IDENTIFICATION AND QUANTIFICATION OF COTTON YIELD MONITOR ERRORS

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Abstract

A Cotton Yield Monitor is a valuable tool for collecting yield map data and making precision farming decisions on a production scale. Researchers have shown an interest in using cotton yield monitors rather than a weighing boll buggy or other weighing mechanism to collect data from production scale variety trials. This will simplify and increase efficiency of harvesting large plots. However, current recommendations suggest that the cotton yield monitor should be recalibrated between varieties. In a variety trial there can be numerous varieties within a field which would require numerous, time consuming calibrations that make data collection using a cotton yield monitor less appealing. Additionally, the new cotton picker designs that incorporate module building capabilities significantly increases the size of the smallest measureable unit of cotton; essentially, one module will be the smallest unit that can be weighed. This will make production scale research solely reliable on the cotton yield monitor once these pickers become popular among producers. This research has tested many environmental and varietal variables to identify potential sources of error in the Ag Leader cotton yield monitor. A total of 106 loads were harvested and weighed (1842 lb average weight) in 2008 at the University of Tennessee Research and Education Center (REC) at Milan. Several recalibration techniques were applied to the data. Without recalibration the average absolute error was 7.2% and the third method of calibration had an average absolute error of 3.8%. Moisture and yield were shown to have a statistically significant effect on monitor error.

Introduction

Yield monitors are an important part of a precision agriculture program. The most common sensing technique used with cotton yield monitors is an optical sensor paired with a light emitter that measures the volumetric flow of cotton as it passes between these two devices. The accuracy as related to yield prediction error for the Ag Leader cotton yield monitor is less than ± 5% when current calibration procedures are implemented.

In a test by Wilkerson et al. (2002) the monitor produced promising results, but variety was shown to have an effect on error. Therefore, calibrations must be performed to maintain monitor accuracy when conditions or varieties change. The logistics of performing calibrations can be rather inconvenient and time consuming. Weighing boll buggies are expensive and are not available in large quantities. Using portable truck scales is another possibility but they can be cumbersome to set up and can have limited accuracy in field conditions. Taking a single load to a gin to weigh it on large truck scales would be extremely inefficient and cotton loss during transit could introduce additional error.

Researchers conducting field variety trials in cooperation with producers would like to use the yield monitor for variety comparisons due to the relative ease of data collection. The current standard of using a weighing boll buggy is suitable, but the new generation of harvesters with module building capabilities will present new issues for production scale variety trials. One module would be the smallest measureable unit of cotton and therefore would require a large area to produce one data point. This suggests that yield monitors will be vital for collecting data when using one of these pickers. Stewart et. al. (2008) and Robertson et. al. (2006), both suggest that the yield monitor is not suitable for collecting variety trial data from on farm tests. The overall objective of this research will further evaluate the systematic errors observed between selected varieties and develop a post processing technique to compensate for monitor errors between varieties.

Methods

Ten commercially available cotton varieties were planted at the REC at Milan in 2008. This study encompassed approximately 125 acres of cotton, and the majority of the field layouts were determined by other studies. Any portion of a field not being used by another researcher was stripped in two varieties. One of the fields was irrigated in an attempt to provide a higher range of yields.

Cotton was harvested in the fall at three different times (rain events occurred between each harvest period) using a Model 9976 John Deere four-row picker equipped with the Ag Leader Insight yield monitor (firmware 4.5.0.0) and CAN-bus sensors (firmware 1.5.0.0). A total of 106 loads were harvested and each load was weighed in a Crust Buster weighing boll buggy (±5 pound resolution). As each load was weighed the monitor weights and the buggy weights were recorded to calculate percent error. Error was defined as the difference between the boll buggy weight and the yield monitor reading. Based on the initial agreement between the monitor weight and the boll buggy weight, the calibration was not changed from the previous year. This same calibration was used on all loads harvested the remainder of the season. Different post-harvest calibration techniques were applied to the data for comparison and will be discussed later.

Five pound seed cotton samples were collected from each load to quantify the moisture content at harvest. Ten pound samples were collected for gin analysis. Care was taken to include cotton from multiple locations in the boll buggy so that samples were representative of the entire buggy load. Sampling times were stratified throughout a harvest period to capture potential diurnal effects from variability in seed cotton moisture at harvest. Moisture samples were sealed in plastic bags and taken to the laboratory where the gravimetric water content was determined using a drying oven at 105° C. Gin samples were placed in canvas bags and sent to a micro-gin to be processed for gin turnout percentage as well as quality characteristics (e.g., micron, strength, color, etc.) using a High Volume Instrument (HVI) machine.

The data was analyzed using Statistical Analysis Software (SAS). An r-squared variable selection test was utilized to consider all variables in all possible combinations and develop a model that would explain the most variability in the data. Variables evaluated were: time of day, area harvested, yield, moisture, gin turnout, spinning consistency index, micronaire, fiber maturity, fiber length, uniformity index, short fiber index, strength, elongation, reflectance, trash count, and trash area. Variables that had higher r-squared values were then analyzed using a stepwise regression to validate their significance.

A comparison of data collected using the yield monitor and weighing boll buggy was analyzed using Mixed Model analysis. Mean separation was used to analyze the mean yield as predicted by the yield monitor and as measured by the weighing boll buggy. Essentially, the two methods were compared to determine if the yield monitor would detect the same differences in yield that were measured by the weighing boll buggy. This is the ultimate test for the yield monitor in the sense that mean separations by yield are what researchers are trying to determine when conducting a yield trial.

Results

Monitor error was calculated by subtracting the weighing boll buggy weight (buggy weight) from the weight predicted by the monitor (predicted weight) and dividing by the buggy weight. The average absolute error for the entire season was 7.2%. There was also a slight linear relationship ($Pr > f = .0001$, $R^2 = .39$) in yield and monitor error. Three back-calibrations were performed in an attempt to remove impact of yield level. The first back-calibration was performed using a high yielding load, a low yielding load, and a mid-range yielding load. The second back-calibration used three loads from the first day of harvest. These two methods were used to calibrate the entire season's data. These calibrations simply shifted the data set and did not remove the relationship of error and yield. For the calibration method #3, each trip was individually calibrated using three loads from one variety. This reduced much of the relationship between yield and error ($R^2 = .13$), and gave the most accurate results. An additional adjustment was made to this calibration by adjusting all buggy weights to 10 percent moisture, further reducing monitor error. This adjustment was made to account for the variation in weight due to changing moisture content levels. A summary of the errors is displayed in Table 1.

Table 1. Summary of monitor prediction error by calibration for the entire season

Back-Calibration	Absolute Error	Root Mean Squared Error	Variance
None	7.2%	8.5%	0.24%
1	4.8%	5.7%	0.32%
2	5.9%	6.2%	0.35%
3	3.8%	4.6%	0.21%
3 Adjusted	3.3%	3.9%	0.15%

Tukey's mean separation test was performed to determine if yields differed by variety identically for each method of measurement (buggy and predicted). The lint yield was calculated utilizing the gin turnout data from the samples. The yield maps were analyzed using GIS software and only the points within the field boundaries were summed to determine the amount of cotton picked for each load. Mean separation letter groupings show how the results of a variety trial would have changed for each method of measurement (Table 2.).

Table 2. Variety Mean Separation by Variety Using Tukey (α = .05)

Variety	Predicted Yield (cal. 3)	Letter Group	Buggy Yield	Letter Group	Buggy Yield Moisture Adjusted	Letter Group
A	1265.4	a	1291.7	a	1329.8	a
B	1173.7	a	1119.8	ab	1148.9	ab
C	1028.9	ab	1113.2	abc	1089.2	abc
D	981.9	b	996.6	bc	928.7	bc
E	990.5	b	991.2	bc	1002.7	bc
F	950.5	b	960.9	bc	961.9	bc
G	914.5	b	924.9	bc	911.4	bc
H	927.0	b	896.7	bc	923.1	bc
I	879.7	b	880.8	c	896.1	c
J	860.9	b	855.6	c	865.2	c

Calibration technique #3 was analyzed using the variable selection technique. A few of the variables measured showed promising results. These variables (yield, moisture content, short fiber index, elongation, and color) were analyzed in a stepwise regression to validate the model's significance. The models and their R^2 values are presented in Table 3. The goal is to use a model similar to the following as a post-processing model for yield data.

Table 3. Most significant models from variable selection technique

Model	R^2
Moisture	0.28
Moisture + yield	0.48
Moisture + yield + short fiber index	0.57
Moisture + yield + short fiber index + color	0.60
Moisture + yield + short fiber index + color + Elongation	0.63

Summary

The monitor had an absolute error of 3.8% when using calibration technique #3 where three calibration loads were selected from each harvest period. The relationship between monitor error and yield suggests that calibration adjustments could be made to the yield monitoring system. This would be very beneficial in the area of variety trials where determining differences in yield are of interest. Currently the mean separation by the two techniques only differs in respect to variety B. With this in mind, the values from the regression analysis show promise for a post processing model that will allow varieties to be compared with an AgLeader cotton yield monitor. Forty-eight percent of the variation between the cotton yield monitor and the boll buggy can be explained by moisture and yield.

Future research will examine the data within each of the three harvest events (i.e. each calibration) with respect to the variables mentioned in Table 3. Variety difference will be evaluated by separating the varieties by location to compare them within a field rather than across the entire farm. Results from this study agree with Robertson et. al. (2006) and Stewart et. al. (2008) that the cotton yield monitor (alone) lacks the accurate necessary for on-farm variety trials. However, with the promising dataset from 2008 and further evaluation, a simple model may be developed that will allow researchers to take full advantage of yield monitoring technology.

References

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