Variety Effects on Cotton Yield Monitor Calibration

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Abstract. *While modern grain yield monitors are able to harvest variety and hybrid trials without imposing bias, cotton yield monitors are affected by varietal properties. With planters capable of site-specific planting of multiple varieties, it is essential to better understand cotton yield monitor calibration. Large-plot field experiments were conducted with two southeast Missouri cotton producers to compare yield monitor-estimated weights and observed weights in replicated variety trials. Two replications of multiple varieties were planted in 12-row plots with 0.97 m row spacing. Plots were harvested with a module-building spindle picker equipped with a yield monitor. A separate module was built for each plot and weighed. Yield monitor data were used to calculate an estimated weight for each module. Significant differences in seed cotton yields were detected between the observed (weighed modules) and estimated (yield monitor) values. In addition to a significant variety main effect, a significant location by variety interaction was present in the error, both in terms of yield (absolute) and as a percentage of the observed yield (relative). Some HVI properties were significantly correlated with the absolute and relative error. Data from additional site-years will be analyzed and other factors will be investigated to try and achieve a better understanding of the factors affecting cotton yield monitor calibration.*

Keywords. *Cotton, harvest, on-farm research, precision agriculture, variety trials, yield monitor*

Introduction

Public and private research and demonstration projects are important for keeping agricultural producers competitive. For precision agriculture studies it is often necessary to work with farmer cooperators to have large enough plot areas to incorporate sufficient variability. Modern grain yield monitors do not impose a significant variety/hybrid-related bias and that greatly reduces the time and labor required compared to weighing the yield from each plot. This has allowed more large-scale, on-farm studies to be conducted using farmers' equipment, better fitting their schedules and eliminating the need to move separate harvest equipment for the study.

Cotton (Gossypium hirsutum L.) is a major crop in the southern U.S. and cotton producers were some of the earliest adopters of precision agriculture methods employing site specific management. However, many reports have shown that cotton yield monitors are sufficiently affected by varietal properties to alter the inferences made from data with multiple varieties. While grain yield monitors base their measurements on contact between the grain and the sensor, seed cotton is transported in an air stream from the header to the basket. Yield is inferred, based on how much material is included in the air stream (e.g., how much light is diminished between an emitter on one side of the chute and a receiver on the opposite side).

Perry and Vellidis (2005) discussed the differences between the error associated with individual loads and the average error for all loads in a field. They reported that field error is usually smaller because it averages out the errors associated with individual loads. However, for research, the individual loads (plots) are important for the desired comparisons. Rains et al. (2002) investigated sources of error in cotton yield monitor data and concluded the two primary sources in their study were use of multiple weigh wagons for comparison and multiple varieties. Cordell et al. (2005) observed significant differences among errors associated with six varieties, with differences ranging from -6.6% to 16.5%. Markinos et al. (2005) observed a similar varietal effect in Greece, with different calibration factors for different varieties. Taylor et al. (2014) compared observed weights to yield monitor predictions over six site-years and reported that errors were significantly different by variety for five of the six site-years. They also reported that while yield monitor error was related to lint turnout data for some site-years, they didn't find a consistent method to adjust for error. Vories et al. (2017) compared six varieties and observed calibration errors of the estimated (yield monitor) yield value relative to the observed (weighed) that ranged from -10.36% to 7.98% with a field average of 4.6%. Average yields based on the observed weights and yield monitor estimates varied somewhat, with the largest error being 5%. However, while the numerical ranking of the varieties varied with the two methods, the statistical grouping was the same for both.

After seed cotton is harvested, the gin separates the lint from the other materials, primarily seed. Differences in turnout, the ratio of lint cotton to seed cotton, are affected by the seed number and size and may correlate with some of the observed varietal differences but Taylor et al. (2014) did not see a consistent response. Since cotton prices are dependent on quality, lint cotton is subjected to high volume instrument (HVI) testing. Micronaire, which is related to the fineness of the lint, and fiber length may affect how the seed cotton interacts with the yield monitor sensors. Leaf grade is a measure of leaf content in cotton and the leaf material would have different properties than seed cotton. Reflectance (Rd) indicates how bright or dull a sample is, and yellowness (+b) indicates the degree of pigmentation. Both can be affected by environmental conditions and other factors. However, cotton yield monitors measure seed cotton, which includes the seed, fiber, and any plant or other material attached to it. HVI measurements are made on the lint, after the seed was removed and some cleaning has taken place; therefore, the HVI values may be of limited use in describing differences in the seed cotton.

With planters capable of site-specific planting of multiple varieties, it is essential to understand the varietal effects on yield monitor calibration. Vories et al. (2017) reported on an AgLeader cotton yield monitor system; however, AgLeader no longer produces the system used in their study. Furthermore, the system installed on John Deere cotton spindle pickers uses microwave rather than optical sensors and may respond differently than the optical sensors. Given the high adoption rate of spindle pickers with on-board module building, replicated on-farm studies could soon become limited to a large enough scale to produce a module from each plot. Even then, the necessity of weighing each module causes the producer to have to slow down when they are usually going at their maximum capability. The objective of this study was to compare yield monitor-estimated weights from a module-building picker to observed weights in replicated variety trials and investigate factors that could relate to any observed varietal effect.

Methods and Materials

Large-plot field experiments were conducted in 2017 in conjunction with two southeast Missouri cotton producers. The study was part of a multi-state project supported by cotton producers through Cotton Incorporated. The two Missouri fields were located approximately 36 km apart in Stoddard and New Madrid Counties (Figure 1).

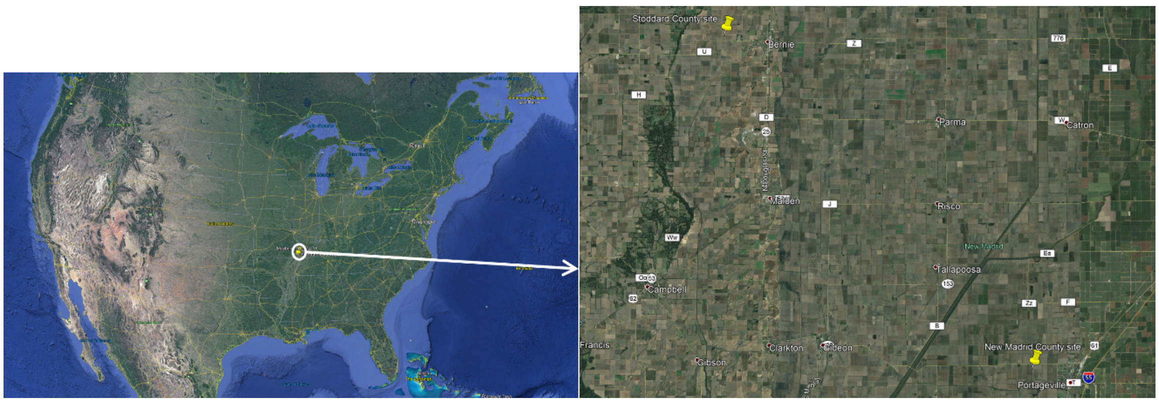

Figure 1. Study locations.

In both locations, the previous crop was cotton and furrow irrigation was used. Using the farmer's equipment, two replications of multiple varieties were planted in 12-row plots with 0.97 m row spacing. Although the New Madrid County location included twelve varieties, this report focused on the eight varieties common to both sites. The crop was managed by the producer and the research team was alerted when it was time for harvest. A separate module was produced from each plot and weighed with portable platform scales (Western Forage Systems, Marsing, ID), with the same set of scales used at both locations. A grab sample of seed cotton was collected from each module and processed at the University of Missouri Fisher Delta Research Center micro-gin for turnout determination and high volume instrument (HVI) fiber analyses. Table 1 contains additional information about the study locations.

Table 1. Study location information.

	Stoddard County	New Madrid County
Cooperator	4-M Farms	Rone Farm Partnership
Soil type	Fine sandy loam	Silt loam / silty clay loam
Planting date	8 May	16 May
Row length (m)	416	381
Harvest date	14 October	11 November
Harvest start time	10:07 AM CDT	12:28 PM CST
Harvest finish time	11:40 AM CDT	4:11 PM CST
Harvester	2011 John Deere 7760	2012 John Deere 7760

The John Deere 7760 cotton spindle pickers harvested six rows and had three microwave-based yield sensors. Yield monitor data from both fields was exported in shapefile format and provided to the research team. Using ArcGIS 10.4 for Desktop (Esri, Redlands, CA), the individual "WetMass" data points were adjusted for area and summed for each module. The systems were not calibrated separately for the studies; therefore, an adjustment was added to the estimated (yield monitor) yields such that the field average of the estimated and weighed modules was the same. The data were not cleaned to remove errors (Sudduth and Drummond, 2007) but no obvious errors were observed. Similarly, no extraneous points from outside the field boundary were contained in the data. Values were compared using SAS PROC GLM (SAS for Windows v.

9.4, SAS Institute Inc., Cary, NC). Mean separation for significant ($p < 0.05$) effects was conducted using Fisher's least significant difference (LSD). Correlations among the parameters were calculated with SAS PROC CORR.

Results and Discussion

When harvesting the first plot in Stoddard County, the picker was unable to harvest 12 complete rows before building a module. Therefore, all subsequent modules at that site contained the seed cotton from six rows. All modules from the New Madrid County site contained the seed cotton from twelve rows.

Figure 1 contains the estimated (yield monitor) versus observed (scales) seed cotton yields and a trendline for the data. For a perfect fit, the slope of the trendline would be 1.0, the intercept would be 0, and the coefficient of determination (R^2) would be 1.0. While an R^2 of 0.79 is considered good in many applications, the magnitude of the residuals in this case indicated that more investigation was needed.

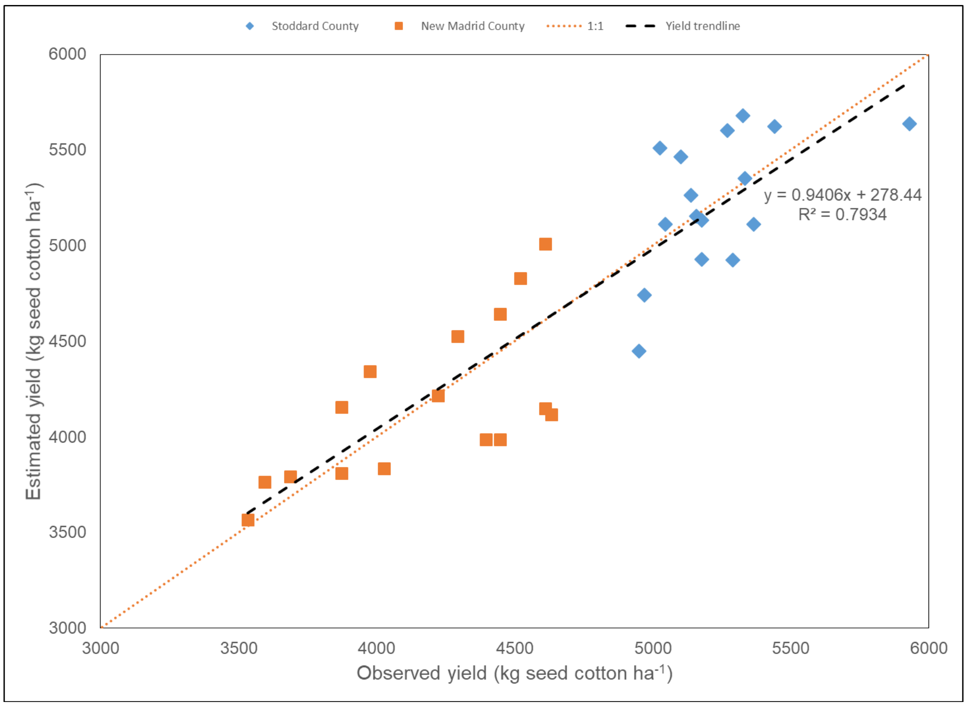

Figure 1. Observed and estimated seed cotton yields in study.

The calibration error of the estimated values relative to the observed averaged -0.1% and ranged from -9.6% to 11.1%. There was little difference between the locations, with errors averaging 0.0% and ranging from -9.6% to 10.1% in Stoddard County and averaging -0.2% and ranging from -9.3% to 11.1% in New Madrid County (Figure 2).

Average yields based on the observed weights varied from 5478 kg seed cotton ha^{-1} (DG 3109 B2XF in Stoddard County) to 3702 kg seed cotton ha^{-1} (NG 3522 B2XF in New Madrid County) (Table 2). While the location main effect was significant for observed yield, with higher yields in Stoddard County, neither the variety main effect nor the location by variety interaction was significant. Average yields based on the weights estimated by the yield monitor varied from 5639 kg seed cotton ha^{-1} (DP 1614 B2XF in Stoddard County) to 3689 kg seed cotton ha^{-1} (NG 3522 B2XF in New Madrid County) (Table 2). The location main effect was significant for estimated yield, as well as the variety main effect and the location by variety interaction. Vories et al. (2017) reported that the numerical ranking between the observed and estimated seed cotton yields varied in their study, but the statistical grouping was the same for both. In this study, however, both the numerical ranking and the statistical grouping were different.

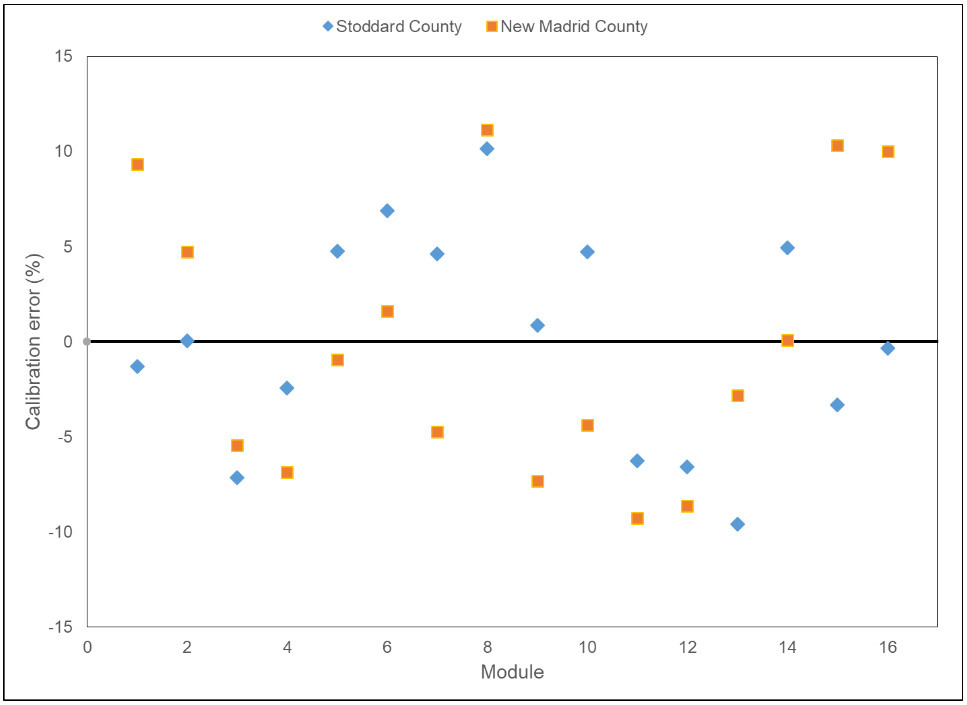

Figure 2. Calibration errors of the estimated (yield monitor) value relative to the observed (weighed).

The absolute calibration error, or the difference between the observed and estimated yield, ranged from -384 kg seed cotton ha^{-1} (DP 1614 B2XF in New Madrid County) to 460 kg seed cotton ha^{-1} (DG 3385 B2XF in New Madrid County). At both locations, the range in absolute error (705 kg seed cotton ha^{-1} and 844 kg seed cotton ha^{-1} for Stoddard and New Madrid Counties, respectively) was similar to the range in observed yield (518 kg seed cotton ha^{-1} and 827 kg seed cotton ha^{-1} for Stoddard and New Madrid Counties, respectively). Relative to the observed yield, the error ranged from -9.0% (DP 1614 B2XF in New Madrid County) to 10.2% (DG 3385 B2XF in New Madrid County). Unlike yield, the location main effect was not significant for absolute or relative error; however, the variety main effect and the location by variety interactions were significant for both.

Turnout and the HVI properties micronaire, length, uniformity, strength, elongation, reflectance, yellowness, and leaf grade were all measured for each module. These properties were included in a correlation analysis with both absolute (kg seed cotton ha^{-1}) and relative (%) error to look for ways to identify the source of and possibly account for the error. Reflectance ($r = 0.50$, $p = 0.004$) and leaf grade ($r = -0.41$, $p = 0.004$) were significantly correlated with absolute error. Length ($r = -0.39$, $p = 0.032$), reflectance ($r = 0.49$, $p = 0.005$), and leaf grade ($r = -0.44$, $p = 0.014$) were significantly correlated with the relative error. Although Vories et al. (2017) reported a significant correlation between observed yield and relative error, none was observed in this study. They also observed a correlation with harvest load number that they thought might have been related to time of harvest and the associated moisture in the air. However, both of these studies were harvested over a fairly short period of time (Table 1).

The agreement between observed and estimated cotton yields must be improved to adequately advance the application of precision agriculture, particularly the site specific planting of multiple varieties. The results of this study support the findings of earlier research and a better understanding of the variety-related and other possible factors affecting cotton yield monitors is needed to allow more on-farm studies and improve site specific recommendations for cotton. While correlations were observed between calibration errors and some of the HVI measurements, HVI is only testing one component (lint) of the total material passing the yield monitor sensors. Data from additional site-years will be analyzed and other factors will be investigated to look for factors affecting yield monitor errors.

Table 2. Observed and estimated seed cotton yield and error of estimated yield.

Variety	Stoddard County	New Madrid County	Variety overall mean
		Observed yield[a] (kg seed cotton ha^{-1})	
DG 3385 B2XF	5387	4529	4958 a[b]
DP 1614 B2XF	5299	4293	4796 a
CG 3527 B2XF	5120	4406	4763 a
DG 3109 B2XF	5478	3954	4716 a
DP 1518 B2XF	5271	4159	4715 a
CG 3475 B2XF	5102	4211	4656 a
NG 4601 B2XF	4960	4113	4537 a
NG 3522 B2XF	5233	3702	4468 a
Location mean[c]	5213 a	4171 b	
		Estimated yield[d] (kg seed cotton ha^{-1})	
DP 1614 B2XF	5639 a[e]	4677 a	5158 a
CG 3527 B2XF	5365 ab	4679 a	5022 a
DG 3109 B2XF	5573 a	4005 b	4789 b
DG 3385 B2XF	5487 a	4069 b	4778 b
DP 1518 B2XF	5122 abc	4399 a	4761 b
CG 3475 B2XF	5133 abc	3911 b	4522 c
NG 3522 B2XF	4927 c	3689 c	4308 cd
NG 4601 B2XF	4595 d	3941 bc	4268 d
Location mean	5230 a	4171 b	
		Absolute error[f] (kg seed cotton ha^{-1})	
DG 3385 B2XF	-100 cd	460 a	269 a
NG 4601 B2XF	365 a	172 ab	180 ab
DG 3109 B2XF	-95 cd	-50 bcd	160 ab
DP 1614 B2XF	-340d	-384 d	134 ab
DP 1518 B2XF	149 abc	-239 c	-45 bc
NG 3522 B2XF	306 ab	14 bc	-73 bc
CG 3527 B2XF	-244 d	-272 cd	-258 cd
CG 3475 B2XF	-32 bcd	300 ab	-362 d
Location mean	1 a	0 a	
		Relative error[g] (%)	
NG 4601 B2XF	7.37 a	3.19 abc	5.28 a
DG 3385 B2XF	-1.84 bcd	10.16 a	4.16 ab
CG 3475 B2XF	-0.63 abcd	7.02 ab	3.19 abc
NG 3522 B2XF	5.83 ab	0.32 bcd	3.08 abc
DP 1518 B2XF	2.79 abc	-5.85 d	-1.53 bcd
DG 3109 B2XF	-2.33 cd	-1.37 cde	-1.85 cd
CG 3527 B2XF	-4.78 cd	-6.16 de	-5.47 de
DP 1614 B2XF	-6.41 d	-8.97 e	-7.69 e
Location mean	0.00 a	-0.21 a	

[a] based on the module weight
[b] variety overall means followed by the same letter are not significantly different based on Fisher's LSD(0.05)
[c] Location means followed by the same letter are not significantly different based on Fisher's LSD(0.05)
[d] based on the adjusted yield monitor estimated weight
[e] variety means within a location followed by same letter are not significantly different based on Fisher's LSD(0.05)
[f] observed – estimated yield
[g] relative to the observed yield

Conclusions

This study addressed the impact of variety on cotton yield monitor calibration for John Deere cotton spindle pickers and investigated factors that could relate to the observed varietal effect.

- Significant differences in seed cotton yields were detected between the observed (weighed modules) and estimated (yield monitor) values.
- In addition to a significant variety main effect, a significant location by variety interaction was present in the error, both in terms of yield (absolute) and as a percentage of the observed yield (relative).
- The HVI properties reflectance and leaf grade were significantly correlated with the absolute error, while length, reflectance, and leaf grade were significantly correlated with the relative error.

Data from additional site-years will be analyzed and other factors will be investigated to try and achieve a better understanding of the factors affecting cotton yield monitor calibration and allow more on-farm studies to improve site specific recommendations for cotton.

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Mention of trade names or commercial products in this paper is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the United States Department of Agriculture.

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