015 (as is basis)

Variety-Location-Year-Irr/Dry	Seed Index, g	Seed/Fiber ratio
Acala1517-08 - Las Cruces - 2015 – Irrigated	9.62 ± 0.15	1.60 ± 0.02
DP340 - Las Cruces - 2014 – Irrigated (Pima)	11.75 ± 0.03	1.56 ± 0.00
DP1044 - Lubbock - 2015 – Dryland	8.49 ± 0.08	1.32 ± 0.02
DP1044 - Lubbock - 2015 – Irrigated	8.74 ± 0.09	1.47 ± 0.02
DP1044 - Stoneville - 2014 – Irrigated	11.13 ± 0.25	1.54 ± 0.01
DP1219 - Lubbock - 2014 – Irrigated	8.46 ± 0.11	1.37 ± 0.01
DP1321 - Stoneville - 2014 – Irrigated	9.88 ± 0.33	1.28 ± 0.02
DP1321 - Stoneville - 2015 – Irrigated	9.47 ± 0.10	1.39 ± 0.01
FM1944 - Stoneville - 2014 – Irrigated	11.13 ± 0.25	1.54 ± 0.01
FM1944 - Stoneville - 2015 – Irrigated	10.42 ± 0.08	1.56 ± 0.01
FM2484 - Lubbock - 2014 – Irrigated	9.49 ± 0.13	1.23 ± 0.01
FM9180 - Lubbock - 2015 – Dryland	9.04 ± 0.14	1.33 ± 0.02
NG4111 - Lubbock - 2015 – Dryland	8.56 ± 0.09	1.33 ± 0.02
NG4111 - Lubbock - 2015 – Irrigated	9.62 ± 0.03	1.46 ± 0.01
PHY339 - Las Cruces - 2014 – Irrigated	11.62 ± 0.22	1.57 ± 0.01
PHY444 - Stoneville - 2015 – Irrigated	10.67 ± 0.18	1.31 ± 0.02
PHY499 - Stoneville - 2015 – Irrigated	9.40 ± 0.12	1.34 ± 0.01
PHY565 - Las Cruces - 2014 – Irrigated	9.39 ± 0.08	1.50 ± 0.02
STV4946 - Lubbock - 2015 – Irrigated	9.72 ± 0.15	1.46 ± 0.05
STV4946 - Stoneville - 2014 – Irrigated	11.22 ± 0.33	1.39 ± 0.02
STV4946 - Stoneville - 2015 – Irrigated	10.88 ± 0.10	1.52 ± 0.02
STV5289 - Stoneville - 2015 – Irrigated	8.59 ± 0.06	1.54 ± 0.01
STV5458 - Lubbock - 2014 – Irrigated	8.59 ± 0.06	1.40 ± 0.04
STV5458 - Stoneville - 2014 – Irrigated	11.39 ± 0.11	1.51 ± 0.01
Pop. average and standard deviation	9.9 ± 1.1	1.44 ± 0.10

Although less pronounced than the 2014 grown STV5458 variety, STV4946 in 2015 also showed different properties in the two locations, and again the seed-fiber ratio and seed index was reduced for the Lubbock location.

The proportion of linters (Table 2), hull, and kernel fractions appeared to be less different from early reports than are the seed index and seed-to-fiber ratio results (Table 2). For instance, the average kernel mass was 54.4% compared with an average value of 55.6% from several studies spanning the period of 1906 to 1944 as summarized by Tharp (1948). However, the percentage of seed linters appears to be reduced compared with many reports. Early reports give average values for this property ranging from 13.2 to 13.8% (Pope and Ware, 1945; Martin and Thomas, 1946) compared with the average value of 10.0% (excluding the one *G. barbadense* sample) obtained from the 2014 and 2015 seed samples (Table 2). From these early studies no linter percentage below 11% was noted, whereas values less than 10% were frequent in the recent data set. This change is may be attributed to multiple effects, including (1) ginning improvements that reduce the level of 'linter' material retained with the seed and (2) breeding for increased fiber yield that reduces resources available to support linter development.

Table 2. Proportion of cottonseed linter, hull and kernel tissues from cotton varieties grown in 2014 and 2015 (as is basis).

Variety-Location-Year-Irr/Dry	Linter, %	Hull, %	Kernel, %
Acala1517-08 - Las Cruces - 2015 – Irrigated	9.9 ± 0.2	35.3 ± 0.6	54.8 ± 0.4
DP340 - Las Cruces - 2014 – Irrigated (Pima)	3.1 ± 0.2	36.4 ± 0.6	60.5 ± 0.5
DP1044 - Lubbock - 2015 – Dryland	11.5 ± 0.4	34.8 ± 0.2	53.7 ± 0.4
DP1044 - Lubbock - 2015 – Irrigated	12.6 ± 0.4	35.2 ± 0.5	52.2 ± 0.5
DP1044 - Stoneville - 2014 – Irrigated	10.8 ± 0.3	34.8 ± 0.6	54.4 ± 0.5
DP1219 - Lubbock - 2014 – Irrigated	12.6 ± 0.4	35.0 ± 0.4	52.4 ± 0.1
DP1321 - Stoneville - 2014 – Irrigated	10.7 ± 0.7	37.5 ± 0.9	51.8 ± 0.2
DP1321 - Stoneville - 2015 – Irrigated	11.4 ± 0.6	36.6 ± 0.1	52.0 ± 0.5
FM1944 - Stoneville -2014 – Irrigated	9.7 ± 0.1	40.0 ± 0.3	50.2 ± 0.3
FM1944 - Stoneville - 2015 – Irrigated	11.2 ± 0.4	37.9 ± 0.2	50.9 ± 0.6
FM2484 - Lubbock - 2014 – Irrigated	9.7 ± 0.1	34.6 ± 0.6	55.7 ± 0.6
FM9180 - Lubbock - 2015 – Dryland	10.4 ± 0.7	36.5 ± 0.9	53.1 ± 0.4
NG4111 - Lubbock – 2015 – Dryland	8.6 ± 0.1	34.9 ± 0.5	56.5 ± 0.4
NG4111 - Lubbock - 2015 – Irrigated	9.7 ± 0.4	34.6 ± 0.5	55.7 ± 0.3
PHY339 - Las Cruces - 2014 – Irrigated	9.3 ± 0.2	33.4 ± 0.4	57.4 ± 0.3
PHY444 - Stoneville - 2015 – Irrigated	6.4 ± 0.5	37.7 ± 0.9	55.9 ± 0.4
PHY499 - Stoneville - 2015 – Irrigated	9.3 ± 0.9	34.4 ± 1.0	56.3 ± 0.3
PHY565 - Las Cruces - 2014 – Irrigated	13.3 ± 0.4	37.2 ± 0.9	49.5 ± 0.5
STV4946 - Lubbock - 2015 – Irrigated	11.0 ± 0.5	35.8 ± 0.4	53.2 ± 0.2
STV4946 - Stoneville - 2014 – Irrigated	10.1 ± 0.7	36.0 ± 0.8	53.9 ± 0.6
STV4946 - Stoneville - 2015 – Irrigated	10.4 ± 0.5	35.5 ± 0.6	54.2 ± 0.2
STV5289 - Stoneville - 2015 – Irrigated	9.7 ± 0.1	35.5 ± 0.0	54.9 ± 0.2
STV5458 - Lubbock - 2014 – Irrigated	8.8 ± 0.4	32.8 ± 0.3	58.4 ± 0.4
Pop. average and standard deviation*	10.0 ± 2.1	35.6 ± 1.7	54.4 ± 2.7

*DP340, a *G. barbadense* sample, has been excluded from the averaging.

For the 2014 and 2015 seed, the percentage of oil and protein in the kernels was typical of prior reports. Oil averaged 17.5% and protein averaged 20.5% of the whole fuzzy seed, compared with mean values of 17.7% oil and 20.8% protein reported by Tharp (1948). Gossypol levels averaged 0.69% on the same basis, which is toward the high end of values typically measured by the author. As gossypol methods were not yet available, no direct comparisons can be made with early studies. The relatively high levels observed, however, appear to be due to most of the samples having been grown under irrigation, which is known to have a pronounced effect on gossypol levels (Stansbury et al, 1956; Pettigrew and Dowd, 2011). Both varieties grown under both dryland and irrigated conditions, DP1044 and NG4111, showed this effect, with irrigation increasing the gossypol levels by 30 and 15%, respectively (Table 3). After calculating the percent protein on an oil free basis, protein levels were similar to those obtained from data in the early reports. Hence, breeding for fiber yield seems to have done relatively little to affect the chemical composition of the kernel tissue.

Table 3. Relative amounts of oil, protein, and gossypol in fuzzy seed from 2014 cotton varieties (as is basis)

Variety-Location-Year-Irr/Dry	Oil, %	Protein, %	Gossypol, %
Acala1517-08 - Las Cruces - 2015 – Irrigated	17.8 ± 0.5	21.1 ± 0.7	0.61 ± 0.04
DP340 - Las Cruces - 2014 – Irrigated (Pima)	21.6 ± 0.7	19.8 ± 0.3	0.88 ± 0.01
DP1044 - Lubbock - 2015 – Dryland	18.0 ± 0.2	19.3 ± 0.6	0.65 ± 0.02
DP1044 - Lubbock - 2015 – Irrigated	17.2 ± 0.4	18.8 ± 0.4	0.75 ± 0.02
DP1044 - Stoneville - 2014 – Irrigated	17.6 ± 0.3	20.8 ± 0.2	0.68 ± 0.02
DP1219 - Lubbock - 2014 – Irrigated	16.8 ± 0.1	20.5 ± 0.3	0.60 ± 0.01
DP1321 - Stoneville - 2014 – Irrigated	16.3 ± 0.2	19.4 ± 0.2	0.67 ± 0.02
DP1321 - Stoneville - 2015 – Irrigated	15.6 ± 0.4	20.6 ± 0.2	0.53 ± 0.03
FM1944 - Stoneville -2014 – Irrigated	15.2 ± 0.1	21.1 ± 0.3	0.51 ± 0.00
FM1944 - Stoneville - 2015 – Irrigated	14.4 ± 0.3	21.9 ± 0.3	0.44 ± 0.01
FM2484 - Lubbock - 2014 – Irrigated	21.8 ± 0.1	16.7 ± 0.2	0.87 ± 0.01
FM9180 - Lubbock - 2015 – Dryland	17.9 ± 0.2	20.0 ± 0.2	0.55 ± 0.01
NG4111 - Lubbock - 2015 – Dryland	17.6 ± 0.2	22.7 ± 0.2	0.66 ± 0.02
NG4111 - Lubbock - 2015 – Irrigated	17.6 ± 0.2	21.0 ± 0.2	0.84 ± 0.00
PHY339 - Las Cruces - 2014 – Irrigated	19.9 ± 0.4	20.6 ± 0.3	0.96 ± 0.01
PHY444 - Stoneville - 2015 – Irrigated	16.7 ± 0.3	22.0 ± 0.1	0.56 ± 0.02
PHY499 - Stoneville - 2015 – Irrigated	16.1 ± 0.2	23.8 ± 0.1	0.57 ± 0.02
PHY565 - Las Cruces - 2014 – Irrigated	15.6 ± 0.2	19.3 ± 0.1	0.72 ± 0.01
STV4946 - Lubbock - 2015 – Irrigated	17.6 ± 0.2	18.5 ± 0.6	0.83 ± 0.03
STV4946 - Stoneville - 2014 – Irrigated	16.7 ± 0.3	19.8 ± 0.3	0.74 ± 0.02
STV4946 - Stoneville - 2015 – Irrigated	19.0 ± 0.3	16.2 ± 0.1	0.83 ± 0.03
STV5289 - Stoneville - 2015 – Irrigated	15.1 ± 0.0	23.8 ± 0.1	0.61 ± 0.02
STV5458 - Lubbock - 2014 – Irrigated	18.8 ± 0.1	21.6 ± 0.1	0.84 ± 0.02
Pop. average and standard deviation	17.5 ± 1.9	20.5 ± 1.9	0.69 ± 0.14

Summary

Field cottons from the 2014-2015 growing seasons were evaluated for a number of seed-fiber traits and compositional properties. Seed-fiber ratio averaged less than 1.5, which is dramatically lower than values reported from many early studies. Correspondingly, seed indices also have fallen, indicating that the breeding of cotton for increased fiber yield appears to have occurred with substantial changes in seed size. Changes in the proportions of linter, hull, and kernel tissues and in the kernel oil, protein, and gossypol composition were less apparent.

Acknowledgements

The authors thank Rick Byler, Greg Holt, and Ed Barnes for providing seed cotton samples.

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