ASSESSMENT OF AGRONOMIC AND FIBER TRAITS IN AN UPLAND COTTON POPULATION FROM $F_{2.3}$ TO $F_{2.6}$ GENERATIONS

Mauricio Ulloa
USDA-ARS
W.I.C.S. Res. Unit
Shafter, CA
William R. Meredith, Jr.
USDA-ARS
C.G. &P. Res. Unit
Stoneville, MS

Abstract

Agronomic and fiber quality cotton (*Gossypium hirsutum* L.) traits were collected and evaluated from generation $F_{2.3}$ (field progeny rows), $F_{2.4}$ (greenhouse single plants), $F_{2.5}$ (field single plants), and $F_{2.6}$ (field progeny rows) on a population of 208 families, developed by a cross of A1006 x 'MD51ne' (A1006 known as 'Fiber Max 832'). Generations were advanced from $F_{2.3}$ to $F_{2.6}$ by the single seed descent method. We used SAS PROC GLM and PROC CORR to perform the analyses of variance and mean separations, and for the association of the above traits within and across generations, respectively. Thirty-four traits were assessed, and only ten have been discussed herein. Lint percentage and boll weight were correlated with all agronomic and fiber quality traits in at least one generation, except for fiber elongation. In addition, lint percentage and boll weight were correlated across generations, indicating some level of association among different environments of collected data. For fiber quality traits, Starlab, Inc. conventional measurements were for the most part correlated with measurements taken by the Advanced Fiber Information System (AFIS[R] Uster), e.g., 2.5% fiber span length from Starlab and AFIS with r = 0.851 and r = 0.899 for generations $F_{2.3}$ and $F_{2.6,}$ respectively. A smaller number of trait measurements, from the AFIS multidata measurement module, was correlated with agronomic traits within generations. Across generations, AFIS analyzed measurements were also less correlated, possibly detecting differences between environments, or/and indicating less inheritable traits. The greenhouse fiber data from $F_{2.4}$ generation was found to possess the highest values for neps (147.8±49.6), seed coat (14.9±6.4), and percentage of immature fiber content (7.7±4.9). Multiple traits can be correlated due to linkage or pleiotropy; or the correlated traits may be components of a more complex variable. The above trait correlations may be useful in developing selection criteria to simultaneously improve yield and fiber quality traits.

Introduction

Many cotton (*Gossypium spp.*) research programs require measurements of agronomic and fiber quality traits such as lint percentage, boll weight, 2.5 and 50% fiber span length, fiber bundle strength, and fineness (micronaire reading, fiber maturity, fiber perimeter, etc.). The cotton research community has standard fiber testing methods (Breeder, Spinning, Areolometer, Sticky, and HVI) for the above traits, which are run in house, or through public or private institutions such the International Textile Center, TX and Starlab Inc., TN. A new fiber testing method has been incorporated into some research programs, which uses the Advanced Fiber Information System (AFIS™) for measuring neps, fiber length and diameter, and trash for fibers. Zellweger Uster, Inc. (Knoxville TN) manufactures the USTER AFIS™. The AFIS provides an improved method of collecting fiber information on cotton quality by separating a sample into single fibers and measuring them. The process is similar to processing conditions encountered in the modern textile machinery (USTER AFIS™).

Modern cotton varieties are good-yielding, day-length neutral, early-cropping plants with easily ginned, and abundant fiber. These improved characteristics resulted from human selection from perennial ancestors with shorter, sparser fiber (Fryxell 1984). Much of the fiber trait variability exhibited by cotton (*G. hirsutum*) at the textile mill has genetic origins. The continuing demands for better quality traits for consumer's goods and the recent movement from ring spinning to faster, less labor intensive and versatile spinning methods has been driving research programs to look for more alternatives to genetically improve lint and fiber quality (Meredith et al., 1991).

Correlation between and among traits can be useful in developing selection criteria, but correlations can also present more difficult scenarios of interpretation of the association for trait's responses. In addition, multiple traits can be correlated due to linkage or pleiotropy; or the correlated traits may be components of a more complex variable. Micronaire and fiber span length, which both influence lint percentage, are a good example of components of a more complex trait (Ulloa and Meredith, 2000). Single trait selection is often utilized to maximize genetic gain in recurrent selection systems. However, traits negatively correlated to the primary trait can deteriorate with single trait selection. Multiple trait selection can be used to prevent or correct correlated trait deficiencies (Dolan et al., 1996). In cotton several studies have reported negative correlations between fiber quality and agronomic traits, e.g., fiber strength and lint percentage (Miller and Lee, 1964), and some other studies did not detect such correlations. For negative correlations, several generations of intermating in an isolation block with approximately 50% self-fertilization changed the genetic correlation between lint yield and fiber strength within their population by reducing the negative effect almost by half (Meredith and Bridge, 1971).

Correlations may be useful in developing selection criteria to simultaneously improve yield and fiber quality traits. The objective of our studies were to investigate the agronomic and fiber quality traits within a genetically diverse population of upland cotton, to compare agronomic and fiber quality traits within and across several generations under different environments, to investigate the inheritance of existing and new fiber quality traits under different systems, and to investigate the direct and correlated responses from the above traits under no selection. Herein, we present a condensed summary of agronomic and fiber quality traits that in some way are related to one another, and they form part of a major goal of any breeding program, cotton lint yield.

Materials and Methods

Genetic Material

The genetic population was developed from crossing A1006 x 'MD51ne' okra. The 'MD51ne' parent generally had high yield and high fiber strength, and low fineness. MD51ne was a BC_2F_2 plant selection that originated from a cross of MD65-11 and 'Deltapine 90' (Meredith 1993). Four backcrosses to MD51ne normal leaf followed by two generations of selection for okra leaf type in the BC_4F_3 heterozygous plant ($L_2l_2^0$) were performed to obtain the isoline of MD51ne okra. A1006 is known as a commercial variety, 'Fiber Max 832', and was bred by CSSI in Australia. Fiber Max 832 also is an okra leaf type cotton. The population used in this study consisted of 208 families.

Agronomic and Fiber Quality Data

The $F_{2.3}$ and $F_{2.6}$ families were grown in one-row plots of size 1x5m. The 208 families were grown on two sites in 1998 and 2000 at Stoneville Mississippi USA. One site, planted around May 15, was a Beulah fine sandy loam soil type, and the other site, planted around May 7, was a Dubbs silt loam with three entries of A1006 and MD51ne okra each used as controls. Nitrogen rates were 112 Kg ha^{-1} applied about 30 days prior to planting. Two replications of plots at each location were used to determine yield, yield components, and fiber properties. Plant density was about 113,000 plants ha^{-1}. Weed control, irrigation, and insect control were standard practices for production of cotton in the Mississippi Delta. Yield components and fiber trait evaluations were determined from 50 boll samples taken from each plot.

The $F_{2.4}$ progeny was grown in the greenhouse in the Winter-Spring of 1999; greenhouse temperature was maintained at approximately 80^0 F. A single plant was planted in a three gallon pot with a soil medium composite of one part of sand, one part of soil and two parts of vermiculite. Slow release fertilizer (20-20-20) and water were supplied to the plants as necessary. The $F_{2.5}$ progeny was grown in the field in the summer of 1999. One site, planted around May 9, was a Beulah fine sandy loam soil type with three entries of A1006 and MD51ne okra. The 208 families were grown in one-row plots of size 1x5m. Only a single plant was harvested from each $F_{2.5}$ family plot. Yield components and fiber trait evaluations for $F_{2.4}$ and $F_{2.5}$ were determined from the total number of harvested bolls from each plant. A commercial testing company, Starr Laboratories of Knoxville, TN, determined fiber properties. In additional, The Advanced Fiber Information System (AFIS^R Uster) at the USDA-ARS, C.G. & P. Res. Unit at Stoneville, MS was also used to determine lint and fiber properties. The AFIS's operator selects the AFIS MultiData Measurement Module and the "Condensed Summary" from the print output option.

Data Analysis

SAS PROC GLM performed the analyses of variance and mean separation. For the association of the agronomic (lint percentage and boll weight), fiber properties data from Starlab, Inc. (fiber strength and 2.5% fiber span length), and fiber properties data from AFIS (number of neps, number of seed coats, 2.5% fiber span length by sample count, mean fiber fineness, immature fiber content, and maturity ratio) within and across generations, PROC CORR was performed by SAS. The analyses were performed only with data obtained from the 208 families. We excluded the parents in the analyses presented herein.

Results and Discussion

Means and standard deviations for agronomic and fiber quality traits from generation $F_{2.3}$, $F_{2.4}$, $F_{2.5}$, and $F_{2.6}$ on a population of 208 families developed by a cross of A1006 x MD51ne are presented in Table 1. The greenhouse fiber data from $F_{2.4}$ generation were found to possess the highest values for neps (147.8±49.6), seed coat (14.9±6.4), and percentage of immature fiber content (7.7±4.9). Greenhouse and field single plant data, from $F_{2.4}$ and $F_{2.5}$ generation respectively, exhibited extensive variation for all traits with greater standard deviations than field progeny row data (Table 1). Neps are defined as a fiber entanglement of two or more fibers, and are caused and/or formed by immature fibers, causing problems in yarn evenness and visual appearance of fabrics. In addition, the lower the Maturity Ratio value the more difficult it is to dye the fibers (USTER^R AFIS).

Correlations among agronomic lint percentage and boll weight, fiber trait data from Starlab, Inc., fiber strength and 2.5% fiber span length, and fiber properties data from AFIS, number of neps, number of seed coats, 2.5% fiber span length by sample count, mean fiber fineness, immature fiber content and maturity ratio, based upon family means agree with previous studies (Meredith et al., 1991; Shappley et al., 1998; Ulloa et al., 2000; Ulloa and Meredith, 2000). Lint percentage and boll weight were correlated with all agronomic and fiber quality traits in at least one generation, except for fiber elongation. Negative correlations between lint percentage and fiber strength, and between boll weight and fiber strength for all assayed generations were observed, being significant at P>0.05 for lint percentage $F_{2.3}$ (r = -0.138) and $F_{2.6}$ (r = -0.150), and for boll weight $F_{2.3}$ (r = -0.172). Components of fiber strength, such as 50% and 2.5% span length, and maturity ratio (Meredith, 1992; Ulloa and Meredith, 2000) were correlated with mean family generations that used field replication plot data, $F_{2.3,}$ and $F_{2.6}$.

Correlations for the above traits across generations $F_{2.3}$ (field progeny rows), $F_{2.4}$ (greenhouse single plants), $F_{2.5}$ (field single plants), and $F_{2.6}$ (field progeny rows) based upon family means are given in Table 2. Lint percentage and boll weight were also correlated across generations, indicating some level of association among different environments of collected data. The frequency distribution of agronomic and fiber quality traits data shows genetic variation consistent with multigenic inheritance (Ulloa et al., 2000). Cotton as well as other crop varieties often shows differential responses when grown in different environments. Observations on the environmental conditioning and family responses for each generation indicated that the primary factors determining relative family responses are the nature and magnitude of the genetic variation. Much of the fiber properties exhibited by *G. hirsutum* L. at the textile mill have been reported to have genetic origins (Meredith et al., 1991). A smaller number of trait measurements, from the AFIS MultiData measurement module, was correlated with agronomic traits within generations. In addition, across generations, AFIS analyzed measurements were also less correlated, possibly detecting differences between environments, or indicating less inheritable traits (Table 2).

Many cotton research programs require measurements of agronomic and fiber quality traits such as lint percentage, fiber strength, length, fineness, etc... It is important that breeders clearly define fiber property breeding objectives in order to genetically improve fiber quality. Indirect selection for one fiber trait may have the potential to change not only one but two different traits, and may have an advantage in cost or simplicity as compared to individual trait selection. However, multiple traits can be correlated due to linkage or pleiotropy; or the correlated traits may be components of a more complex variable (Ulloa and Meredith, 2000). The inheritance of various quantitative characters, which involves the nature and magnitude of the genetic variation, determines the appropriate breeding method to be followed for their improvement. The above trait correlations may be useful in developing selection criteria to simultaneously improve yield and fiber quality traits. More research is needed in order to develop such selection criteria.

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Table 1. Means and standard deviations for agronomic and fiber quality traits from generations $F_{2.3}$ (field progeny rows), $F_{2.4}$ (greenhouse single plants), $F_{2.5}$ (field single plants), and $F_{2.6}$ (field progeny rows) on a population of 208 families, developed by a cross of A1006 x 'MD51ne' (A1006 known as 'Fiber Max 832').

	Mean and Standard Deviation for each Generation			
Trait Name	**$F_{2.3}$**	**$F_{2.4}$**	**$F_{2.5}$**	**$F_{2.6}$**
Lint Percentage [%]	37.1 ± 1.4	38.2 ± 2.5	36.9 ± 2.7	35.5 ± 1.7
Boll Weight [g]	4.7 ± 0.3	4.5 ± 0.7	4.4 ± 0.8	4.7 ± 0.4
Fiber Strength [kN m kg^{-1}]	242.0 ± 13	-	238.1 ± 21	235.0 ± 14
2.5% Fiber Span Length [mm]	30.1 ± 0.8	-	29.3 ± 2.5	30.1 ± 1.0
Number of Neps† Count /g	102.6 ± 14.4	147.8 ± 49.6	109.4 ± 48.3	147.9 ± 28.0
Number of Seed Coats† Count/g	11.0 ± 2.0	14.9 ± 6.4	11.4 ± 5.5	7.1 ± 1.5
2.5% Fiber Span Length† by Sample Count [mm]	37.4 ± 1.0	38.0 ± 2.8	36.2± 3.0	38.5 ± 1.5
Mean Fiber Fineness† (weight per unit length) [Fine mTex – millitex]	175.7 ± 5.8	173.3 ± 14.2	175.7 ± 17.8	164.3 ± 5.9
Immature Fiber Content† Percentage [IFC - %]	4.7 ± 0.6	7.7 ± 4.9	4.3 ± 1.6	5.9 ± 0.6
Maturity Ratio† (fiber ratio with $\geq$0.5/$\leq$0.25 circularity [Unit]	0.95 ± 0.02	0.89 ± 0.10	0.96 ± 0.08	0.93 ± 0.02

†AFIS = Advanced Fiber Information System Measurements, (USTER® AFIS, Zellweger Uster Knoxville TN, 37919)

Table 2. Correlation comparison for agronomic and fiber quality traits from generations $F_{2.3}$ (field progeny rows), $F_{2.4}$ (greenhouse single plants), $F_{2.5}$ (field single plants), and $F_{2.6}$ (field progeny rows) on a population of 208 families, developed by a cross of A1006 x 'MD51ne' (A1006 known as 'Fiber Max 832').

	Correlation Comparisons for each Generation					
Trait Name	**$F_{2.3}$ vs $F_{2.4}$**	**$F_{2.3}$ vs $F_{2.5}$**	**$F_{2.3}$ vs $F_{2.6}$**	**$F_{2.4}$ vs $F_{2.5}$**	**$F_{2.4}$ vs $F_{2.6}$**	**$F_{2.5}$ vs $F_{2.6}$**
Lint Percentage [%]	0.389***	0.425***	0.541***	0.398***	0.514***	0.670***
Boll Weight [g]	0.180*	0.177*	0.298***	0.283***	0.195**	0.234**
Fiber Strength [kN m kg^{-1}]	--	0.211**	0.418***	--	--	0.475***
2.5% Fiber Span Length [mm]	--	0.250***	0.416***	--	--	0.413***
Number of Neps Count /g†	0.182*	0.119	0.208**	-0.044	0.156*	0.071
Number of Seed Coats† Count/g	0.071	0.040	0.198**	0.023	0.084	0.040
2.5% Fiber Span Length by† Sample Count [in]	0.176*	0.221**	0.447***	0.008	0.294***	0.284***
Mean Fiber Fineness† (weight per unit length) [Fine mTex – millitex]	0.269***	0.098	0.341***	0.032	0.286***	0.059
Immature Fiber Content† Percentage [IFC - %]	0.121	0.015	0.388***	0.071	0.098	0.041
Maturity Ratio† (fiber ratio with $\geq$0.5/$\leq$0.25 circularity [Unit]	0.258***	0.071	0.425***	0.084	0.191**	-0.015

*, **, *** significant at P<0.05, 0.005, 0.0005, respectively.

†AFIS = Advanced Fiber Information System Measurements, (USTER® AFIS, Zellweger Uster Knoxville TN, 37919)