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A BETTER UNDERSTANDING OF THE NUMBER OF FIBERS PER SEED IN COTTON

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Abstract

Over the past century, cotton research has led to significant improvements in cotton yield. However, since 1984 the national average cotton yield has decreased. This is bad news for an industry that needs stability to survive and compete in an increasingly competitive world market. Cotton lint yield can be broken down into several different, but intricately related components. It has been proposed that an increase in one of these yield components, the number of fibers per seed, could lead to an overall increase in yield. Therefore, the number of fibers per seed and cottonseed surface area were studied to gain a more thorough understanding of these factors. This study found that the number of fibers per seed was indeed a variable trait, but varied much less when fiber quality was good. Data indicated that both the type of ginning (hand or saw-ginning) and environmental conditions played a significant role in the number of fibers per seed. Immature cotton exhibited an artificially higher number of fibers per seed due to an abundance of broken fibers. Saw-ginned cotton also displayed an artificial increase in the number of fibers per seed due to broken fibers caused by the harshness of processing. Because of these effects, it was suggested that hand-ginning cotton samples would be best in breeding programs looking at the number of fibers per seed. In addition to these effects, a significant effect of genotype on the number of fibers per seed was discovered. Genotypes were ranked similarly over most years and locations, indicating that this could be a trait of interest in a cotton breeding program.

Introduction

Lint yield can be broken down into several different, but intricately related, components (Worley et al, 1976). The component of interest in this study was the number of fibers/seed. It has been proposed that increasing the number of fibers per seed could result in a yield increase (Lewis et al, 2000). The number of fibers per seed can be calculated by multiplying the cottonseed surface area by the number of fibers per unit seed surface area. However, the surface area of the cottonseed has proven to be a somewhat difficult property to quantify, due to the seed's irregular shape and variability. Farr (1931) made extensive measurements of seeds of varying ages, and then used these measurements to determine the approximate surface area of a mature cottonseed in this study to be 132 mm^2; however, this value is not useful to cotton researchers today because of the variability imposed by genetic and environmental factors and because of the relative decrease in cottonseed size over the years (Culp and Harrell, 1975). Hodson (1920) developed a method for determining surface area of a cottonseed by measuring ethanol displacement by a 100-seed sample. Hodson found the range of cottonseed surface area for twenty-five genotypes to be approximately 114 mm^2 to 156 mm^2. Hodson's method has become the standard for cottonseed surface area determination in the industry due to the relative ease of determination. However, due to the aforementioned variability and seed size and shape changes, digital image analysis was used to determine cottonseed surface area for this study. The objective of this study was to gain a better understanding of the different factors that influence the number of fibers per seed in cotton, and thus a better understanding of how to quantify and select for this trait in a breeding program.

Materials and Methods

Six different genotypes of cotton (*Gossypium hirsutum* L.) were grown at four locations in the Texas High Plains during the 2002 and 2003 growing seasons. The six genotypes (four commercial and two breeding lines) were selected based on the amount of fiber per seed previously measured. 'Acala Maxxa' and 'FiberMax 958' were selected as high lint per seed lines, 'DeltaPine 50' and 'Paymaster HS 26' were selected for medium lint per seed, and 'CA 3084' and 'CA 3050' were selected for low lint per seed. These six genotypes were also attractive for this study because of their varied genetic backgrounds. The four different locations were comprised of an irrigated and a dryland site at both the Lubbock and Halfway Texas Agricultural Experiment Stations. All locations were planted in a randomized complete block design. In all years and locations, there were four replications per location, and one row/plot per genotype per replication. The cotton was grown using common growing practices for the Texas High Plains.

The cotton was harvested by snapping off the boll from the plant. Twenty-five bolls were harvested per plot. An average of two seeds per lock was set aside for a sample to be hand-ginned, but at least one seed was taken from every intact lock for the sample of 200 seeds. An effort was made to vary the position within the lock from which the seed was taken, but only mature seeds were chosen, and motes and trash were removed when possible. These 200 seeds were mixed by hand to randomize the sample, and then gently hand-ginned. The remaining cotton from each sample was placed in a sack and later ginned on a 10-saw laboratory gin. The seeds were acid-delinted and seed surface area was measured using WinSEEDLE 2003b image analysis system (Regent Instruments, Inc., Quebec, Canada). The sample of 200 hand-ginned, delinted seeds was placed in a plexiglass tray and separated so that seeds did not touch each other before the image was scanned. Four measurements were made per sample, and the seed were shaken in the tray and re-separated between each replication. The lint was analyzed by the International Textile Center in Lubbock, Texas, using the Advanced Fiber Information System (AFIS) and HVI. Three AFIS measurements were made for each sample. Data were analyzed by SAS (SAS Institute Inc., Cary, NC) using Fisher's protected LSD and analysis of variance.

Results and Discussion

Verification of Sampling Method

In order to ensure that the data collected from this experiment were valid, a test of the sampling method was necessary. If the sampling method was good, and there was no bias between the two treatment samples, one would not expect to see much difference between the HVI measurements for micronaire or strength for the two ginning treatments. This is because these fiber quality parameters are not likely to be changed by processing. Indeed, the HVI data show that the values for micronaire and strength for both saw-ginned and hand-ginned cotton are very similar. Furthermore, if the sampling method was good, one would expect to see differences between the HVI measurements for length and length uniformity for the two ginning treatments. The saw-ginned samples should have a lower value for both length and length uniformity, due to rough processing resulting in broken fibers. More broken fibers would result in a lower mean length and greater variability in the sample, producing lower length uniformity. The HVI length and length uniformity data do show a difference between the saw-ginned and hand-ginned cotton, with saw-ginned cotton being shorter and less uniform. Therefore, the sampling method can be considered to be reliable, with a minimum of bias due to error. This indicates that the data will also be reliable.

Differences in the Number of Fibers per Seed—Environmental Impact

Number of Fibers per Seed: Data indicate that there is a difference in the number of fibers per seed between the two years in the study, 2002 and 2003. Figures 1 and 2 illustrate the difference between the two years for both hand-ginned and saw-ginned cotton. Hand-ginned cotton from 2002 ranged from 16,405 to 19,026 total fibers per seed, while saw-ginned cotton from the same year ranged from 21,037 to 27,327 fibers per seed. Hand-ginned cotton from 2003 ranges from 15,168 to 15,650 total fibers per seed, while saw-ginned cotton from the same year ranges from 18,206 to 18,963 fibers per seed. It is obvious from these figures that there was a substantial difference between the numbers of fibers per seed for hand- and saw-ginned cotton. This difference was larger in 2002, but still present in 2003.

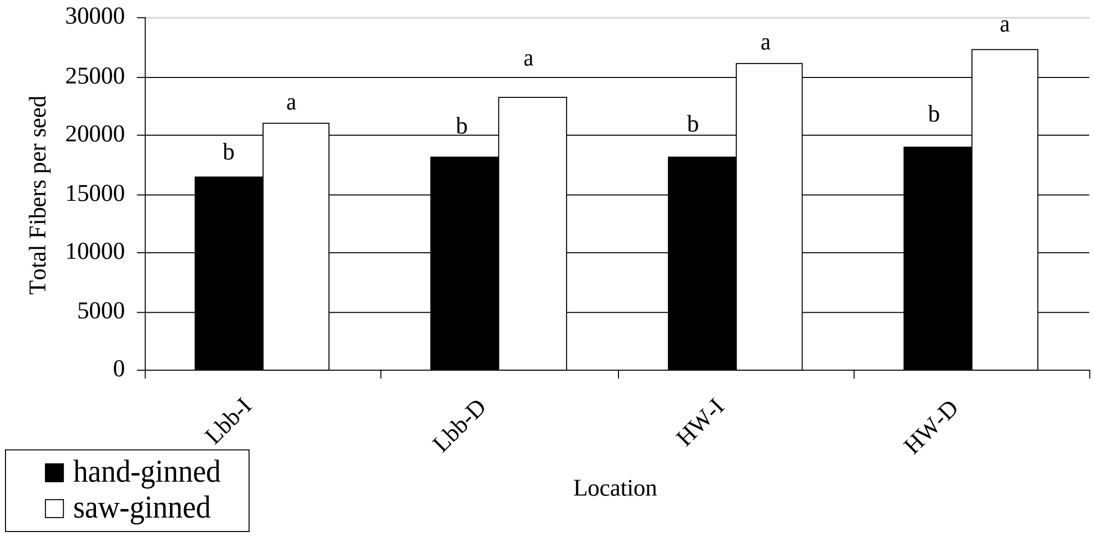

Figure 1. Number of fibers per seed averaged across genotypes and replications over four locations in 2002, hand-ginned vs. saw-ginned cotton samples.

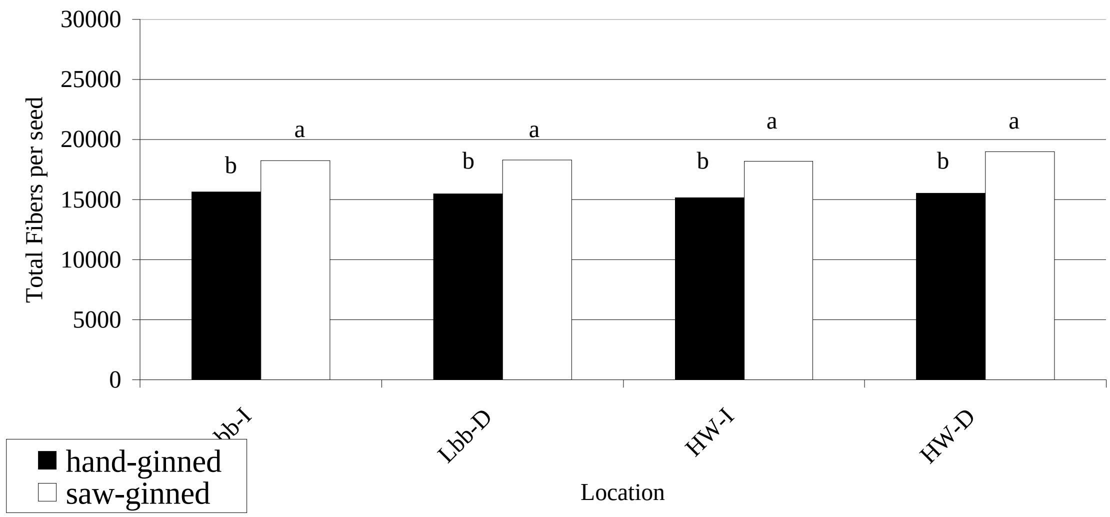

Figure 2. Number of fibers per seed averaged across genotypes and replications over four locations in 2003, hand-ginned vs. saw-ginned cotton samples.

Short Fiber Content by number (SFC(n)): Values for SFC(n) ranged from 8 to 16 percent of fibers for hand-ginned cotton in 2002, and from 16 to 37 percent of fibers for saw-ginned cotton in the same year (Figure 3). SFC(n) in 2003 ranged from 5 to 6 percent for hand-ginned cotton, and from 13 to 17 percent for saw-ginned cotton (Figure 4). This indicates that the increase in the number of fibers per seed could be mostly due to an increase in short fibers. This would mean that the increase in fibers per seed was due to an increase in broken fibers instead of in spinnable fibers per cottonseed, and therefore an artificial increase instead of a real increase in the number of fibers per seed.

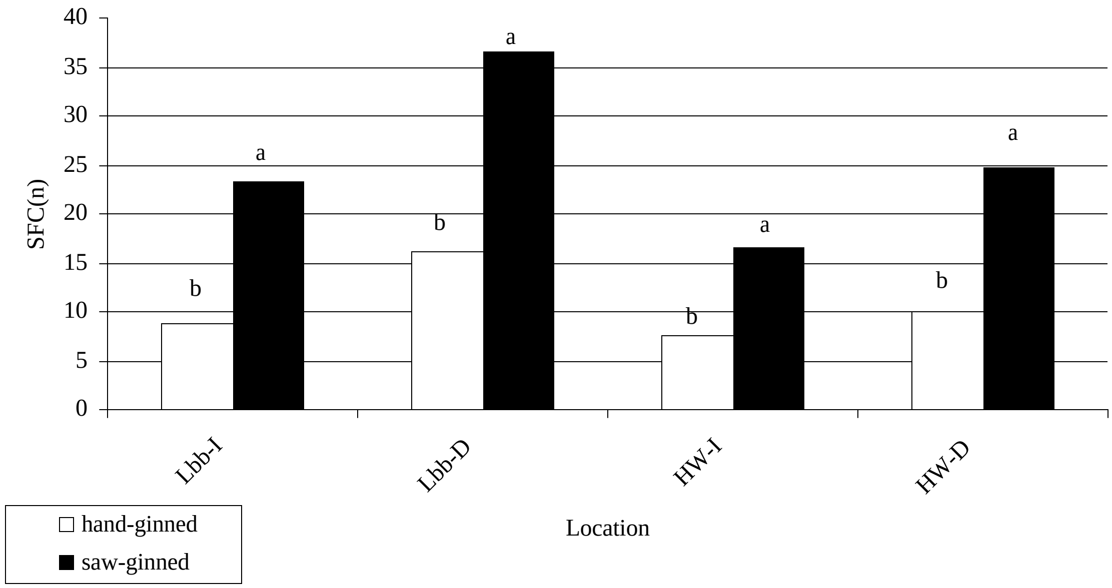

Figure 3. Short fiber content (by number) averaged across genotypes and replications over four locations in 2002, hand-ginned vs. saw-ginned cotton samples.

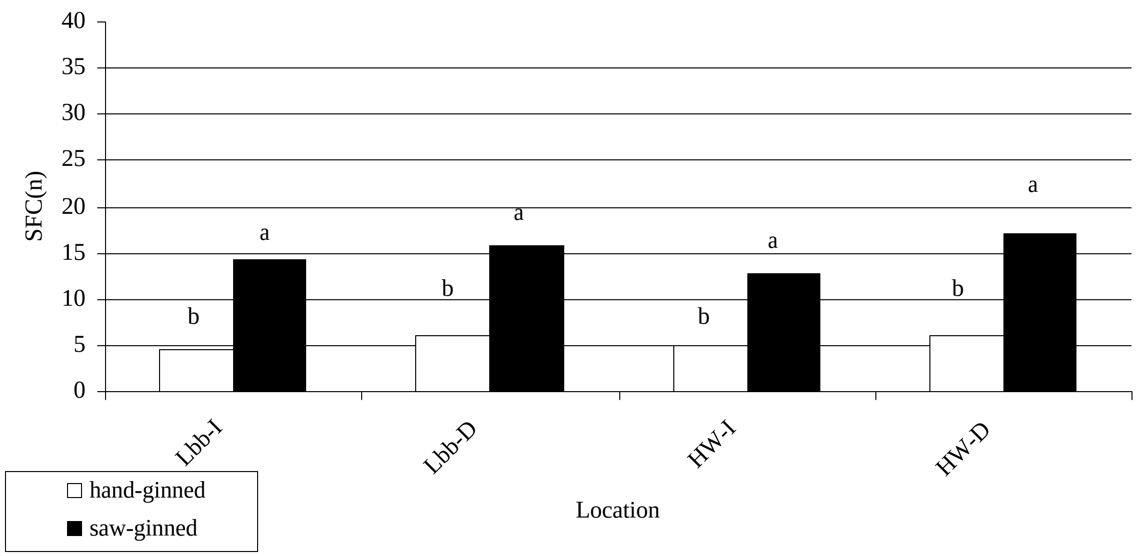

Figure 4. Short fiber content (by number) averaged across genotypes and replications over four locations in 2003, hand-ginned vs. saw-ginned cotton samples.

This increase in short fiber content is very apparent in length distribution histograms comparing saw-ginned cotton to hand-ginned cotton (Figures 5 and 6). These histograms show that not only is SFC(n) increased with the harsh processing of saw-ginning, but also the number of more desirable long fibers is decreased, ultimately decreasing the value of the cotton on both ends of the length spectrum. Therefore, the increased number of fibers per seed can be explained by the increase in SFC(n), but the difference in SFC(n) between 2002 and 2003 for both types of ginning suggests that there is another factor that could be important for broken fibers.

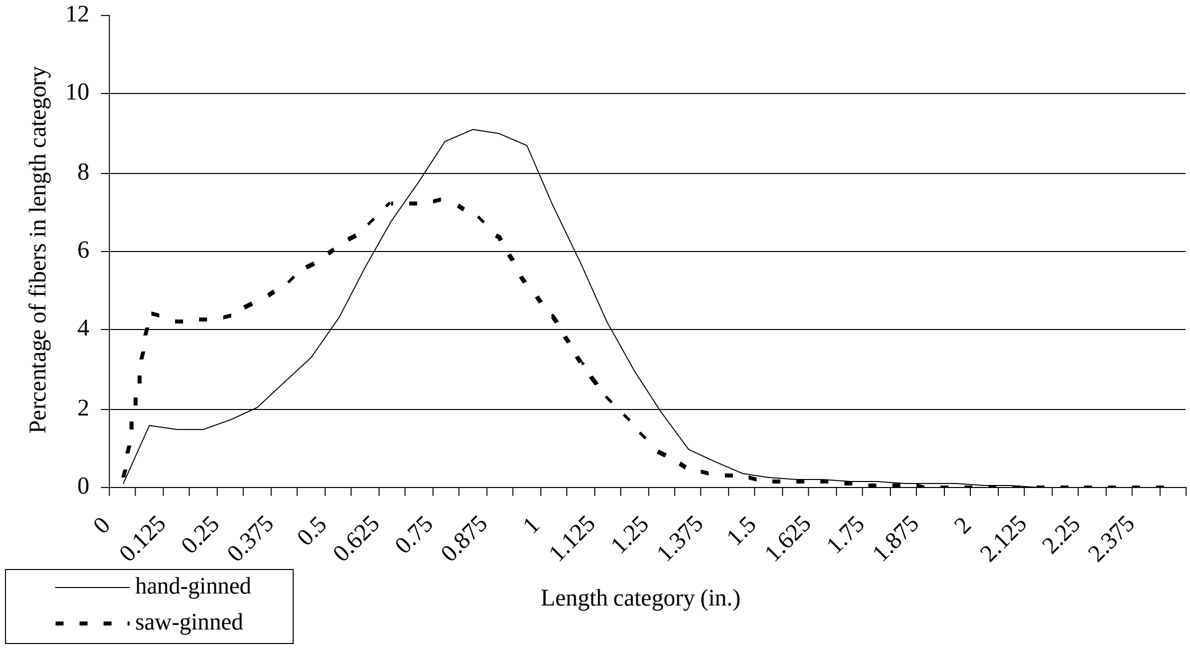

Figure 5. Length distribution histogram for CA 3050 at Lubbock Dryland 2002, hand-ginned vs. saw-ginned cotton.

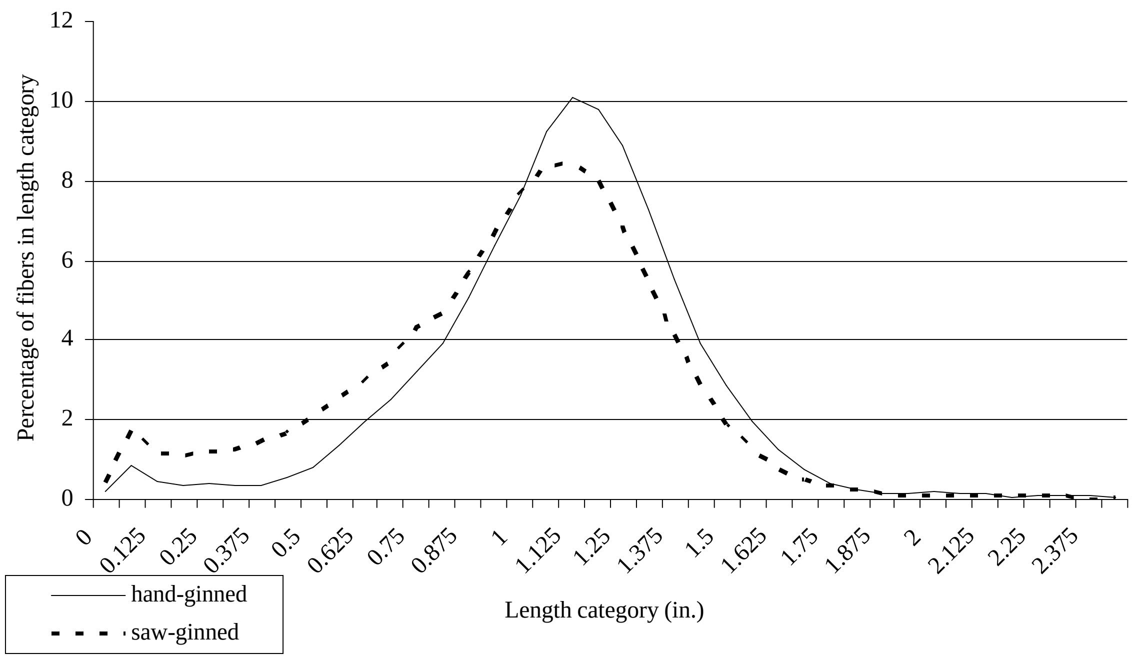

Figure 6. Length distribution histogram for CA 3050 at Halfway Irrigated 2003, hand-ginned vs. saw-ginned cotton.

Maturity: Maturity of cotton is a very important component of fiber strength in cotton—generally the more mature the fiber, the stronger it is, and the less mature, the weaker it is. Therefore, immature cotton fibers break more easily, a fact that would explain the increase in the total number of fibers per seed as well as the increased SFC(n) for all cotton in 2002 when compared to 2003. Figure 7 shows that maturity was higher for cotton at most locations in 2003 as opposed to 2002, and the only location where maturity values for the two years were similar, the SFC(n) was also very similar. Thus, immature fibers break more easily no matter how they are processed. So the increased number of fibers and the increased short fiber content are probably due to poor maturity for that year.

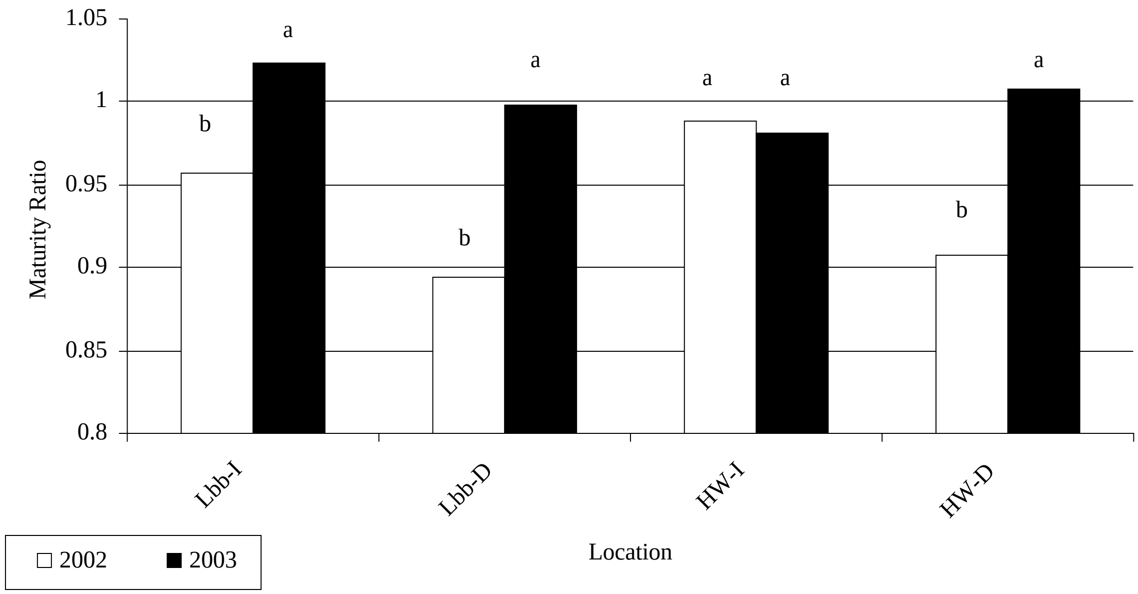

Figure 7. Maturity ratio averaged across genotypes and replications over four locations, 2002 vs. 2003 hand-ginned cotton.

Conclusions: The number of fibers per seed is a variable trait, but varies much less when fiber quality is good. Mature fibers break less easily, leading to fewer broken fibers and thus a lower SFC. This also means that there are fewer "created" fibers for mature cotton as opposed to immature cotton, so the value for the number of fibers per seed is a truer value for mature than immature cotton. Environmental conditions play a big role in maturity, so this variable is difficult to control, and therefore a concern when dealing with the number of fibers per seed. For both years, however, the number of fibers per seed for hand-ginned cotton was less variable and likely more representative of the true value. Ginning by hand is a gentler process than saw-ginning, and breaks significantly fewer fibers regardless of fiber quality. Since maturity has such an impact on the number of fibers per seed, and is difficult to control, hand-ginning should result in more accurate data for this parameter, which would be valuable when the number of fibers per seed is a trait of concern in a breeding program.

Role of Genetics in the Number of Fibers per Seed

Data indicate that both processing and environmental conditions play a role in the number of fibers per seed, and it is possible that there is a genetic component to this trait as well. Indeed, for most years and locations, the contribution of genotype to the variability in the number of fibers per seed is highly significant at the α=0.05 level. In fact, the only instance in which genotype was not significant at this level was at Lubbock Irrigated in 2002, which was the first field to be sampled, ginned, and otherwise processed for this project. It is possible that human error could have been a contributing factor in this issue, and that it would have otherwise been significant at the α=0.05 level. However, the contribution of genotype at Lubbock Irrigated in 2002 was significant at the α=0.10 level.

In addition to the significant effect of genotype on the number of fibers per seed, the different genotypes are ranked similarly over most years and locations. Again, the only instance in which the genotypes did not rank in the same way for the number of fibers per seed was at Lubbock Irrigated in 2002. For all of the other years and locations, 'Acala Maxxa' was always ranked as having the highest number of fibers per seed, followed by 'FiberMax 958'. 'CA 3084', 'CA 3050', and 'Paymaster HS 26' were always ranked after 'FiberMax 958' in varying orders. Finally, 'DeltaPine 50' was always the lowest-ranking genotype for the number of fibers per seed (Figure 8). This indicates that the number of fibers per seed is also controlled somewhat by genetic factors, and that breeding programs aimed at improving this trait could be successful.

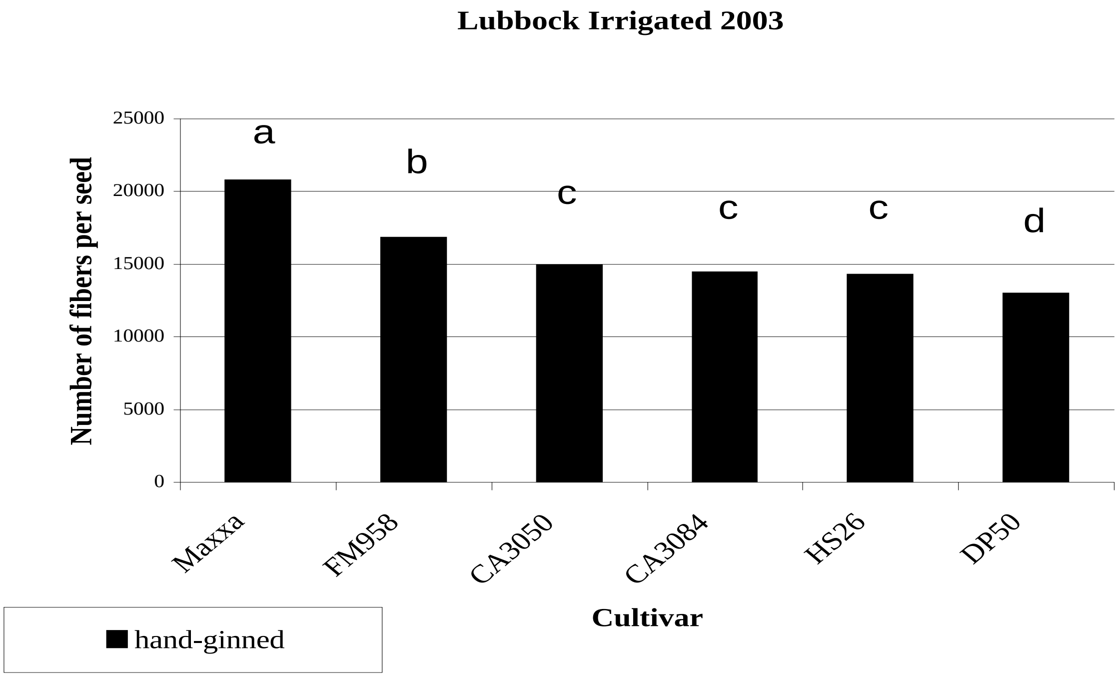

Figure 8. The total number of fibers per seed averaged across replications over six genotypes at Lubbock Irrigated in 2003.

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