Rapid Sampling System for Determination of Cotton Fiber Quality Spatial Variability

G. F. Sassenrath, E. R. Adams, J. R. Williford

Abstract. The introduction of accurate, reliable cotton yield monitors has increased the value of spatial information pertaining to cotton growth and yield potential, and has contributed to the development and incorporation of site-specific methodologies into cotton production systems. While knowledge of the spatial variability of cotton yield is important for developing profitable management strategies, cotton quality also contributes to the net return. Cotton fiber is graded for several properties, including physiological maturity. The price of the cotton is then derived from the measured fiber quality. Variability in cotton yield contributes substantially to differences in profitability from various regions within production fields. Variability in fiber quality parameters will contribute additional alterations in the profitability of field regions. Currently, the determination of spatial patterns of fiber quality is performed by hand—harvesting areas of research or production fields. While this provides some measure of the degree and extent of variability in fiber properties, hand harvesting is tedious, time consuming, and error prone. Moreover, hand-harvested cotton displays distinct differences in fiber properties from that harvested mechanically. The time and labor commitment to adequately sample a large production field makes hand harvesting untenable for rapid and accurate determination of spatial patterns of fiber quality. Our research examines the spatial variability of fiber quality and quantity, with an end to delineating the underlying parameters contributing to that variability. To adequately address the variability of fiber production, we needed an accurate, rapid method of spatially sampling seed cotton for determination of lint properties. Moreover, to assure similarity between our measures of cotton fiber properties and those received by the producer or the gin, we needed a method of sampling the cotton after it had been mechanically harvested. We developed a sampling system that attaches to the transfer chute of the cotton harvester. The sampling system diverts the harvested cotton from the picker basket to a small sampling bag, allowing rapid subsampling of the harvested cotton in a spatially registered location. The sampling system has been tested for two harvest seasons, and found to be a reasonable method to measure the spatial variability of cotton fiber.

Keywords. Cotton, Harvesting, Spatial variability, Cotton fiber quality, Geospatial sampling.

Knowledge of crop spatial variability contributes to an understanding of the profitability of each variant area within a production field and aids in the design of profitable site-specific management strategies. Inputs can be targeted to anticipated yield, thus optimizing the return on investment, conserving resources, and minimizing any negative environmental impact. In cotton (Gossypium sps.), the price paid to producers is directly determined from the measured quality of the cotton lint (National Cotton Council, 1992). Because higher fiber quality insures better spinning with fewer disruptions in processing (Deussen, 1992), the price paid for the cotton is directly dependent on the fiber properties and physiological maturity of the lint (Bradow et al., 1996; 1997). While cotton yield monitors are now available that measure the spatial variability of harvested yield (Wilkinson et al., 2001; Sassenrath—Cole et al., 1999), there is no adequate method for determining spatial differences in fiber quality. Spatial variance of fiber properties will impact the value of the harvested cotton. Without spatially registered information on fiber properties, the profitability of locations within the field are not known and hence reliable management zones based on profit margin cannot be delineated. Moreover, fiber properties may depend on field and environmental conditions in a manner different from that of yield components. Knowledge of the spatial variability of fiber properties will allow us to determine the impact of deleterious fiber properties on profitability and the correlation of field and environmental conditions on fiber development. This knowledge can lead to improved management strategies to minimize or control the development of inferior fiber properties. By knowing the spatial profitability, producers will be better able to delineate management zones based on profit potential and develop realistic management scenarios for cotton production, managing for both fiber properties and yield.

To date, studies examining spatial variability of fiber quality have relied on harvesting the cotton lint by hand (Johnson et al., 1999, 2002). While this gives a reasonable
estimate of the extent and range of fiber variability, it introduces error in the measured fiber properties. Hand-harvested cotton can have different properties than machine-harvested cotton (Calhoun et al., 1996). Moreover, while hand-harvesting cotton is reasonable for small plot sizes, the labor and time required make it not amenable for a production setting. Differences in the ginning process also contribute to changes in fiber properties (Williford et al., 1986; Anthony and Bragg, 1987). The small gins commonly used by researchers do not have cleaners such as are used in production gins. Cleaning the lint removes leaves and trash, which increases the lint value, but also shortens the fibers due to the additional processing, lowering the lint quality and price (Williford et al., 1986). The different impacts of the harvesting and ginning methods on the final fiber quality further complicate comparisons between cotton fiber properties obtained from production-level harvesting and ginning and research-level methods.

Our previous research examining the spatial variability of fiber properties relied on hand sampling cotton from the picker chute (Sassenrath—Cole et al., 1998; 2001). While this sampling method provided information on the spatial patterns of fiber quality on large production fields, it was dangerous for the person performing the fiber sampling and gave inconsistent samples. We needed a more reliable, consistent method of sampling cotton fiber as it was mechanically harvested.

Our objective in this research was the development of a sampling system that would safely and accurately remove a portion of the cotton during mechanical harvest for determination of fiber properties. The research results presented here describe the sampling system built for a commercial cotton harvester that diverts cotton from the chute as it is being transferred from the picking unit to the basket. The cotton sample is then ginned and analyzed for various fiber properties. The sampling system spatially registers the harvested sample for development of spatial variability maps of fiber properties within production fields.

**MATERIALS AND METHODS**

**COTTON PRODUCTION**

Cotton was planted in 1-m wide rows in a 4.1-ha research field and a 5.7-ha production field. Standard agronomic recommendations for weed and insect control, fertilization and cultivation were followed. The cotton was defoliated near 60% open boll. Harvesting was performed with a two-row Case IH 2022 mechanical cotton picker (Case IH, Racine, Wis.) equipped with a cotton yield monitor (PF 3000, AgLender, Ames, Iowa) and the sampling system described below.

**SAMPLER DESIGN**

The sampling system was designed and attached to the right outer chute of the cotton picker. This chute received cotton from the outermost drum, which picked cotton from the right side of the right row of cotton. After the cotton was removed from the spindles by the doffers, it was forced up through the four chutes into the picker basket by the forced air blower system. Each of the four chutes of the two-row picker had a cotton flow sensor for yield monitoring.

The sampler was designed to momentarily divert cotton from the picker transfer chute to a small sampling station where a cotton sample was collected for later analysis. The diversion mechanism was mounted to the chute extension above the bend, 49.5 cm below the basket and 53.3 cm above the upper chute joint (fig. 1). This was sufficiently high as to not interfere with the yield sensors or safety sensors of the picker. The diversion mechanism was the full width of the chute (23.5 cm), ensuring a representative sample was removed from the cotton stream. The diversion mechanism consisted of an elbow attached to the duct with a paddle gate that diverted the cotton into the sampler chute (fig. 2). The paddle gate (fig. 3) was constructed of 12-gauge sheet metal welded to a pivot rod and mounted to a pillow block-type bearing (fig. 4). This assembly was attached to the angle iron frame mounted to the front of the picker transfer chute. The lever attached to the gate with a collar and set screw. In the closed position, the back section of the gate lay against the inside top face of the picker chute and the front section of the gate closed the sampling chute. When the lever was put into the open position, the front of the gate swung back, opening the sampling chute. The back portion of the gate swung

**Figure 1. Cotton sampling system installed on commercial cotton picker.**

**Figure 2. Close-up of top portion of sampling chute attached to cotton chute.**
forward 57.5° to partially block the picker chute and force a portion of the cotton into the sampling chute. Because of the decreased flow when the sampling gate was opened, a wedge was installed in the lower edge at the top of the picker chute to divert the cotton upwards and into the basket (fig. 3). This addition was necessary to prevent cotton from falling out of the picker between the basket and the chute when the gate was opened during the sampling operation.

The elbow of the diversion mechanism was constructed of 16-gauge steel, welded onto an angle iron frame that was mounted to the front of the picker transfer chute with 8-mm carriage head bolts (fig. 2). The sampling duct, made from 22-gauge sheet metal, was attached to the outer edge of the elbow (figs. 2, 3, and 4). The duct led to a collared collection basket, to which were attached 45.7-cm² mesh sacks for collecting the cotton sample (figs. 5 and 6). A lever was machined from a 10-mm tube with a clevis attached at each end and positioned from the collection basket to the top of the sampling chute. The lever was attached to the gate and operated its opening and closing. A machined handle was attached to a connecting rod at the back of the collection basket and attached to the bottom of the lever. The movement of the handle initiated sampling (figs. 5 and 6) and closed the gate at sampling completion.

A platform was built around the cab of the picker to allow a second person to operate the sampling chute, collect the cotton samples, and ride safely (fig. 1). An operator’s seat was mounted to the platform and equipped with a seat belt. The sampling duct ended with a collared chamber that held the 45.7- × 45.7-cm mesh sack for sample collection. The sacks could be changed quickly as the picker moved through the field to sample different regions of the field. The filled mesh bags were tagged and put into larger cotton sacks for later ginning and determination of fiber properties.

SAMPLE COLLECTION AND SPATIAL REGISTRY

The cotton samples were ginned with a 10-saw research gin (Eagle Gin Co., Memphis, Tenn.), which required a minimum sample size of approximately 300 g of seed cotton. The sampling interval necessary to collect this minimum sample was calculated to be around 10 s, given the length of row that the picker would cover in a given amount of time traveling at a near constant rate of speed (3.2 km/h). An additional 10 s was needed to remove the sample bag and replace it with an empty bag for the next sample. From these estimates, the total sampling interval was set at 20 s, with the
The cotton picker speed was calibrated and maintained near 3.2 km/h during the fiber sampling operations. The typical picking speed for this type of picker is closer to 6.4 km/h. In order to allow sufficient time for sample collection and bag replacement as described above, the sampling speed was reduced. This decrease in picking speed during the test may have affected picking efficiency. Slight changes in field conditions, such as rains or heavy weed infestation, would alter the rate of picking. The cotton yield was measured continuously with an AgLeader cotton yield monitor. The yield monitor was calibrated by weighing each load of cotton picked and correcting the weight recorded by the yield monitor with the measured weight.

After ginning the harvested cotton on the 10-saw research gin, the cotton lint was classified at the USDA-AMS grading office in Dumas, Arkansas. Measurements were: color, staple, micronaire, extraneous matter, strength, HVI color, color Rd, color +R, leaf, hvi trash, length, and uniformity. Of these measurements, the color, staple, leaf, micronaire, extraneous matter, strength, and uniformity were used to determine the price of the cotton (USDA Agricultural Marketing Service, 2002).

The geographic information system (ArcView 3.2 with Spatial Analyst, ESRI, Redlands, Calif.) was used to visualize maps of the fiber parameters and cotton yield.

**RESULTS**

With the sampling apparatus attached, the air speed in the cotton chute was reduced more than 30% from that measured in the unrestricted cotton chute (table 1), but it still allowed sufficient lift to prevent clogging during harvest. The smaller size of the sampling chute resulted in a greater velocity of air flowing through it than through the standard cotton chute with the sampling chute installed. This increased air velocity ensured the cotton sample was completely and rapidly transferred to the sampling bag. After the sample was taken and the gate closed, the continued air flow from the picker transfer chute through the partially closed sampling chute removed any additional cotton that remained in the sampling chute, thereby preventing contamination of cotton from one sampling region to the next. Because of the reduced velocity...
Table 1. Air speed and flow in the picker and sampling chutes.

<table>
<thead>
<tr>
<th>Chute</th>
<th>Average Air Speed ±s.d. (m/s)</th>
<th>Average Air Flow ±s.d. (m³/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sampling chute</td>
<td>27.4 ± 2.23</td>
<td>0.58 ± 0.047</td>
</tr>
<tr>
<td>Standard cotton chute with</td>
<td>22.2 ± 2.26</td>
<td>1.22 ± 0.124</td>
</tr>
<tr>
<td>sampling chute installed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard cotton chute</td>
<td>34.8 ± 2.64</td>
<td>1.91 ± 0.145</td>
</tr>
</tbody>
</table>

through the cotton chute, it was necessary to insert a wedge-shaped airflow diverter at the lower edge of the picker chute to lift the cotton into the picker basket (fig. 3). This wedge directed the cotton into the picker basket and prevented cotton from falling out between the chute and basket.

During the preliminary tests with the sampler, the gate did not block a sufficient portion of the chute to direct a large enough cotton sample to the sampling bags in the brief time allotted for sample collection. To correct this, the back portion of the gate was elongated to block more of the cotton chute. If too much of the cotton chute was blocked by the gate, the cotton would rapidly build up in the chute, clogging the entire chute. For this reason, the entire stream of cotton could not be diverted to the sampler. By having a portion of the flow continue through the cotton chute, this problem was circumvented and the chute never became blocked with cotton. The optimal gate depth was found to cover all but 2.54 cm of the picker chute. This allowed sufficient diversion of the cotton to rapidly fill the sampling bag, yet allowed adequate air flow through the picker chute to avoid clogging.

For the optimal gate clearance (2.54 cm), an adequate sample size could be collected in less than 10 s for all but the lowest yielding areas. Having the gate open for a 10-s sampling collection would allow 10 s for changing the sampling sack, keeping the total sampling interval at 20 s. At some locations, problems arose from either too small a sample (low cotton yield) or human error, and the sample was not captured in this timeframe (seen as missing data points in fig. 9).

The approximate position of each sampling location was estimated from the beginning and ending latitude and longitude points as described above. This method is an approximation to the actual geographical position of each sample and was an acceptable estimate for sampler testing. Future refinements of the sampling system to achieve greater accuracy in the determination of sampling position are discussed below.

Tests with the sampling system document the extent of spatial variability in fiber properties (fig. 8). In this example, the micronaire is seen to vary widely across the 5.7-ha production field. In this sample run, four of the 180 sampling bags yielded fiber samples that were too small to be ginned and classified (presented as grey mottled squares, fig. 8). The summation of all fiber qualities was used to determine the value of the cotton, plotted as the total discount or premium of each sample (fig. 9). The harvested cotton ranged in value from a $0.06/lb premium to greater than $0.30/lb discount.

The spatial patterns of fiber properties (fig. 8) and fiber value (fig. 9) make site-specific management for fiber properties tenable. The information on cotton value can be linked with the yield and management input costs to determine profit margin, from which management zones can be delineated based on profit potential.

![Figure 8. Variability of micronaire in a 5.7-ha production cotton field. Grey mottled squares indicate areas of missing data.](image)

![Figure 9. Variability of lint discount ($/kg) applied to harvested lint based on fiber classification. White blocks represent lint with a slight premium.](image)

**CONCLUSION**

Precision management systems rely on knowledge of inherent field variability to correct problems and match inputs with potential profits. The fiber sampling system allows determination of variance in fiber properties. Management inputs can then be designed for the following growing season to ameliorate the conditions which led to the suboptimal properties. A differential harvest, in which cotton is harvested according to its fiber properties, has been tried by several researchers, including ourselves. Although an interesting concept, it is not amenable to a large-scale production system. More appropriately, the additional information on fiber properties could be used to develop ginning recommendations to improve the quality of the cotton lint (McAlister, 2001) and to design a marketing strategy for the cotton lint. Also, the spatially contiguous regions of fiber...
properties and lint value indicate the potential for developing
management strategies to improve fiber quality.

The sampling system worked well for rapidly and
consistently sampling fiber from a cotton picker. An
additional consideration in designing the sampling system is
that all internal surfaces be as smooth as possible and free
from rough or sharp edges that would snag the cotton,
resulting in contamination of cotton between sampling areas
and potentially clogging the chute. Moreover, for safety
considerations, the gate should move smoothly, preventing
any sparks that could ignite the cotton.

Future advances are being designed to allow increased
accuracy and greater ease of sample collection. Potential
modifications to the sampling system that are being explored
include development of an automatic gate control triggered
by geographical position and switching gate control to have
two collection bags mounted allowing improved sampling
time between samples for near-continuous sampling. Continuous
sampling would allow picker speeds to remain closer to
optimal (~6.4 k/h).

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