MEASURING FIBER PERIMETER FOR BREEDING PROGRAMS, USING THE FIBER MATURITY TESTER (FMT)

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Abstract

Fiber Maturity Tester (FMT) was used to measure perimeter, maturity and micronaire of cotton fibers in Extra Long Staple (ELS) cotton breeding program selecting cultivars with small perimeter, high maturity and good micronaire. During the breeding program the fiber perimeter of the newly bred cultivars was significantly reduced and the maturity significantly increased while the micronaire remained within the acceptable limits and all the other traits were maintained or improved.

Introduction

Cotton is usually bred for yield and the fiber quality traits: strength, length and micronaire. The micronaire is ought to measure the fineness but actually measures a combination of fiber fineness and maturity (Thibodeaux and Rajasekaran 1999). Fine fibers with small perimeter and high maturity make finer and stronger products with better dye absorption. Those two traits, which are presumably controlled by different genes (John and Crow, 1992), are difficult to measure and are therefore usually replaced by the micronaire. However, using the micronaire as a fineness criterion in breeding programs might be misleading, as the same micronaire value may indicate either coarse immature fibers or fine mature ones (Montalvo and Von Hoven, 2005).

The objective of our study was to develop Extra Long Staple cotton cultivars (ELS, *Gossypium barbadense*) of the Pima type, with small perimeter and high maturity. Many methods were developed to measure the fineness and maturity but most of them are either too slow or too expensive for use in commercial breeding programs, where thousands of measurements must be taken in a short time between harvest and planting. One of them, the Fiber Maturity Tester (FMT, Shirley Laboratories, GB.), is fast, reliable and inexpensive. It measures the micronaire and the maturity indirectly using the dual pressure method, the maturity is calculated from the mature/immature fiber ratio and is a linear function of the circularity: the ratio between the fibers wall area and the area of a perfect circle with the same perimeter (Thibodeaux and Rajasekaran 1999). For our program we had to calculate the perimeter from the FMT maturity and micronaire.

The relations between the fiber cross section measurements that were first published by Thibodeaux and Evans were quoted in the article above as follows:

P = fibers cross section perimeter.
A = fibers cross section wall area.
θ = fiber circularity, = $4\pi A/P^2$
Mic = micronaire = $[8.56(A/P)^2+1.196]^{1/2}- 2.35$
M = maturity **= θ/0.577**
From the above formulas we draw the formula for P=*F* (M,Mic):
P = $[(Mic + 2.35)^2 /M^2 {}^{-}7.443842 (1.96 / M^2)]^{1/2}$

The micronaire lines over the maturity – perimeter axes are neither linear nor parallel (Fig.1.) However, in the relevant range of maturity and perimeter they might be considered as linear and parallel.

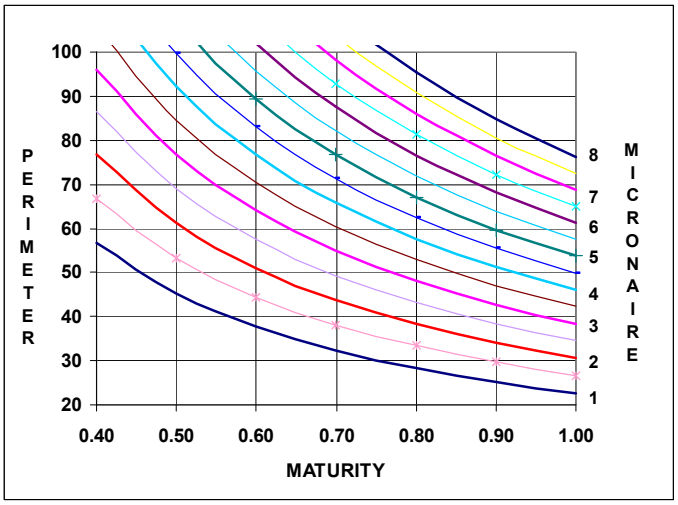

Fig. 1. The relations between the maturity (X axis) the perimeter (Y axis) and the micronaire (colored lines).

Materials and Methods

FMT Series 2 was used to measure micronaire and maturity. The FMT needs calibration which was not available. To overcome this problem all the samples of the tested entries were taken from replicated experiments that contained known cultivars. Analysis of variance was performed (GENSTAT, vsn. GB) and the least significant difference (Lsd.) was calculated at significance level of P=0.05. All the data was than standardized to Lsd units by dividing each measurement by its corresponding Lsd. Each entry was then compared to the known cultivars for breeding decisions.

Results and Discussion

Validation of the measuring method

Israel-Seeds non-calibrated FMT was compared to arealometer, AFIS, HVI and single instrument micronaire. (The arealometer micronaire was computed from the wall area and the perimeter using the above formulas). Between the single instrument micronaire and the HVI, FMT and arealometer there were correlations of 0.95, 0.88 and 0.82 respectively, all highly significant at P<0.001. The FMT and the HVI were about the same (P= 0.288 in t test) but the arealometer micronaire was much lower (Fig. 2). The correlation of the maturity measurements between the FMT, and the AFIS and the arealometer, were 0.551 and 0.499, respectively, both significant at P<0.05, but between the AFIS and the arealometer the correlation was only 0.023, not significant. The perimeter differences between cultivars across environments are very consistent (fig. 3). Taking all this data into consideration it was concluded that FMT is adequate for the needed measurements. During the first years of the breeding program, when above formulas were not available yet, the ratio micronaire/maturity, that had proven later to be highly correlated with the perimeter (fig. 4), was used as the selection criterion.

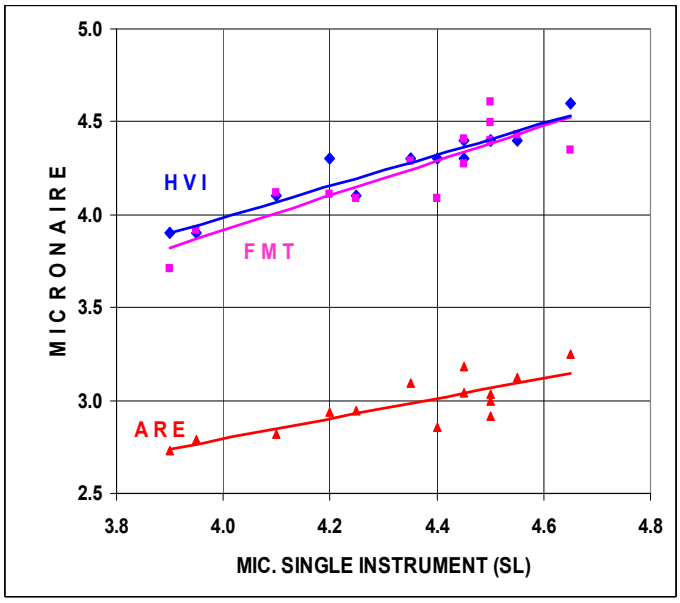

Fig. 2. Micronaire measurement with HVI, FMT and Arealometer (ARE) are compared with the single instrument micronaire (X axis).

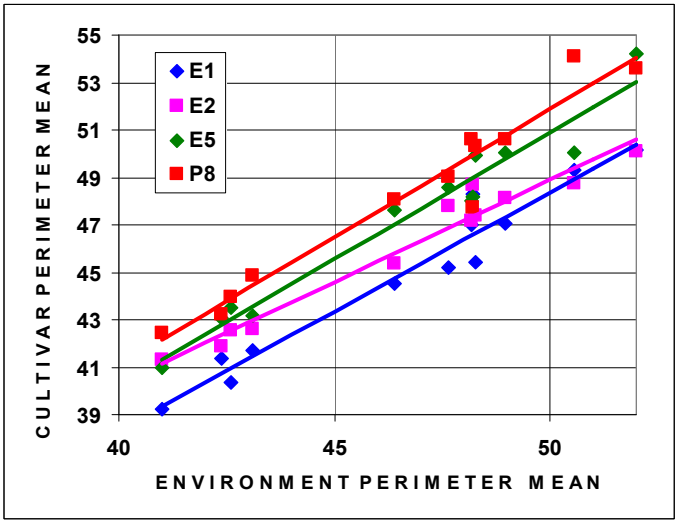

Fig. 3. The cultivar-perimeter-mean of the cultivars E1 E2 E5 and P8 in each environment (Y axis) is plotted vs. the environment-perimeter-mean over all cultivars (X axis).

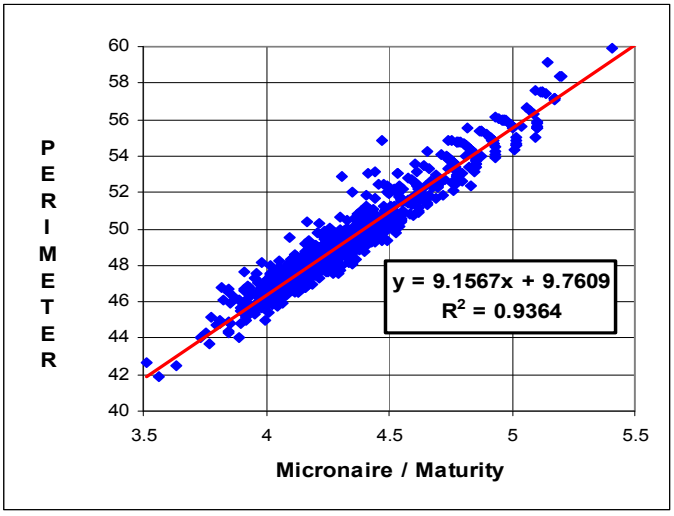

Fig. 4. The relations between the fiber perimeter and the micronaire / maturity ratio.

Results of the breeding program

Stage # 1: Israel-Seeds perimeter breeding program started with an old cultivar F177 which was released in 1988. The cultivar PF15 that has lower perimeter and micronaire but maintains the maturity was released in 1997, and in 2002 cultivars P8 and P11 were released. P8 has higher maturity, intermediate perimeter and the same micronaire as F177 (fig. 5). P8 is currently the main ELS cultivar in Israel. P11 maintains the micronaire with lower perimeter and higher maturity than P8 but is planted only on small area due to limited adaptability.

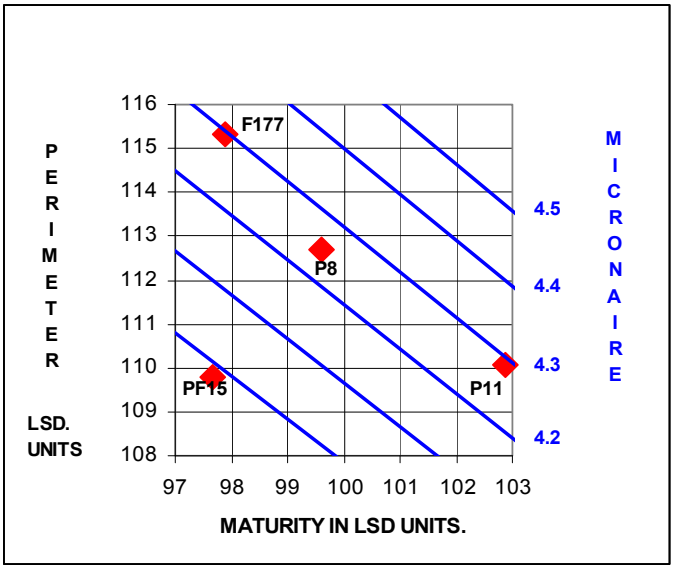

Fig. 5. The maturity, perimeter and micronaire of 4 commercial cultivars from Israel Seeds breeding program. The data is an average of 13 environments, 4 replications in each environment. The units are Lsd units as explained in the text. The diagonal lines are micronaire lines in micronaire units.

Stage # 2: Israel-Seeds E series cultivars have a reduced perimeter, increased maturity and only a slight reduction of the micronaire when compared with P8 (fig. 6). E2 and E1 were released for commercial planting in 2007.

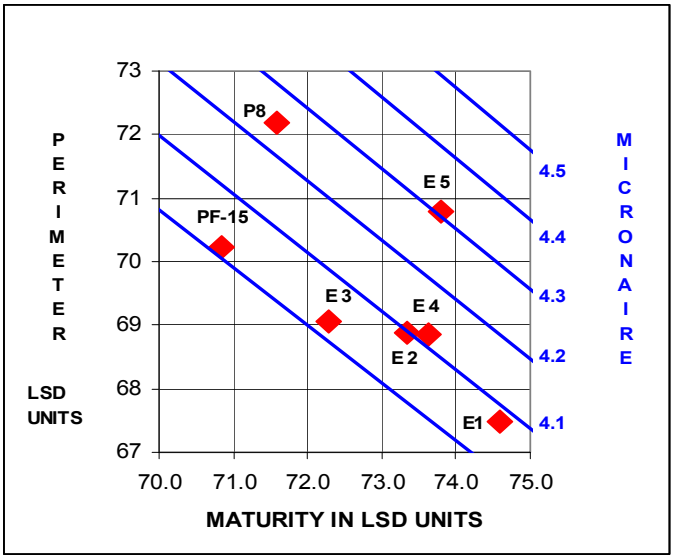

Fig. 6. Five new cultivars from Israel Seeds breeding program (the E series) and two older ones (PF15 and P8). The data is average of 8 environments, 4 replications in each environment. The units are Lsd units as explained in the text. The diagonal lines are micronaire lines in micronaire units.

Stage # 3: The objective of this stage is to further reduce the perimeter, increase the maturity and simultaneously improve or maintain yield, earliness, disease resistance and other desirable traits. This stage is now in process. It have not yet achieved its goal, but it is seems feasible (fig 7). The perimeter can be further reduced while the maturity is maintained or raised, but the micronaire must be reduced.

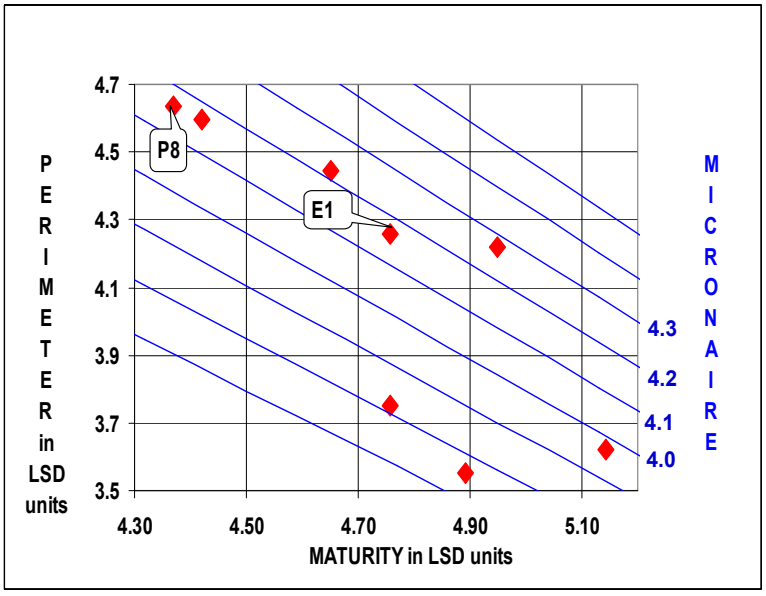

Fig. 7. New lines from Israel Seeds breeding program (unsigned red dots) and two commercial cultivars (P8 and E1). The diagonal lines are micronaire lines in micronaire units.

Conclusions

ELS cotton can be bred for small perimeter, high maturity and good micronaire. It presumably can be done in upland cotton (*Gossypium hirsutum*) too. FMT is an efficient instrument to carry on the necessary measurements.

References

John, M.E., and L.J. Crow. 1992. Gene Expression in Cotton (*Gossypium hirsutum* L,) Fiber: Cloning of the mRNAs. In Proc. of the national Academy of sciences of the United Stats of America (PNAS) 89: 5769-5773.

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