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Testing of an Impact Plate Yield Monitor for Peanuts: Mounting Configurations and Air Pressure Correction

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Abstract. *A commercially available Ag Leader® impact plate grain yield monitor kit was adapted to be installed on an Amadas M2108 4-row pull type peanut combine to evaluate its accuracy in yield prediction for two different mounting configurations and to assess the benefits of providing yield prediction correction by sensing the pneumatic conveyance air pressure. For the two impact plate configurations, the yield monitor load sensor was mounted onto a curved bar rack installed at an elbow in the clean peanut conveying duct just prior to its entrance into the basket. In the first configuration, the bar rack was installed to float in the elbow section of the duct, mounted solely to the load sensor and not touching the duct on any sides. In the second configuration, the upper edge of the bar rack was hinged against the duct, allowing the impact of peanuts to impart a torque on the bar rack assembly. In the floating configuration, average absolute error of yield predictions from 17 loads was 12.7% and in the hinged configuration, average absolute error of yield predictions from 8 loads was 6.6%. Observations made during the study indicated that the hinged configuration was less likely to collect, or wedge, trash between the bar rack and the duct, which may explain its greater accuracy in yield predictions. Using the floating impact plate configuration, inclusion of fan air pressure as an additional independent variable in a multiple linear regression equation, load weight prediction errors were 9.8% across 9 loads, compared to 11.6% with impact plate sensing only across the same loads.*

Keywords. *Yield monitor, peanut, impact, precision agriculture, sensors.*

Introduction

Precision agriculture is becoming a staple in most row crop producers' management strategies. Producers are using variable rate application of inputs through zone management, and yield monitors to define and assess these zones. A survey conducted by Winstead et al. (2010) indicated yield monitoring to be second among precision agriculture technologies in terms of current use and intended future use. Yield monitors for grains and cotton allow the producer to make adjustments to their management strategy if their yield goals for certain zones were not met. Producers are already using zone management in peanuts but have no way of quantifying whether what they are doing is working or is not working; they have no report card. Development of an accurate, consistent yield monitor for peanuts will solve this problem.

Studies have shown that yield monitors can be used to quantify production. A study conducted by Thomas et al. (1999) investigated their Peanut Yield Monitoring System (PYMS) that included load cells mounted below the hopper basket of a peanut harvester. Further research (Durrence et al., 1999) evaluated the PYMS, which showed that the system was accurate in constructing load- and field-level data for the harvested crop. While the PYMS demonstrated good ability to predict load and field weight, its in-load resolution was poor relative to yield monitoring technologies available for grains and cotton. The technology was patented but has not been commercialized. Several studies have been conducted on the use of an Ag Leader® cotton yield monitoring system for peanut (Rains et al., 2005; Porter et al., 2012; Porter et al., 2013), although this product is no longer available for purchase. This project is an expansion of research that began in 2012 at Clemson University on use of a grain yield monitor for peanut (Fravel et al., 2013a).

Moisture modules are typically used in grain yield monitors to convert yield predictions to a dry weight basis. Analyses conducted by Porter et al. (2013) indicated that inclusion of moisture content in optical yield monitoring could reduce yield prediction error by approximately 30-50%. While some in-shell moisture meters for peanut have been developed (Kandala et al., 2008; Kandala et al., 2010; Trabelsi and Nelson, 2010), there are currently no commercially available technologies for incorporation to a peanut yield monitoring system. An investigation reported by Fravel (2013) used a handheld grain moisture meter for in-shell peanut and indicated an average absolute prediction error of 10% across 48 samples, or ±2% moisture content. As an alternative to moisture sensing in the project presented here, a pressure sensor was installed in the pneumatic conveying air stream to assess its ability to reduce yield prediction error of the impact sensor. In a positive pressure, dilute phase pneumatic conveying system, air pressure at the fan outlet can be correlated to solids mass flow rate and serves as an indication of the energy load on the conveying system (Mills, 2004).

Fravel et al. (2013) attributed some of the yield prediction error encountered during 2012 testing with lodging of foreign matter and vines at the impact plate due to the way the bar screen was mounted and also with the amount of vibration being generated by the older peanut combine used. Studies conducted here were focused on addressing and investigating these assumptions through use of a newer model combine and analysis of two different impact plate configurations: floating and hinged plate. In an effort to identify a method of further reducing yield prediction error, air pressure data was investigated as a multiple regressor, but was not available for the hinged plate configuration.

Specific objectives were an expansion of the impact plate yield monitor study described in Fravel et al. (2013). Research was conducted at the Clemson University Edisto Research and Education Center in 2013 to evaluate the effects on load weight prediction error as a function of impact plate mounting configuration and to quantify the ability of pneumatic conveying air pressure sensing to reduce load weight prediction error.

Materials and Methods

An Ag Leader® 4000201 (Ag Leader® Technology, Ames, Iowa) impact plate was mounted on an Amadas 2108 pull type peanut combine and an Ag Leader® Integra monitor was paired with this sensor. Installation and setup for this system was similar to that described in Fravel et al. (2013) and shown in figure 1a. Two configurations of the bar screen attached to the impact plate sensor were employed: one where the bar screen was allowed to float in its position with no hinge (fig. 1b) and one where the piano hinge position was moved to the downstream side of the airflow (fig. 1c), opposite that shown in figure 1a. In the configuration including the hinge, the bar screen was made to overlap on the outside of the duct on the upstream side of the airflow. The bar screen was not allowed to touch the sides of the duct in either configuration, providing 0.64 cm (0.25 in) or less clearance on all sides, except where the hinge was mounted. Also, the shaft speed sensor that was already installed on the peanut combine from the factory was used as input for the elevator shaft speed.

(a) (b) (c)

Figure 1. Impact sensor and bar screen placement at upper bend of clean peanut delivery chute of the harvester: (a) bar screen hinged on upstream edge (reproduced with permission from Fravel et al., 2013), (b) bar screen in floating configuration for part of 2013 harvest, and (c) bar screen hinged on downstream edge for part of 2013 harvest.

The air pressure sensor used was a model 1126 differential gas pressure sensor (Phidgets Inc., Calgary, Alberta, Canada) with a range of -25 to 25 kPa (-3.6 to 3.6 psi). One port on the pressure sensor was left open to the atmosphere and the other connected to a probe mounted in the top of the duct work halfway in between the damper for the clean air fan and the cross auger of the combine (fig. 2a). The probe ported to the sensor (fig. 2b) was inserted to the center of the duct with the open end perpendicular to the air stream to provide static pressure. Data acquisition of the analog signal from the air pressure sensor was conducted using a model 1018 interface kit (Phidgets Inc., Calgary, Alberta, Canada). Data acquisition software was developed in Visual Basic 2010 Express (Microsoft Corp., Redmond, Wash.); analog inputs were collected at a data rate of 10 Hz, logging the average of 10 readings each second. Spatial position was logged each second and provided by a model 1040 GPS (Phidgets Inc., Calgary, Alberta, Canada).

(a) (b)

Figure 2. Air pressure sensor probe position in the clean air duct: (a) probe, as installed on clean air duct between damper and cross auger and (b) probe, prior to installation in clean air duct.

Linear regression models were developed using the Analysis ToolPak Add-In for Microsoft Excel 14.0 (Microsoft Corp., Redmond, Wash.) with the sum of sensor readings (SSR) across every data point logged for each load as the independent variables and each corresponding load weight as the dependent variables. Because the AgLeader Integra data export does not provide raw sensor data, Impact plate sensor SSR for each load was calculated as the sum of the crop flow readings (lb/s) and fan pressure sensor SSR for each load was calculated as the sum of the air pressure readings (psi).

Testing for the impact plate and air flow sensor was done on Nix Farms and Bates Farms, and at Clemson University Edisto Research and Education Center, all of which are located in Barnwell County, South Carolina. Both runner type and virginia type peanuts were harvested during the 2013 season. The first half of the season the impact plate was in the floating configuration previously described and during the second half of the season in the hinged configuration. Each load harvested was weighed in a Pioneer dump cart fitted with scales.

Results and Discussion

Average absolute error in load weight prediction for the floating plate configuration was 11.6% when using a single variable linear regression as a function of impact plate SSR and 9.8% when using a multiple linear regression as a function of impact plate and air pressure SSRs. Plots of predicted load weight versus actual load weight across the same nine loads for these two models are provided in figure 3 with coefficients of determination of 0.53 and 0.55, respectively. For these data, inclusion of air pressure as a second regressor improved load weight prediction by 16%.

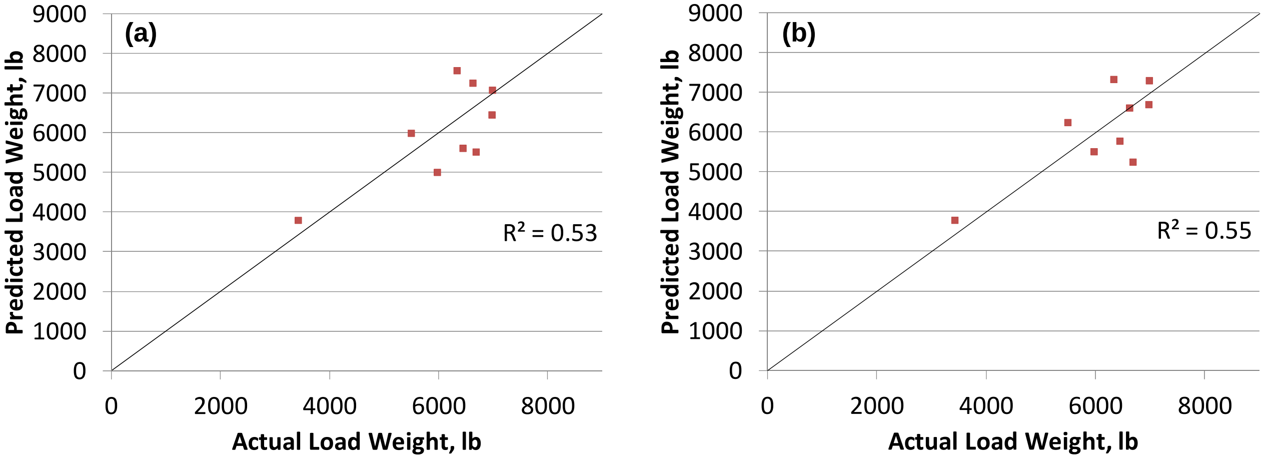

Figure 3. Predicted load weight vs. actual load weight for floating plate configuration: (a) for single variable linear regression as a function of impact plate SSR and (b) for multiple linear regression as a function of impact plate and air pressure SSRs.

Predicted load weight as a function of actual load weight across eight loads was substantially improved by changing to the hinged mounting configuration (fig. 4). In changing configuration from floating to hinged plate, the coefficient of determination was increased from 0.53 to 0.83 (a 57% improvement) and the average absolute error in load weight prediction was reduced from 11.6% to 6.6% (a 43% improvement). These improvements are consistent with field observations that periodic lodging of foreign and vine material between the clean peanut duct and impact plate was substantially reduced when using the hinged plate configuration. In the floating configuration, the majority of lodged material was observed to be at the downstream edge of the bar screen, where the hinge was placed for the hinged configuration. It should be noted that these loads were distinct from the loads used for the floating plate configuration and direct comparison therefore may not be valid.

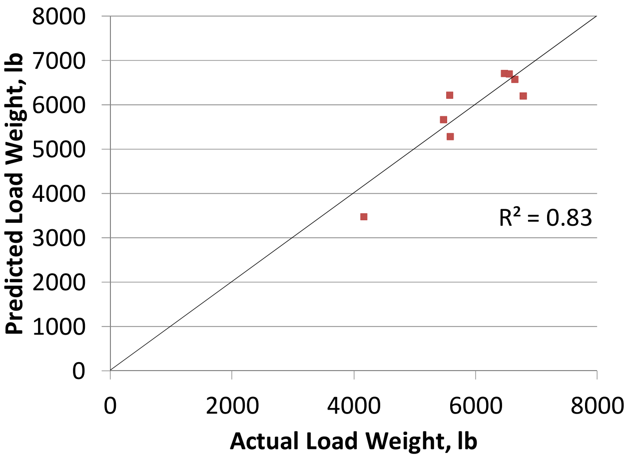

Figure 4. Predicted load weight vs. actual load weight for hinged plate configuration with a single variable linear regression as a function of impact plate SSR.

Comparisons of average absolute load weight prediction error across regression models for the two configurations and two regressors were performed in JMP Pro 10.0 (SAS Institute, Cary, N.C.) using one-way ANOVA and Fisher's LSD tests (α=0.05), the results of which are presented in table 1. As compared to floating configuration with impact plate SSR only as a regressor, inclusion of air pressure as a regressor and changing to the hinged configuration both resulted in a numerical reduction in load weight prediction error, although these differences were not statistically different at the α=0.05 level. For the single variable regression models using impact plate SSR, a statistically significant difference in load weight prediction error only existed between the floating and hinged configurations at or above the α=0.20 level.

Table 1. Average absolute load weight prediction error in error across regression models. Rows not connected by same letter are statistically different.

Configuration (Regressors)	Avg. Abs. Error		SD
Floating (Impact)	11.6%	a	5.6
Floating (Impact + Air Pressure)	9.8%	a	6.6
Hinged (Impact)	6.6%	a	5.3

An Ag Leader® through beam optical cotton sensor paired with an Ag Leader® InSight monitor was tested on the same loads for comparison reasons but the data is not presented in detail here for brevity. Setup and data analysis for the cotton sensor on the Amadas 2108 was the same as described in Fravel (2013). For the loads corresponding to the floating plate configuration, average absolute load weight prediction error of the cotton sensor was 7.8% with air pressure correction reducing the error to 5.6%. For the loads corresponding to the hinged plate configuration, average absolute load weight prediction error of the cotton sensor was 5.7%. Cotton sensor errors were not statistically different from each other (α=0.05) and they were generally not statistically different from impact sensor errors, the exception being that the lowest two cotton sensor errors (5.6 and 5.7%) were statistically different from the greatest impact sensor error (11.6%).

Conclusions

The results show that the downstream-hinged mounting of the impact sensor reduced the load weight prediction error as compared to the floating configuration used by Fravel et al. (2013). Based on observations, the improvement in error was likely attributable to reduction in lodging of plant material between the impact plate and the duct. Further testing is planned across multiple growers' machines to better quantify expected load weight prediction error across different operating conditions. Widening of the bar screen to comprise the full width of the clean peanut duct may contribute to further reductions in error.

While not statistically significant, the results also suggest that load weight prediction error can be reduced by using the clean air duct pressure to apply a correction to impact sensor data. One challenge in using the air pressure data is with incorporation to commercially available yield monitoring systems. Research in peanut yield monitoring at Clemson University has been focused on identification of a commercially available platform that can be adapted for use in peanut. This approach has been employed because the researchers involved believe it to be the most viable option to introducing a commercially available peanut yield monitor to the market. Emphasis was placed here on the impact plate system because the Ag Leader cotton yield monitor is no longer supported or available.

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