Evaluation of Crop Management Effects on Fiber Micronaire, 2000

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Abstract

Arizona has experienced a trend toward increasing fiber micronaire values in recent years resulting in substantial discounts on fiber value. There is some evidence to suggest management can impact fiber micronaire. Approximately 250 cases were identified in cotton production areas in Arizona ranging from the lower Colorado River Valley to near 2,000 ft. elevation with grower cooperators in the 2000 season. Field records were developed for each field by use of the University of Arizona Cotton Monitoring System (UA-CMS) for points such as variety, planting date, fertility management, irrigation schedules, irrigation termination, defoliation, etc. Routine plant measurements were conducted to monitor crop growth and development and to identify fruiting patterns and retention through the season. As the crop has approached cutout and the lower bolls began to open, open boll samples have been collected from the lowest four, first position bolls (theoretically the bolls with the highest micronaire potential on the plant) from 10 plants, ginned, and the fiber analyzed for micronaire (low 4). From that point forward, total boll counts per unit area and percent open boll measurements are being made on 14-day intervals until the crop is defoliated. Following defoliation, final plant maps were performed. Relationships among low 4 samples micronaire, irrigation termination (IT), defoliation, and final crop micronaire were analyzed.

Introduction

In recent years an increasing percentage of the Arizona cotton crop has been classified with micronaire ranges in excess of 4.9, resulting in a discount of the market value of the fiber. In 1999, slightly over 40% of the Arizona Upland cotton crop was classed with micronaire values greater than 4.9. For example, Group 6 micronaire values (5.0-5.2) can result in \$0.05/lb. discounts and Group 7 (≥5.3) \$0.10/lb. discounts. With low market values of cotton lint, as have been experienced recently (i.e. ~ \$0.50/lb.), discounts of this magnitude can have a devastating impact on farm revenues. Some economists have estimated that this problem has resulted in a loss of revenue to the Arizona cotton producers of approximately \$13 to 15 million per year in the past several years. However, some cotton marketing professionals in Arizona have indicated that they believe these losses in revenue due to high micronaire are in the range of \$20 to 25 million per year over the past four to five years. Thus, this is a problem that is impacting the profitability of Arizona cotton production at this time.

Fiber properties such as micronaire are the product of three primary factors: 1) genetics, 2) environment, and 3) management. The statement is often made that "only 30% of the cotton micronaire properties are determined by genetics (variety) with 70% determined by agronomic management [sic]". This claim is hard to substantiate. The trends associated with increasing micronaire levels in Arizona reveal a slight increase in average micronaire values in the early 1990's (~1993) and again in about 1996. It is interesting to note a similar trend is apparent with data from the entire U.S. cotton belt. Also, in review of the micronaire distributions among all cotton producing regions in the U.S., there is a somewhat normal distribution pattern with a peak micronaire value at approximately 4.9-5.0 and distinct drop above 5.0. These two points support the hypothesis that there is a strong genetic component associated with recent trends in Arizona and U.S. micronaire values and that varieties have been developed to "push" the micronaire limits (i.e. 5.0). There is also ample evidence to support the position that Arizona, particularly the low elevation locations (< 2,000 ft.), has a hot environment that is conducive to high micronaire production (hot conditions for both day and

This is part of 2001 Arizona Cotton Report, The University of Arizona College of Agriculture and Life Sciences, index at http://ag.arizona.edu/pubs/crops/az1224/

night temperatures). Thus, it appears that in Arizona we are producing a cotton crop in an environment that is conducive to high micronaire production with varieties that, as a whole, have a tendency toward high micronaire as well. The relationships associated with high micronaire and the third primary component (management) is not well understood in the context of desert cotton production.

Based on an analysis of data from several locations in Arizona, it appears that there is indeed a relationship associated with location and variety and fiber micronaire. From this data there also appears to be a relationship between fiber micronaire and management, in that certain growers within given areas tend to have a very high percentage of their crop classed with high micronaire and another set of growers in the same area have a very low percentage of their crop with low micronaire using basically the same group of varieties. It is the purpose of this research project to better delineate the contributions associated with genetics, environment, and management on fiber micronaire. More specifically, this project will attempt to focus on management factors that are important in determining fiber micronaire. The ultimate objective is to identify management factors that are critical in producing both high yields and micronaire values < 5.0.

Methods and Materials

Approximately 250 cases (fields) were identified with grower-cooperators throughout central and western Arizona with Upland (*Gossypium hirsutum* L.) cotton. Routine plant measurements for each site were carried out on a regular basis at approximately 14-day intervals throughout the season. Measurements taken included: plant height, number of mainstem nodes, number of flowers per 50 feet of row, and the number of nodes from the top fresh white flower to the terminal (NAWF). Sequential plant maps were also collected on regular intervals. Petiole and leaf blade samples were also be collected at the time of plant measurements for nutrient analyses in the laboratory. As the crop approached cutout and the lower bolls began to open, open boll samples were collected from the lowest four, first position bolls (theoretically the bolls with the highest micronaire potential on the plant) from 10 plants, ginned, and the fiber analyzed for micronaire (low 4). From that point forward, total boll counts per unit area and percent open boll measurements were made on 14-day intervals until the crop was defoliated. Relationships among low 4 samples (micronaire), irrigation termination (IT), defoliation, and final crop micronaire are evaluated below. Field records were developed for each field by use of the University of Arizona Cotton Monitoring System (UA-CMS) for points such as variety, planting date, fertility management, irrigation schedules, irrigation termination, defoliation, and all plant measurement data.

The aggregate dataset that was developed from 250 cases monitored over the course of the 2000 season was subjected to the following analyses: correlation, principle component analysis, and a series of regression analyses. Locations for the 250 cases monitored during the 2000 season are presented in Table 1. Results were analyzed statistically (correlation, principal component (PC), and regression) in accordance to procedures outlined by Steel and Torrie (1980) and the SAS Institute (SAS, 1990).

Classification and Regression Trees (CART), a computationally intensive statistical algorithm was used to determine the importance of how a host of factors ranging from farm, district, variety, recursive parent, Bt transgenic or not, irrigation termination, boll load, and other factors influence the micronaire premium or discount. Codes for all varieties as used in the analysis are shown in Table 2. Micronaire premium/discount price quotes on 16 November 2000 for DSW were used in this analysis. To understand the algorithm, think of a jar full of marbles with each price quote representing one marble in the jar. Each marble or price quote has farm, district, variety, etc. stamped on it. The first question CART addresses is what variable and accompanying magnitude can be used to split the marbles into two jars so that the prices in each jar are as close to one another as possible. Closeness if defined in relation to total sum of squared errors for this analysis. Then, subsequent divisions occur until all price quotes are placed into terminal categories or nodes of the same value or less than a minimum number of observations (5 for our analysis). Although a variable may not give the best split for a node, it may give the second or third best split. CART utilizes this concept of surrogate splits to determine the relative importance of different variables. A surrogate split is essentially how well each variable predicts the action of the best linear split. In addition, missing data for independent variables are filled in with predicted values based on correlations of existing data. CART keeps track of the performance of each variable for all splits and normalizes all variables so that the most important variable has a ranking of 100. This information is provided in Table 3.

A tree with one node for every observation would have no node impurity but would likely produce spurious results from a test sample. Whereas, a very small sized tree will inadequately represent the relationships embodied in the data. To determine the trade-off between tree complexity and accuracy, optimal tree size was determined using the *v*-fold (*v* equal to 10 for our results) Cross-Validation (CV) procedure. This is a preferred method for sample sizes less than around 900 cases (Stone). The CV procedure has been referred to as the "leave-one-out" estimate. First, the entire data is randomly divided into *v* different subsets, $L_1, \ldots, L_v$, that are equal or nearly equal in size. A classification tree with a specified number of terminal nodes is computed *V* times, each time leaving out one of the L_v subsamples out to serve as a test sample. Misclassification costs for each L_v test sample are then averaged over each of the different sized trees to determine their respective CV error. The explanatory tree for our data shown in Figure 1 is the tree with the minimum CV error. Additional information regarding the procedures and properties of estimates obtained from CART are discussed in Breiman et al., Efron and Tibshirani, Horowitz and Carson, Lim, Loh, and Shih, and Tronstad.

An additional evaluation was conducted using PC analysis to basically determine which variables belong to the same physiological grouping that could be linked to the final micronaire. By using PC analysis unrelated variables are separated into their related groups called PCs so that variables with strong association in the same group can be scored along independent axis against the dependent variable in a subsequent reduced regression procedure. The restructured groups contain the many correlated variables in smaller sets of components of the original variables herein called PC1,...,PCn (Table 4). Principal components (PC1,…,PCn) are typically considered meaningful if they possess an eigenvalue >1 and if the percentage of total variation explained by the PCn is high. The variable that contributes least to the underlying relationship within the grouping of variables (PCn) can be deleted from further analysis thereby simplifying the data set. Data codes for the characteristic cotton variables measured are presented in Table 3.

Results

The body of data from the 250 cases that were sampled during the 2000 season was analyzed by use of correlation procedures, PC analysis, selective regression procedures, and CART analyses. In each case factors relating to final micronaire were the target objectives to identify.

Principal Component Analysis and Stepwise Regression procedure

A PC analysis indicated that the first PC has an eigenvalue of 10.19 and explains 55.5% of the total variation in the data set (Table 4). This eigenvalue is relatively large and suggests that PC1 represent about 12 variables that should be considered for further evaluation. Principal component 2 and PC3 explain an additional 12.2% and 9.6% of the total variation respectively. Others account for a much smaller variation and therefore were dropped from further evaluation. By examining the eigenvectors (weights-W) and the rotated factor patterns with the PC scores (loadings-L), variables with large W and L, either negative or positive are considered to contribute to the PC. From Table 4, COHUAP, HUPB, HUPD, HUBC, HUIT, HNRCO, GBM, HNRFB, FFB, HUFB, PM, and HNRPB were considered from PC1. Additional variables considered from PC 2 and 3 include, FRFB, FRPB, FRCO, NDFB, NACB1, and Low4Mik. The selected variables were then subjected to a stepwise regression procedure against the "finalmic". Results of the summary of the stepwise selection procedure indicate that R25MIC, HNRFB, HUIT, BM, YIELD, and FRFB are parameters that have significant influence in determining the value of the final micronaire.

From the analyses that have been conducted (basic correlation analysis and a series of multiple regression models), a few parameters have shown some significance. These parameters include:

1. Heat units accumulated after planting (HUAP) to irrigation termination.
    a. In general, as HUAP increased, micronaire increased also.
2. The number of green bolls on the plant as the crop approached cutout.
    a. As the number of green bolls increased, the micronaire tended to be lower
3. The position of the first fruiting branch.
    a. With lower first fruiting branch, micronaire tended to be lower.

From a physiological point of view, the relationships associated with these parameters make some sense. Point 1 is consistent with the results from the IT X Variety experiment at MAC previously described. Point 2 is logically related to lower micronaire due to a larger carbohydrate sink being associated with a larger green boll load and thus more competition for existing carbohydrates among existing bolls (and fibers). With the generally uniform fruiting patterns experienced in the 2000 season, Point 3 seems reasonable in that boll filling periods for all stages of the fruiting cycle would be similar. This would result in more uniform micronaire development and less tendency for a high carbohydrate deposition rate to occur that might be reflected in higher micronaire readings. However, it is reasonable that if a non-uniform fruiting pattern were experienced (gaps occurring in the fruiting pattern of the crop) that a lower first fruiting branch may result in higher micronaire since the existing bolls on the plant would have less carbohydrate competition and therefore possibly a longer boll filling period. This is speculative however, and points out the need for a continuation of work like this for more than one season.

CART Analysis

Figure 1 provides a tree diagram of the variables and their levels or classes that CART selected as being most important for explaining the price premium and discount received from each case or field. For example, irrigation termination that occurs before reaching 2,942 HUAP with a variety of either SG747(1), ST4892BR(4), BR9801(10), BR9802(11), and AP6101(23) were classed together receiving a premium/discount of -6.53¢/lb. The most favored micronaire level segregated (-0.84¢/lb.) by CART occurred when irrigation termination was before 2,942 HUAP, variety was not one of those mentioned in the last scenario, the farm was 34 out of the 37 farms in the experiment (not 11, 17, or 25), and FRPB (fruit retention at peak bloom) was greater than 45.5. If one is unable to have an irrigation termination date before 2,942 HUAP, varieties of SG821(3), ST4892BR(4), BR9801(10), BR9802(11), DP675(12), DP565(13), PM1560BR(15), DP655BR(17), OPAL(19), DP90B(20), AP9257(21), AP6101(23), and JSX22(26) yielded the second best category of micronaire discount at -2.64¢/lb.

The relative importance of variables determined by CART is described in Table 3. Variety was the most important factor (100.00) followed by irrigation termination (HUAP) at 90.86, recursive parent to varieties considered (81.30), farm (76.39), and so on. Because there were almost as many recursive parents as varieties (23 vs. 30), the explanatory power of recursive parent as the surrogate split for variety was almost as good as the actual variety variable itself. Irrigation termination (HUAP) at 90.86 means that irrigation termination explains 90.86 percent as much as variety in isolating on the optimal splits. The low explanatory power of soil type is partly attributed to the fact that many of these values were missing for the current data set analyzed. But the low ranking for field, transgenic, and FFB (first fruiting branch, node number) are indicative that these variables were not a factor in determining final micronaire.

Acknowledgements

The financial support provided by the Arizona Cotton Growers Association and Cotton Inc., Anderson Clayton Company, and Handwerker-Winburne is greatly appreciated. We gratefully acknowledge the excellent assistance from the personnel at the Maricopa Agricultural Center. Also the hard work and technical assistance provided by the research assistants with the UA Cotton Agronomy program is greatly appreciated.

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1. Cotton fiber quality (micronaire) assessment locations, AZ, 2000.

Districts	Sites
Buckeye	Moore UAVT Youngker
Casa Grande	Pate
Eloy	Dixon Shedd TOFASL
Magma	Barcello Koepnick
Maricopa	Clayton CN9 Cooley Kortsen Field 30 NMGT OBS Salmon Scott UAVT IT/VAR
Mohave	DWAK VWAK Sherrill Vandersl
Parker	CRIT-UAVT Hancock McGuire Mullion
Sacaton	Button
Stanfield	TOFAVV
Tonopah	Gill Odom Reed
Vicksburg	Cramer
Yuma	Barkley Dunn Hulstran Marlatt Osborn Weichens

Figure 1. Tree of variables and levels or classes for explaining the micronaire premium and discount received

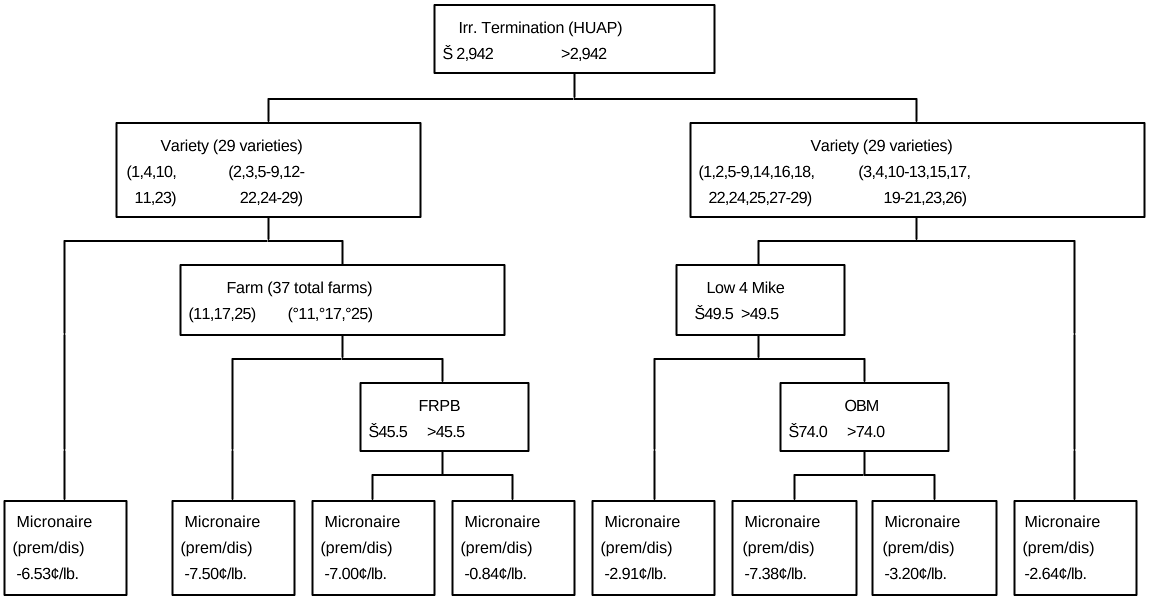

Table 2. Code for Varieties

1 = SG747
2 = DP422BR
3 = SG821
4 = ST4892BR
5 = BXN47
6 = ST474
7 = ST4691B
8 = DP451BR
9 = DP388
10 = BR9801
11 = BR9802
12 = DP675
13 = DP565
14 = DP458BR
15 = PM1560BR
16 = SG501BR
17 = DP655BR
18 = SG125BR
19 = OPAL
20 = DP90B
21 = AP9257
22 = AP7126
23 = AP6101
24 = HS46
25 = DP33B
26 = JSX22
27 = DP5415
28 = DP20B
29 = DP428B

Table 3. Relative importance of variables in explaining the micronaire premium and discount received.

Variable	Relative Importance	Number of Categories
Variety	100.00	30
Irrigation Termination (HUAP)	90.86	
Recurrent Parent	81.30	23
Farm	76.39	37
FRCO (fruit retention at cut-out)	63.06	
HNRCO (height:node ratio at cut-out)	59.74	
HNRPB (height:node ratio at peak bloom)	56.74	
OBM (open bolls at maturity)	50.93	
FRPB (fruit retention at peak bloom)	34.93	
HUAP (heat units accum. after planting)	32.39	
FRFB (fruit retention at first bloom)	29.72	
PBHUAP (heat units at peak bloom)	28.02	
COHUAP (heat units at cut-out)	27.18	
District	26.30	12
HUFFB (HUAP at first fruiting branch)	25.84	
PM	25.53	
PDHUAJ (HU since Jan. 1 at planting)	25.32	
NACB (nodes above cracked boll)	22.65	
Low4Mik (Low 4 sample micronaire)	21.37	
FBHUAP (heat units at first bloom)	14.79	
FBNODE (total nodes at first bloom)	12.69	
FINFR (final fruit retention)	7.04	
HNRFB (height:node ratio at first bloom)	6.76	
Yield (lbs. Lint/acre)	5.08	
BM (total boll count at cut-out)	4.46	
GBM (green boll count at cut-out)	3.41	
HUFINFR (HU at time of final fruit ret.)	0.22	
Irrigation Initiation	0.07	
FFB (first fruiting branch, node number)	0.00	
Field number	0.00	4
Soil type	0.00	5
Transgenic	0.00	2

Table 4. Loadings (L) and eigenvectors (W) of the PC axes from PC analysis of data of cotton variables. Eigenvalues and their contribution to total variation are listed at the bottom of the table.

	PC 1		PC 2		PC 3		PC 4		PC 5		PC 6		PC 7	
Variables	L	W	L	W	L	W	L	W	L	W	L	W	L	W
HUPD	0.75	-0.22	-0.25	0.19	-0.17	-0.07	-0.03	-0.17	-0.05	0.21	0.07	0.04	-0.33	-0.35
FFB	-0.80	0.15	-0.13	-0.31	-0.01	-0.04	-0.01	0.40	0.04	-0.12	0.19	-0.04	0.03	-0.04
NDFB	0.05	-0.10	-0.25	-0.44	0.05	0.04	0.05	-0.23	-0.16	0.06	-0.07	-0.04	0.11	0.51
HUFB	0.58	-0.30	-0.71	-0.03	0.27	0.11	0.03	0.10	0.02	-0.02	-0.09	0.08	-0.13	-0.08
FRFB	-0.18	0.22	0.89	0.23	-0.05	0.05	-0.05	-0.31	-0.07	0.28	0.11	-0.12	0.07	0.08
HNRFB	-0.71	0.29	0.53	-0.11	-0.18	-0.10	-0.18	0.05	-0.10	0.14	0.32	0.05	-0.04	-0.13
PBHUAP	0.75	-0.30	-0.59	0.10	-0.04	0.02	0.11	-0.04	0.01	0.00	-0.12	0.05	-0.18	-0.16
FRPB	-0.33	0.27	0.86	0.19	-0.03	0.07	-0.03	-0.16	0.01	0.12	0.04	-0.13	0.19	0.16
HNRPB	-0.54	0.25	0.54	-0.08	0.32	-0.18	-0.32	-0.10	-0.10	0.11	0.20	-0.07	-0.15	-0.20
HUCO	0.77	-0.30	-0.53	0.06	0.08	0.05	0.16	-0.07	0.02	0.10	-0.09	-0.02	-0.21	0.10
FRCO	-0.24	0.23	0.77	0.25	0.07	0.14	0.07	-0.12	-0.01	0.08	-0.04	-0.16	0.04	-0.05
HNRCO	-0.66	0.22	0.34	-0.25	0.15	-0.18	-0.24	0.05	-0.03	0.16	0.27	-0.12	-0.24	-0.17
HUBC	0.74	-0.22	-0.29	0.17	0.19	-0.31	-0.18	0.01	0.41	0.24	0.17	-0.02	0.11	0.35
PM	-0.49	0.24	0.56	0.13	0.25	0.25	0.25	0.10	-0.06	0.02	0.06	0.06	0.22	0.04
BM	0.00	-0.08	-0.29	-0.04	0.82	0.53	0.82	0.38	0.02	0.11	0.06	0.14	0.12	0.10
GBM	-0.7	0.28	0.53	0.02	-0.04	-0.02	-0.04	0.21	0.16	0.02	0.16	-0.07	0.14	0.07
OBM	-0.22	0.19	0.45	0.23	-0.10	0.04	-0.10	-0.09	-0.11	-0.17	0.03	0.39	0.73	0.45
NACB	0.14	-0.03	0.21	-0.01	0.80	0.58	0.80	0.00	-0.06	0.34	-0.06	-0.27	-0.23	-0.02
HUIT	0.61	-0.20	-0.31	0.13	0.14	-0.22	0.04	0.23	0.46	0.45	0.43	0.05	0.03	0.26
Low4Mik	0.12	0.05	0.14	0.49	-0.06	0.00	-0.06	0.14	0.08	-0.21	-0.01	0.32	0.36	-0.09
R25MIC	-0.02	-0.01	0.01	0.27	-0.02	-0.20	-0.02	0.51	0.90	-0.06	-0.13	-0.57	-0.07	0.12
YIELD	-0.27	0.14	0.20	-0.06	0.01	-0.10	0.01	0.20	-0.11	0.55	0.84	0.47	0.02	-0.12
Eigenvalue	10.19		2.25		1.71		1.26		1.16		0.91		0.88	
Percent of total	55.5		12.2		9.6		6.9		6.3		5.0		4.8	