# A FIBER QUALITY AND POST-HARVEST DECAY MODEL

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## Abstract

This research studied the effects of delayed harvests and fiber exposure on the different cotton fiber properties. We found a significant downward trend for microafis and fiber strength values when harvest was delayed. A clear downward trend was observed in the upper quartile length values which were reduced when harvest was delayed.

A decay function was used to model deterioration trends. The boll exposure period was found to be a reasonable predictor of the fiber quality values across harvest dates. For the upper quartile length, the predicted and actual values had poor agreement across harvest dates. For the microafis and fiber strength, however, the models showed good performance.

## Introduction

Two factors are key determinants of crop returns: total yield and fiber quality. In general it is expected that yield increases as the number of open bolls increases. However, open bolls that are not harvested at an optimal time may lose quality due to weather factors. Therefore, it is important to develop a model that will be able to explain simultaneously the behavior of yield and fiber quality as the season progresses. This will provide a more precise day-to-day estimate of the value of the harvest. As a result, the harvest initiation date could be optimized to maximize yield and quality as emphasized by Parvin (1990).

Based on the above facts, a comprehensive research was conducted with the objectives: 1) to develop a model to predict initial cotton fiber quality; 2) to develop a model to predict fiber quality of cotton as a function of harvest date; and 3) to develop a model to predict crop value over the harvest period. This report only includes a discussion of the second objective of this research.

## Experimental Procedures

Field experiments were conducted during the cotton growing seasons in 1993 and 1994. The crop was planted at the Plant Science Research Center of Mississippi State University. The cotton cultivar used was DES119. Cultural practices followed those used by commercial farmers. The plants, however, were thinned such that there were only 10 to 12 plants per 1.5 m of row. Thinning was done when the plants were about 40 days post emergence for the 1993 experiment. For the 1994 experiment, the plants were thinned three weeks after the planting date. This thinning permitted a more homogeneous plant stand in the sampling area. Average daily temperature, rainfall, and solar radiation were recorded throughout the experiments. These weather components were recorded at a weather station located about 300 m from the field.

Sampling procedures for these experiments were conducted as follows:

Whenever possible, 25 to 45 bolls from different plants, located at the same node position, and opened on the same day, were tagged. From these, five to nine bolls were harvested on the day they were tagged. The fiber quality properties obtained from these bolls were then considered as the initial fiber quality value.

Five to nine bolls from the remaining bolls on the initial fiber quality experiment were harvested every week. Thus, each node position was harvested over four weeks. This step provided information about the effect of weather components on fiber quality when harvest was delayed.

The bolls harvested from a given node position on a given harvest date were considered as one sample. This means that five samples were obtained from each node since five harvests were performed, including the harvest performed on the day the bolls opened. From each sample, five bolls were selected and their fiber properties were analyzed. This number of bolls represented the number of replications for that corresponding sample. In this experiment, 30 node positions were observed. For some node positions, however, it was impossible to conduct more than one harvest due to the few bolls produced at those positions. As a result, 83 samples were collected instead of 150 in 1993. In 1994, the number of samples collected was 88.

The bolls collected from the above experiments were analyzed by using the Advance Fiber Information System (AFIS) machine to obtain fiber upper quartile length and microafis values. The upper quartile length is the fiber length which is exceeded by 25% of the fiber by weight in the test specimen as defined by Behery (1993). The term microafis is analogous to micronaire. This analysis was performed in the USDA-Southern Regional Research Center (USDA-SRRC), New Orleans, LA. To reduce the variability of the fibers among different locks of each boll, it was decided to proceed with the following steps: 1) lint samples from the middle seed of each lock from the same boll were combined and analyzed (their quality was assumed to represent the quality of that boll); 2) if the number of seeds of a given lock was even, then the fibers from the two middle seeds were taken; and 3) if the middle seed was a "mote" (i.e., an undeveloped embryo) then the

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two adjacent seeds were taken. The number of fibers analyzed for one replication, one boll, was 4,000.

The remaining fibers after the AFIS machine conducted its measurements were used to measure fiber strength by using a Stelometer instrument. In this analysis, all fibers from the five bolls of each sample were combined together and analyzed. This was done since the Stelometer instrument requires sample sizes of at least 0.5 g. It was assumed that the quality values obtained represented the fiber strength of the given sample. Three measurements were taken for each sample. Prior to analyzing, all samples were preconditioned at standard conditions of 70°C and 65% RH. For the 1993 experiment, the analysis was performed in the USDA-SRRC, New Orleans, LA. For the 1994 experiment the analysis was conducted in STARLAB®, Inc. Knoxville, TN.

## Modelling Approach and Methods

A model was proposed to predict the fiber quality of a specific boll on the $k^{th}$ day after opening. The model was a simple decay model as described by Mesterton-Gibson, (1988). A basic assumption given this model was that the fiber quality on the $k^{th}$ day after opening will always be less than the initial quality. The model was expressed as follows:

$$FQ_{rij(k+1)} = (Exp(R_{rij(k+1)})) * FQ_{rij(0)}$$

where: $FQ_{rij(k+1)}$ is the fiber quality of a boll located at the main stem node i and branch node position j on the $(k+1)^{th}$ day after opening, k=0 indicates the day when a boll opens; $FQ_{rij(0)}$ is the initial fiber quality of a boll located at the main stem node i and branch node position j on the day the boll opens; $Exp(R_{rij(k+1)})$ represents Quality Reduction Factor, ranging from 1 to 0, when bolls are harvested on the $(k+1)^{th}$ day after opening; r is an index to denote the specific property and is equal to 1, 2, and 3 to represent fiber length, microafis, and fiber strength, respectively.

The $R_{rij(k)}$ component is a function of weather factors, and is expressed as follows:

$R_{rij(k)}$=f(opened boll exposure period,
cumulative heat units,
cumulative rainfall, and
cumulative solar radiation).

This function was parameterized by employing the following approach:

1) The general linear model procedure (SAS GLM Procedure) was used to test if there was a significant downward trend in fiber quality values as a function of the boll exposure period, cumulative heat units, cumulative rainfall, and cumulative solar radiation.

2) The actual fiber quality values were plotted against the opened boll exposure period, cumulative heat units, cumulative rainfall, and cumulative solar radiation during the boll exposure period. The plots provided additional information to show if indeed there was a decay trend as a function of the predictor variables.

## Results and Discussion

The open boll exposure period and weather conditions during the harvest period in 1993 and 1994 are summarized in Table 1. The weather conditions considered were cumulative heat units, cumulative rainfall, and cumulative solar radiation. The open boll exposure period and weather conditions were set equal to zero at the time of the initial harvest. The cumulative weather conditions were the cumulative weather conditions from the initial harvest through the subsequent harvests. The daily heat units were calculated by subtracting 12.8°C from the average daily temperature. This followed the procedure described by Young et al. (1980).

It was observed that the fiber quality values fluctuated across the harvest dates. This fluctuation may be due to the variability between bolls within a given position on the branch. A smaller variability was noted for branch position 1 bolls. It was thus decided that only branch node position 1 would be considered in the fiber decay analysis. The assumption was that the bolls from branch node position 1 were more homogeneous than those from branch node position 2. For the 1993 experiment, positions included in the analysis were 7.1 to 12.1. For the 1994, positions considered were 7.1 to 11.1.

Statistical analysis was performed to detect if indeed the exposure period and weather conditions affected the fiber quality values. The analysis was performed on each group of positions harvested on the same day for each year. For the 1993 experiment, positions 7.1, 8.1, and 9.1 were grouped, positions 10.1, 11.1, and 12.1 formed a second group. For the 1994 experiment, positions 7.1, 8.1, and 9.1 were grouped, positions 10.1 and 11.1 formed a second group.

The statistical procedure used in the analysis was the general linear model procedure (SAS, 1985, GLM Procedure). The procedure was run by using the SAS program. The model used was as follows:

FIBER QUALITY = {MSN, HD, MSN * HD}

where MSN is the main stem node number, HD represents either the opened boll exposure period, cumulative heat units, cumulative rainfall, or cumulative radiation. In the SAS program, MSN was placed in the 'class' statement. 'Class' statement in SAS specifies the classification variables. With this statement, the effect of HD was analyzed in each main stem node number, and the consistency of the HD effect acros MSN was represented by the MSN*HD interaction. The p-value for the Sum Square Type III indicated the significant effects of these factors.

The fiber quality values were transformed into logarithmic values prior to the analysis to to linearize the exponential trend in the data. Note that this data trend and the exponential model used before follow the assumption that the quality reduction factor will decrease exponentially when harvest is delayed. The linearization then permitted a straigthforward statistical analysis of the data as was detailed above.

The results of the analysis are summarized in Tables 2 through 5. The results show that the upper quartile length is not significantly affected by the boll exposure period and the weather conditions. The microafis and fiber strength values, however, were observed to be significantly affected by the boll exposure and weather conditions.

The results also indicate that whenever one factor significantly affects the microafis or fiber strength, the other factors will also follow the same trend. Consequently, it is difficult to conclude which factor is dominant in decaying the fiber as harvest is delayed. This is because the four factors included in this analysis (opened boll exposure period, cumulative heat units, cumulative rainfall, and cumulative radiation) are highly correlated with each other.

Based on the above, it was assumed that the decrease of microafis and fiber strength values depends largely on boll exposure period. This empirical assumption was set based on the following: 1) the boll exposure period may compound the other three factors. The longer the boll exposure period the higher the chance to have high cumulative heat units, high cumulative rainfall, and high cumulative radiation; and 2) the longer the cotton bolls are exposed to the weather, the higher the chance to have bacteria and fungi on those cotton bolls. Hake et al. (1992) stated that under favorable conditions these bacteria and fungi begin to feed on the sugars and on the surface of the fibers. This feeding creates a rough surface on those fibers. This damage will reduce micronaire and strength values as also indicated by Meredith (1989).
To be consistent with the above assumption, all bolls from the positions harvested on the same day in the same year were combined and the average upper quartile length, microafis, and fiber strength for each harvest date were calculated. The summary of the average quality values of each group of positions for the 1993 and 1994 experiments is shown in Tables 6 and 7. These average values were then plotted against the boll exposure period. The plots are shown in Figures 1, 2, and 3.

Figure 1 indicates that even for the upper quartile length, the downward trend can be observed if four outlier points are excluded. The four outlier points are the average upper quartile length values generated from the group of positions: 1) 7.1, 8.1, and 9.1 harvested on October 2, 1993, coded B; 2) 10.1, 11.1, and 12.1 harvested on October 1, 1993, coded A; 3) 7.1, 8.1, and 9.1 harvested on September 13, 1994, coded C; and 4) 10.1 and 11.1 harvested on September 26, coded D. The reasons for selecting these outliers for elimination were: 1) We have assumed that fiber quality cannot improve after boll opening. Thus, points showing much higher value than a previous observation were assumed to be outliers. This was observed on points A and B; 2) Points C and D were excluded because their values were relatively far from the general trend of the other values in their groups.

Figures 2 and 3 emphasize that the microafis and fiber strength values decreased as the boll exposure period increased for both years of experiments. The slopes of the downward trend for both years are very similar. Based on these figures, it can safely be assumed that the decay rate of the microafis in 1993 and that in 1994 are similar. The same assumption could be applied to fiber strength.

The trend observed in Figures 1 to 3 strongly supports the assumption that the boll exposure period can be used as a predictor to determine the amount of decay that will occur on cotton fiber when harvest is delayed. For this reason, the following simple decay model was proposed to predict the fiber quality values as the harvest is delayed.

$$FQ(OBEP,i,j)=a(i,j)* EXP(- b * OBEP)$$

where FQ(OBEP,i,j) represents either upper quartile length, microafis or fiber strength value at position [i.j] after being exposed to the weather for OBEP days, a(i,j) represents the initial fiber quality value at position [i.j], b represents the decay rate, and OBEP is the opened boll exposure period in days.

The values of a(i,j) and b were determined by using the curve fitting methods available in the Sigma Plot® software. For the upper quartile length, data from the 1993 and 1994 experiments were combined in the analysis to obtain the decay rate b. For the microafis and strength, the analysis was performed on both years. The final decay models were then generated as follows:

$$UQL(OBEP,i,j)=IUQL(i,j)*EXP(-0.0016030 * OBEP)$$

$$MIC(OBEP,i,j)=IMIC(i,j)*EXP(-0.0021835 * OBEP)$$

$$STR(OBEP,i,j)=ISTR(i,j)*EXP(-0.0026855 * OBEP)$$

where: UQL(OBEP,i,j) is the upper quartile length of position [i.j] after being exposed to the weather for OBEP days; MIC(OBEP,i,j) is the microafis values of position [i.j] after being exposed to the weather for OBEP days; STR(OBEP,i,j) is the fiber strength values of position [i.j] after being exposed to the weather for OBEP days; IUQL(i,j), IMIC(i,j), and ISTR(i,j) represent the initial upper quartile length, microafis, and strength at position [i.j], respectively; OBEP is the open boll exposure period, days.

By using these models, the values of the upper quartile length, microafis, and fiber strength were predicted across the harvest dates. The predicted and actual values for the three fiber quality components are shown in Figures 4 through 6.

Figure 4 shows that the model does not work well when predicting the upper quartile length. The intercept of the regression line is far from zero. The slope value is 0.61285, which is far from one. The $R^2$ value obtained is 0.72. The fluctuation of the actual upper quartile length data contributed to this poor prediction.

Figure 5 clearly shows that the model predicts the microafis values well across the harvest dates. The intercept and slope values are very close to zero and one, respectively. The $R^2$ is also high, 0.99. A similar performance is observed for the fiber strength model, Figure 6.

## Conclusions

The boll exposure period was found to be a reasonable predictor of the fiber quality values across harvest dates. The model developed is termed the 'fiber decay' model. For the upper quartile length, the predicted and actual values have poor agreement across harvest dates. For the microafis and fiber strength, however, the models show good performance.

**Note:**
Mention of products or trademarks does not imply endorsement by USDA-ARS or by Mississippi State University.

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Table 1. Exposure period and weather conditions during the harvest period in 1993 and 1994.

| HD | OBEP (day) | CHU (ºC) | Cum.Rain (mm) | Cum. Rad. (MJ/m$^2$) |
|---|---|---|---|---|
| **1993:** | | | | |
| Positions 7.1;8.1;9.1 | | | | |
| 9/4 | 0 | 0 | 0 | 0 |
| 9/11 | 7 | 75.5 | 1.27 | 138.5 |
| 9/18 | 14 | 131.1 | 31.75 | 265.9 |
| 9/25 | 21 | 201.9 | 44.45 | 375.0 |
| 10/2 | 28 | 246.4 4 | 8.26 | 523.6 |
| Positions 10.1;11.1;12.1 | | | | |
| 9/9 | 0 | 0 | 0 | 0 |
| 9/18 | 9 | 78.6 | 1.75 | 144.6 |
| 9/23 | 14 | 125.2 | 35.56 | 242.0 |
| 10/1 | 22 | 186.6 | 48.26 | 387.5 |
| 10/8 | 29 | 229.0 | 48.26 | 516.4 |
| **1994:** | | | | |
| Positions 7.1;8.1;9.1 | | | | |
| 9/13 | 0 | 0 | 0 | 0 |
| 9/23 | 10 | 89.9 | 49.53 | 170.8 |
| 9/29 | 16 | 117.9 | 49.53 | 278.6 |
| 10/8 | 25 | 184.2 | 78.49 | 430.2 |
| 10/17 | 34 | 216.9 | 107.45 | 493.7 |
| Positions 10.1;11.1 | | | | |
| 9/16 | 0 | 0 | 0 | 0 |
| 9/26 | 10 | 55.9 | 49.53 | 150.8 |
| 10/5 | 19 | 124.9 | 78.49 | 306.7 |
| 10/17 | 31 | 176.2 | 107.45 | 427.1 |
| 10/24 | 38 | 219.5 | 146.81 | 475.3 |

Note:
HD = harvest date (mmonth/day),
OBEP = open boll exposure period,
CHU = cumulative heat units, ºC,
Cum. Rain = cumulative rainfall, mm,
Cum. Rad = cumulative solar radiation, MJ/m$^2$.

Table 2. Result summary of the statistical analysis of the effect of boll exposure period on fiber quality across main stem nodes for the 1993 and 1994 experiments.

| Fiber Quality | p-value MSN | HD | MSN * HD |
|---|---|---|---|
| **1993**: | | | |
| Positions 7.1;8.1;9.1 | | | |
| UQL | 0.7051 | 0.7842 | 0.8009 |
| Microafis | 0.4263 | 0.0014 | 0.4427 |
| Strength | 0.1180 | 0.0073 | 0.0310 |
| Positions 10.1;11.1;12.1 | | | |
| UQL | 0.3910 | 0.5112 | 0.2182 |
| Microafis | 0.8094 | 0.4366 | 0.8403 |
| Strength | 0.1637 | 0.0442 | 0.1510 |
| **1994**: | | | |
| Positions 7.1;.8.1;9.1 | | | |
| UQL | 0.1955 | 0.7113 | 0.2066 |
| Microafis | 0.6146 | 0.1524 | 0.7388 |
| Strength | 0.5800 | 0.0484 | 0.3728 |
| Positions 10.1;11.1 | | | |
| UQL | 0.4716 | 0.1705 | 0.7189 |
| Microafis | 0.4934 | 0.7710 | 0.0970 |
| Strength | 0.0016 | 0.0015 | 0.0066 |

Note: UQL = upper quartile length
BN = branch node position
MSN = main stem node
HD = exposure day
MSN * HD = interaction between main stem node and exposure day.

Table 3. Result summary of the statistical analysis of the effect of cumulative heat units on fiber quality across main stem nodes for the 1993 experiment.

| Fiber Quality | p-value MSN | HD | MSN * HD |
|---|---|---|---|
| **1993**: | | | |
| Positions 7.1;8.1;9.1 | | | |
| UQL | 0.6844 | 0.8875 | 0.7811 |
| Microafis | 0.4177 | 0.0019 | 0.5638 |
| Strength | 0.0774 | 0.0051 | 0.0199 |
| Positions 10.1;11.1;12.1 | | | |
| UQL | 0.3691 | 0.5942 | 0.2128 |
| Microafis | 0.8085 | 0.3986 | 0.8437 |
| Strength | 0.1418 | 0.0386 | 0.1326 |
| **1994**: | | | |
| Positions 7.1;8.1;9.1 | | | |
| UQL | 0.2119 | 0.7144 | 0.1967 |
| Microafis | 0.7619 | 0.1447 | 0.6077 |
| Strength | 0.6192 | 0.0558 | 0.4900 |
| Positions 10.1;11.1 | | | |
| UQL | 0.5162 | 0.1755 | 0.7808 |
| Microafis | 0.4185 | 0.7881 | 0.0754 |
| Strength | 0.0008 | 0.0006 | 0.0036 |

Note: UQL = upper quartile length
BN = branch node position
MSN = main stem node
HD = cumulative heat units
MSN * HD = interaction between main stem node andcumulative heat units.

Table 4. Result summary of the statistical analysis of the effect of cumulative rainfall on fiber quality across main stem nodes for the 1993 experiment.

| Fiber Quality | p-value MSN | HD | MSN * HD |
|---|---|---|---|
| **1993:** | | | |
| Positions 7.1;8.1;9.1 | | | |
| UQL | 0.7523 | 0.9797 | 0.8200 |
| Microafis | 0.4476 | 0.0052 | 0.5594 |
| Strength | 0.2177 | 0.0158 | 0.0530 |
| Positions 10.1;11.1;12.1 | | | |
| UQL | 0.2334 | 0.9776 | 0.2182 |
| Microafis | 0.5367 | 0.2935 | 0.5490 |
| Strength | 0.1481 | 0.0406 | 0.1925 |
| **1994:** | | | |
| Positions 7.1;8.1;9.1 | | | |
| UQL | 0.2396 | 0.6300 | 0.1231 |
| Microafis | 0.7341 | 0.0933 | 0.6308 |
| Strength | 0.7726 | 0.0691 | 0.4999 |
| Positions 10.1;11.1 | | | |
| UQL | 0.4953 | 0.1189 | 0.7601 |
| Microafis | 0.4375 | 0.6877 | 0.0915 |
| Strength | 0.0027 | 0.0023 | 0.0112 |

Note: UQL = upper quartile length
BN = branch node position
MSN = main stem node
HD = cumulative rainfall
MSN * HD= interaction between main stem node and cumulative rainfall.

Table 5. Result summary of the statistical analysis of the effect of cumulative radiation on fiber quality across main stem nodes for the 1993 experiment.

| Fiber Quality | p-value MSN | HD | MSN * HD |
|---|---|---|---|
| **1993:** | | | |
| Positions 7.1;8.1;9.1 | | | |
| UQL | 0.6857 | 0.7685 | 0.7783 |
| Microafis | 0.4427 | 0.0012 | 0.4043 |
| Strength | 0.1235 | 0.0074 | 0.0341 |
| Positions 10.1;11.1;12.1 | | | |
| UQL | 0.4082 | 0.4924 | 0.2277 |
| Microafis | 0.8288 | 0.4432 | 0.8583 |
| Strength | 0.1666 | 0.0454 | 0.1464 |
| **1994:** | | | |
| Positions 7.1;8.1;9.1 | | | |
| UQL | 0.1919 | 0.7538 | 0.2483 |
| Microafis | 0.7267 | 0.1798 | 0.6494 |
| Strength | 0.5291 | 0.0488 | 0.4359 |
| Positions 10.1;11.1 | | | |
| UQL | 0.5459 | 0.1423 | 0.8225 |
| Microafis | 0.3026 | 0.8946 | 0.0512 |
| Strength | 0.0010 | 0.0009 | 0.0045 |

Note: UQL = upper quartile length
BN = branch node position
MSN = main stem node
HD = cumulative radiation
MSN * HD = interaction between main stem node and cumulative radiation.

Table 6.Average upper quartile length of bolls opened on the same day when harvest was delayed for the 1993 and 1994 experiments.

| Harvest Date | Upper Quartile Length (in.) |
|---|---|
| **1993:** | |
| Positions combined: 7.1;8.1;9.1 | |
| Sep.4 | 1.257(0.054) |
| Sep.11 | 1.239(0.065) |
| Sep.18 | 1.230(0.064) |
| Sep.25 | 1.234(0.061) |
| Oct.2 | 1.267(0.053) |
| Positions combined: 10.1;11.1;12.1 | |
| Sep.9 | 1.252(0.091) |
| Sep.18 | 1.269(0.064) |
| Sep.23 | 1.253(0.055) |
| Oct.1 | 1.282(0.072) |
| Oct.8 | 1.223(0.089) |
| **1994** | |
| Positions combined: 7.1;8.1;9.1 | |
| Sep.13 | 1.218(0.121) |
| Sep.23 | 1.248(0.078) |
| Sep.29 | 1.201(0.118) |
| Oct.8 | 1.232(0.127) |
| Oct.17 | 1.190(0.123) |
| Positions combined: 10.1;11.1 | |
| Sep.16 | 1.272(0.087) |
| Sep.26 | 1.168(0.111) |
| Oct.5 | 1.200(0.071) |
| Oct.17 | 1.190(0.100) |
| Oct.24 | 1.184(0.068) |

Note: Number in parenthesis represents the standard deviation of all bolls at the positions combined.

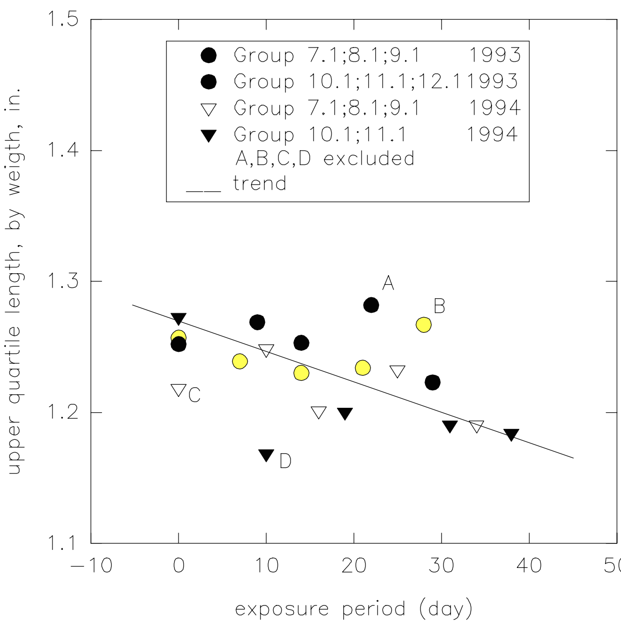


Figure 1. Upper quartile length vs opened boll exposure period.

Table 7. Average microafis and fiber strength values of bolls opened on the same day when harvest was delayed for the 1993 and 1994 experiments.

| Harvest date | Microafis | Strength (g/tex) |
|---|---|---|
| **1993:** | | |
| Positions combined: 7.1;8.1;9.1 | | |
| Sep.4 | 5.873(0.590) | 25.589(1.819) |
| Sep.11 | 5.635(0.605) | 24.369(0.510) |
| Sep.18 | 5.461(0.753) | 23.901(0.630) |
| Sep.25 | 5.404(0.444) | 23.828(1.232) |
| Oct.2 | 5.175(0.638) | 23.465(0.742) |
| Positions combined: 10.1;11.1;12.1 | | |
| Sep.9 | 5.617(0.726) | 26.306(1.560) |
| Sep.18 | 5.481(0.877) | 25.361(1.384) |
| Sep.23 | 5.477(0.768) | 25.416(0.785) |
| Oct.1 | 5.025(0.472) | 24.344(1.087) |
| Oct.8 | 5.488(0.599) | 24.624(1.003) |
| **1994** | | |
| Positions combined: 7.1;8.1;9.1 | | |
| Sep.13 | 4.001(0.504) | 19.378(0.764) |
| Sep.23 | 3.872(0.446) | 18.911(1.332) |
| Sep.29 | 3.921(0.587) | 18.000(0.527) |
| Oct.8 | 3.757(0.805) | 18.067(1.108) |
| Oct.17 3 | .804(0.310) | 17.689(1.614) |
| Positions combined: 10.1;11.1 | | |
| Sep.16 | 4.276(0.824) | 19.300(1.018) |
| Sep.26 4 | .295(0.343) | 19.183(0.900) |
| Oct.5 | 4.193(0.706) | 18.350(0.596) |
| Oct.17 | 4.135(0.768) | 18.433(0.528) |
| Oct.24 | 4.457(0.719) | 18.067(0.216) |

Note: 1) number in parenthesis at microafis column represents the standard deviation of all bolls at the positions combined.
2) number in parenthesis at strength column represents the standard deviation of all combined measurements for each position.

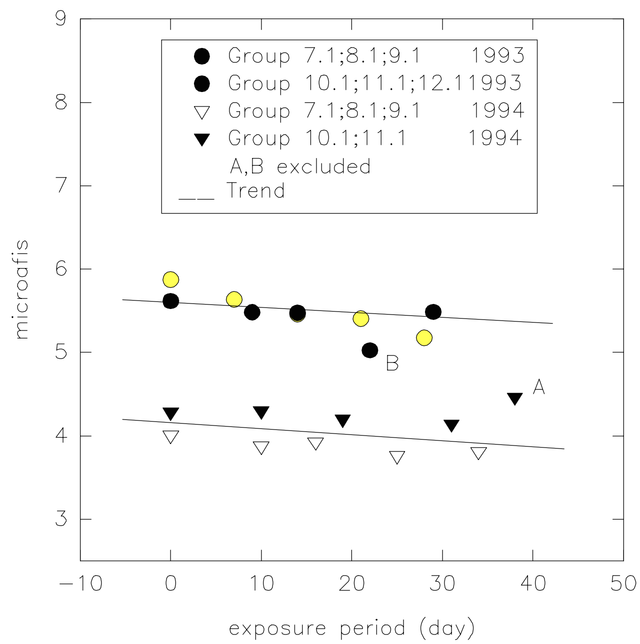


Figure 2. Microafis values vs opened boll exposure period.

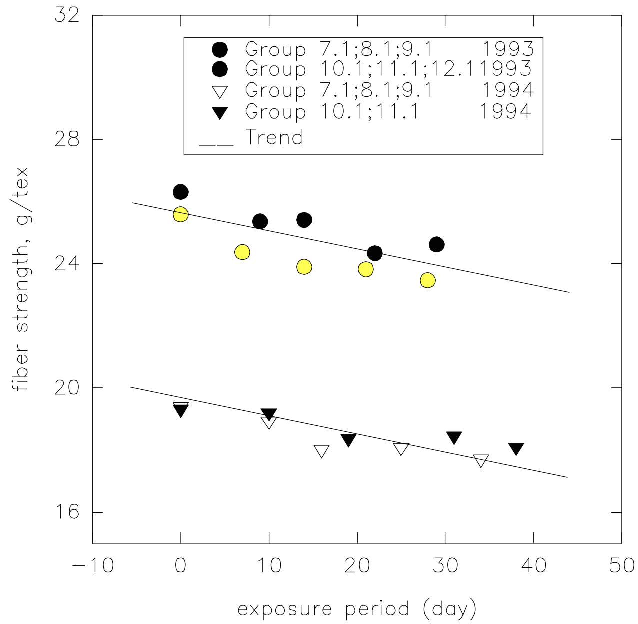


Figure 3. Fiber strength values vs opened boll exposure period.

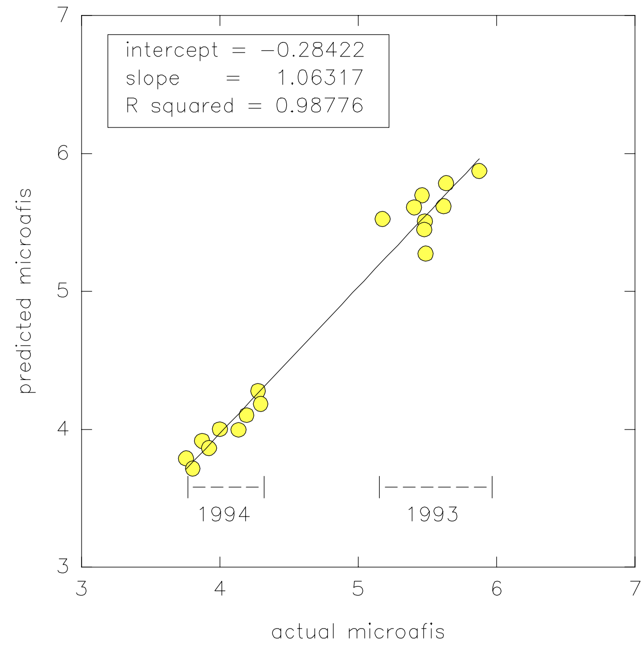


Figure 5. Predicted and actual microafis values when harvest was delayed.

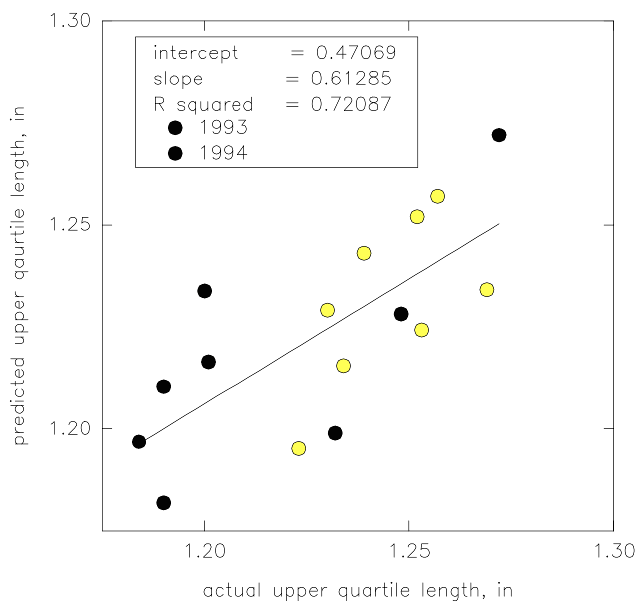


Figure 4. Predicted and actual upper quartile length when harvest was delayed.

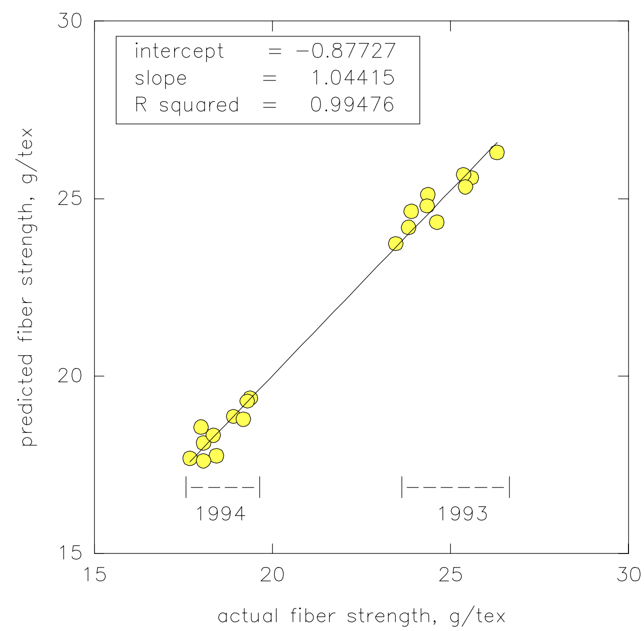


Figure 6. Predicted and actual fiber strength values when harvest was delayed.