6-1-2015

# Comparing Yield Monitors with Weigh Wagons for On-farm Corn Hybrid Evaluation

Bjorn P. Nelson
*Iowa State University*

Roger Wesley Elmore
*University of Nebraska-Lincoln*, roger.elmore@unl.edu

Andrew W. Lenssen
*Iowa State University*, alenssen@iastate.edu

Published October 16, 2015

RESEARCH

# Comparing Yield Monitors with Weigh Wagons for On-farm Corn Hybrid Evaluation

Bjorn P. Nelson, Roger W. Elmore, and Andrew W. Lenssen*


## Abstract

For many years, on-farm yield evaluations of corn (*Zea mays* L.) hybrids were done with weigh wagons, handheld moisture testers, and measuring wheels. Today, most combines have continuous flow yield and moisture sensors. Published research results comparing the accuracy of combine-mounted sensor systems with that of weigh wagons are limited for on-farm corn hybrid evaluation. This study examined the accuracy of combine-mounted yield sensors with traditional weigh wagon methodology in on-farm corn hybrid strip trials. Data from combine-mounted sensors for plot weight, moisture percentage, and yield were compared with weigh wagon weight, handheld moisture testers, and calculated yield in six nonreplicated strip trials in 2012, 2013, and 2014 in east-central South Dakota. A total of 195 total entries were compared. Pearson correlation coefficients and linear regressions for weight, moisture percentage, and yield were calculated for each environment and for all environments combined. The Pearson correlation coefficients across all environments were 0.998 for weight of grain in pounds, 0.928 for grain moisture content percentage, and 0.983 for yield in bushels per acre corrected for moisture content. The probability of nonsignificance for weight, moisture percentage, and yield was $P < 0.0001$. Linear regression models predicting combine-mounted sensor of sample weight, sample moisture, and yield with the traditional system were significant at $P < 0.0001$ for all three measurements. Yield monitors can be used successfully for on-farm hybrid evaluations, replacing traditional methods that use weigh wagons, measuring wheels, and handheld moisture testers.


Bjorn P. Nelson and Andrew W. Lenssen, Dep. of Agronomy, Iowa State Univ., Ames, IA 50011; Roger W. Elmore, Dep. of Agronomy and Horticulture, Univ. of Nebraska-Lincoln, Lincoln, NE 68583; formerly Dep. of Agronomy, Iowa State Univ., Ames, IA 50011.
Received 27 Feb. 2015. Accepted 1 June 2015.
*Corresponding author (alenssen@iastate.edu).

**Abbreviation:** GPS, global positioning system.

Published in Crop, Forage & Turfgrass Management
DOI: 10.2134/cftm2015.0135


## METHODS USED TO COMPARE CORN VARIETIES AND HYBRIDS

Evaluating corn performance has long been important, and methodologies used have changed over time. For centuries, seeds were handpicked based on appearance and kernels from the most attractive ears were planted the following year. As recently as the 1930s, open-pollinated corn was selected based on the appearance of the ears, with the biggest and best-looking ears saved to provide seed for planting the following year's crop (Reinhart and Ganzel, 2003) (Fig. 1a).

**Table A. Useful conversions.**

| To convert Column 1 to Column 2, multiply by | Column 1 Suggested Unit | Column 2 SI Unit |
|---|---|---|
| 0.405 | acre | hectare, ha |
| 0.914 | yard, yd | meter, m |
| 2.54 | inch | centimeter, cm ($10^{-2}$ m) |
| 62.71 | 56-lb bushel per acre, bu/acre | kilogram per hectare, kg/ha |
| 0.304 | foot, ft | meter, m |


Corn Breeding 101: A Lesson in Basic Corn Genetics. Tom Bechman September 2014.

Dekalb Area Agricultural Heritage Association, Inc.

Figure 1. (a) Yield comparison methodologies for corn hybrid selection by farmers when corn was picked at harvest. (b) Hybrids were selected by ear shape and size or volume harvested from plots instead of by grain yield.

Figure 2. Weigh wagon, grain cart, and seed tender ready for harvesting a corn hybrid strip trial.

Evaluation of corn performance continued to be an important factor in agriculture with the development of hybrid corn in the 1930s. Farmers selected higher-yielding hybrids and purchased that seed for planting the following year. At that time, grain was harvested on the ear. Volume of ear production was used to determine the best varieties (Fig. 1b). In early years of hybrid seed comparisons, baskets were used to visibly show differences between hybrids.

In the 1950s, self-propelled combines for corn harvest that threshed the grain in the field were introduced and the seed industry switched to measuring grain production with mobile weigh wagons for on-farm evaluations. Seed companies purchased weigh wagons to evaluate hybrid performance in on-farm strip trials (Fig. 2). Weight and moisture data were collected for each hybrid and the harvested area was measured for calculation of yield per acre. Weigh wagons are little changed since their introduction; they are a wagon with a scale. Moisture percentage of the harvested grain is still determined from each plot with a handheld moisture tester.

In recent years, most on-farm test plots have been designed to be at least 0.25 acres in area. Weigh wagons typically hold 150 bu of grain. In some cases, a seed tender or a grain cart is used to improve the efficiency of harvest by providing in-field temporary grain storage during harvest of on-farm strip variety trials. Moisture content is measured from a 1-qt-sized grain sample that is collected when the grain is transferred into the weigh

**Table 1. Corn hybrid entry number, planted rows, seeding rate, plot length, row spacing, and harvested area comparing traditional weigh wagon methodology and combine-mounted yield sensors from six locations in South Dakota.**

| Location | Year | Entries | Rows | Seeding rate | Length | Row spacing | Harvested area | Weigh wagon calibration | Combine sensor system |
|---|---|---|---|---|---|---|---|---|---|
| | | | | PLS† acre$^{-1}$ | ft | inches | acres/plot | | |
| Wessington | 2012 | 12 | 12 | 27,500 | 2679 | 30 | 1.85 | 25 times/season | Ag Leader Insight |
| Woonsocket | 2012 | 25 | 8 | 26,000 | 440 | 30 | 0.20 | 2 times/season | JD Apex 2600 |
| Hitchcock | 2013 | 43 | 8 | 32,000 | 1090 | 30 | 0.50 | 2 times/season‡ | JD Apex 2600 |
| Wolsey | 2013 | 52 | 6 | 30,000 | 625 | 30 | 0.22 | 2 times/day | JD Apex 2630 |
| Hitchcock | 2014 | 54 | 8 | 31,000 | 1080 | 30 | 0.50 | 2 times/season‡ | JD Apex 2600 |
| Yale | 2014 | 9 | 8 | 28,500 | 2354 | 30 | 1.08 | 2 times/season | CIH AFS Pro 700 |

† PLS, pure live seed.

‡ Weigh and wagon and combine-mounted yield sensor calibrated on day of corn strip study harvest.

wagon. The distance harvested for weighing is measured with a measuring wheel to the nearest foot.

Conventional strip trials have a number of challenges that increase plot error, including: (i) small plot area influenced by planting skips and wheel ruts, (ii) wind influence on weigh wagon accuracy, (iii) a single moisture sample is obtained that may not be representative of the entire plot, (iv) measuring wheels can provide inaccurate measurements due to lack of uniformity of soil surface and residue cover, and (v) potential human transcription errors when collecting and collating data.

As most farmers have increased their planted acres, many have less interest in traditional on-farm corn hybrid strip trials due to time and equipment constraints. Modern farm equipment, including combines, headers, and grain carts, has greatly increased grain-holding capacity, whereas weigh wagon grain capacity has changed little over several decades. Additionally, increased yields limit the ability of weigh wagons to measure weight from larger plot areas in a single event.

Tools exist today to improve the quality and quantity of data gathered at the farm level. Combine-mounted yield monitors were introduced in the early 1990s for use in measuring grain yield and moisture. Although numerous combine-mounted yield sensors have been developed (Reyns et al., 2002), most commercial units determine grain yield by measuring mass flow in the clean grain elevator. Grain moisture can be determined once per second, providing a large sample of data points even for 0.25-acre plots. A differential global positioning system (GPS) provides an accurate determination of harvested area, while an onboard computer calculates yield (Grisso et al., 2009). Data can be stored in the onboard computer and displayed with a monitor in the combine cab. While adoption of combine-mounted yield monitors was slow initially, improved technologies have increased accuracy and adoption has increased. In 2010, approximately 60% of the planted corn acres in the United States were harvested by combines equipped with yield monitors (Schimmelpfennig and Ebel, 2011). Some growers use the technology to create a whole-farm test plot—each hybrid, field, soil type, zone, etc. are evaluated using postharvest mapping and decisions are based on the collected yield information (Griffin and Erickson, 2009). Other growers have yield monitors but do not use the information because they do not understand how or do not have the time. Additionally, other growers have yield monitors but do not use the technology at all.

Strip trials are used primarily by seed dealers and farmers. Visual appraisal by customers of hybrid growth and development, and subsequent yield results are an important marketing tool despite the lack of varietal replication at any specific location.

Few studies have been published comparing combine-mounted yield monitor and moisture sensors with traditional weigh wagon methodology for on-farm corn hybrid evaluation in strip trials. There are studies from the 1990s (Krill, 1996) and early 2000s (Al-Manasneh and Colvin, 2000; Grisso et al., 2002); however, these are not current considering advances in computer processing power, GPS, and yield monitor accuracy (Fulton et al., 2009; Taylor et al., 2011; Risius, 2014).

The objective of this study was to compare combine-mounted yield and moisture sensors with traditional weigh wagon methodology for on-farm corn hybrid testing. We hypothesize that yield monitors provide a simpler and more accurate method for on-farm hybrid evaluation and overcome challenges associated with traditional weigh wagon methods.

## LOCATIONS

Soils at the six locations where studies were conducted represent a broad area of central South Dakota. Predominant soils included Houdek loam (fine-loamy, mixed, superactive, mesic Typic Argiustoll), Prosper loam (fine-loamy, mixed, superactive, mesic Pachic Artiustoll), Dudley silt loam (fine, smectitic, mesic Typic Natrustoll), Stickney silt loam (fine, smectitic, mesic Glossic Natrustoll), and Beadle loam (fine, smectitic, mesic Typic Argiustoll). Annual rainfall ranges from about 21 to 24 inches; annual temperature ranges from about 10°F in midwinter to nearly 90°F in July. Specific field sites were located in farmer-cooperator fields near Hitchcock, Wessington, Wolsey, Woonsocket, and Yale, SD (Table 1).

**Table 2. Minimum, maximum, and mean grain weight and Pearson correlation coefficients for comparing traditional weigh wagons and combine-mounted yield sensors from six locations in South Dakota.**

| | | | Weigh wagon | | | Yield monitor | | | Correlation |
|---|---|---|---|---|---|---|---|---|---|
| Location | Year | Entries | Min. weight | Max. weight | Mean weight | Min. weight | Max. weight | Mean weight | *r* |
| | | | lb | | | | | | |
| Wessington | 2012 | 12 | 7960 | 8800 | 8388 | 8150 | 9022 | 8601 | 0.923 |
| Woonsocket | 2012 | 25 | 608 | 1180 | 931 | 608 | 1178 | 926 | 0.934 |
| Hitchcock | 2013 | 43 | 3360 | 6200 | 5211 | 3393 | 7172 | 5432 | 0.984 |
| Wolsey | 2013 | 52 | 1106 | 1736 | 1400 | 912 | 1736 | 1268 | 0.972 |
| Hitchcock | 2014 | 54 | 4480 | 6360 | 5359 | 4610 | 6691 | 5543 | 0.941 |
| Yale | 2014 | 9 | 7200 | 9150 | 8078 | 7102 | 9210 | 7946 | 0.982 |
| Combined | | 195 | 608 | 9150 | 4015 | 608 | 9210 | 4086 | 0.998 |

**Table 3. Regression analyses for traditional weigh wagon grain weight predicting combine-mounted yield sensor grain weight within and across six locations in South Dakota.**

| Location | Year | Entries | Regression | *P > F* |
|---|---|---|---|---|
| Wessington | 2012 | 12 | $y^{\dagger} = -43 + 1.030x^{\ddagger}$; $r^2 = 0.852$ | $P < 0.0001$ |
| Woonsocket | 2012 | 25 | $y = 40 + 0.952x$; $r^2 = 0.872$ | $P < 0.0001$ |
| Hitchcock | 2013 | 43 | $y = -516 + 1.142x$; $r^2 = 0.968$ | $P < 0.0001$ |
| Wolsey | 2013 | 52 | $y = -304 + 1.12x$; $r^2 = 0.945$ | $P < 0.0001$ |
| Hitchcock | 2014 | 54 | $y = 2 + 1.034x$; $r^2 = 0.886$ | $P < 0.0001$ |
| Yale | 2014 | 9 | $y = 151 + 0.965x$; $r^2 = 0.963$ | $P < 0.0001$ |
| Combined | | 195 | $y = -112 + 1.046x$; $r^2 = 0.996$ | $P < 0.0001$ |

† *y* = weight from the yield monitor in pounds.

‡ *x* = weight from the weigh wagon in pounds.

## MEASUREMENTS

Corn hybrids were planted in strip trial plots in central South Dakota. There were two trials in 2012, two in 2013, and two in 2014, with 195 yield comparisons between traditional weigh wagon methodology and combine-mounted yield monitors. A summary of production practices for each of the six strip trials is provided (Table 1). Individual corn hybrid strips ranged from 6 to 12 rows wide and 440 to 2679 feet long, depending on the location; row spacing was 30 inches at all sites. Planting rates were identical to those used by the cooperating farmer at each location. Individual strips were harvested by the cooperator's combine and their yield monitor for grain weight, moisture, and yield. Following combine harvest of each strip, the grain from each strip was then weighed with a weigh wagon, seed tender, or grain cart. The moisture concentration was taken with a moisture tester. The Hitchcock 2013 and Hitchcock 2014 environments used the same combine, yield monitor, weigh wagon, and a GAC 2000 (DICKEY-john, Auburn, IL) moisture tester. All other environments used different combines, yield monitors, and weigh wagons. A mini GAC *plus* (DICKEY-john, Auburn, IL) was used at Wessington 2012, Woonsocket 2012, Wolsey 2013, and Yale 2014. Harvested plot length was determined to the nearest foot with a measuring wheel. Statistical analyses were completed with SAS Version 9.4 (SAS Institute, 2008) using PROC CORR and PROC REG procedures to determine relationships between yield monitor and traditional weigh wagon methodologies for each environment and across all environments.

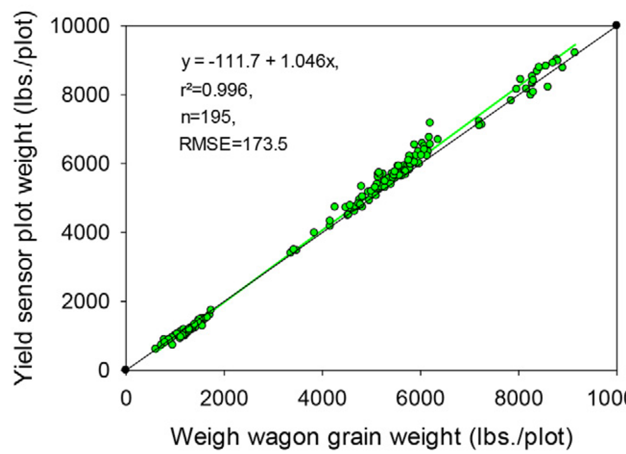


Figure 3. Relationship of grain weight between weigh wagons and combine-mounted yield sensors from six environments in South Dakota, 2012 to 2014.

## GRAIN WEIGHT

The Pearson correlation coefficients for weight ranged from 0.923 to 0.984 for the six environments (Table 2). When all environments are combined, the Pearson correlation coefficient was 0.998, significant at $P < 0.0001$ (Table 2). Regression analysis of traditional weigh wagon predicting combine-mounted yield sensor were significant at $P < 0.0001$ for each environment and for all environments combined (Table 3). Regression analysis using traditional weigh wagon weight to predict combine-mounted yield sensor grain weight from all trials provided an $r^2$ of 0.996

**Table 4. Minimum, maximum, and mean percentage moisture content of grain and Pearson correlation coefficients for comparing traditional moisture testers and combine-mounted moisture sensors from six locations in South Dakota.**

| Location | Year | Entries | Conventional moisture tester | | | Combine-mounted moisture sensor | | | Correlation |
|---|---|---|---|---|---|---|---|---|---|
| | | | Min. | Max. | Mean | Min. | Max. | Mean | $r$ |
| | | | % | | | | | | |
| Wessington | 2012 | 12 | 10.3 | 11.4 | 10.8 | 10.0 | 12.3 | 11.4 | 0.008 |
| Woonsocket | 2012 | 25 | 11.0 | 20.3 | 13.5 | 11.6 | 16.8 | 13.3 | 0.864 |
| Hitchcock | 2013 | 43 | 15.6 | 29.2 | 20.0 | 15.1 | 25.8 | 19.4 | 0.948 |
| Wolsey | 2013 | 52 | 14.7 | 25.1 | 17.7 | 12.9 | 20.5 | 15.5 | 0.957 |
| Hitchcock | 2014 | 54 | 16.0 | 24.7 | 18.7 | 15.9 | 21.5 | 18.2 | 0.931 |
| Yale | 2014 | 9 | 13.5 | 17.0 | 15.8 | 14.5 | 18.9 | 16.9 | 0.963 |
| Combined | | 195 | 10.3 | 29.2 | 17.4 | 10.0 | 25.8 | 16.6 | 0.928 |

**Table 5. Regression analyses for traditional handheld moisture sensor predicting combine-mounted sensor grain moisture concentration within and across six locations in South Dakota.**

| Location | Year | Entries | Regression | $P > F$ |
|---|---|---|---|---|
| Wessington | 2012 | 12 | $y^{\dagger} = 11.2 + 0.015x^{\ddagger}$; $r^2 = 0.001$ | $P < 0.9801$ |
| Woonsocket | 2012 | 25 | $y = 6.4 + 0.510x$; $r^2 = 0.747$ | $P < 0.0001$ |
| Hitchcock | 2013 | 43 | $y = 3.8 + 0.783x$; $r^2 = 0.898$ | $P < 0.0001$ |
| Wolsey | 2013 | 52 | $y = 2.1 + 0.761x$; $r^2 = 0.916$ | $P < 0.0001$ |
| Hitchcock | 2014 | 54 | $y = 5.9 + 0.656x$; $r^2 = 0.867$ | $P < 0.0001$ |
| Yale | 2014 | 9 | $y = -0.8 + 1.116x$; $r^2 = 0.928$ | $P < 0.0001$ |
| Combined | | 195 | $y = 2.6 + 0.808x$; $r^2 = 0.861$ | $P < 0.0001$ |

† $y$ = grain moisture percent from yield monitor.

‡ $x$ = grain moisture percent from traditional tester (GAC2000 or mini GAC Plus).

with slope not different from the 1:1 trend line (Fig. 3). The root mean square error (RMSE) was 173.5, 4.25, and 4.32% of mean grain weight values for weigh wagon and combine yield sensor mean values, indicating a strong relationship between these two methods for determining grain weight.

## GRAIN MOISTURE

The Pearson correlation coefficients for moisture methodology ranged from 0.008 to 0.963 for the six strip trials (Table 4). The Wessington 2012 environment had a particularly poor, nonsignificant correlation. Possible explanations for the low correlation include sampling error, a small number of entries, and most likely, the limited range of values for grain moisture for the handheld sensor (1.1 moisture units from low to high) (Table 4) and for the combine-mounted moisture sensor (2.3 moisture units from low to high) (Table 4). The other five environments had a high correlation with significance of $P < 0.0001$. The combined environments had a Pearson correlation coefficient of 0.928, $P < 0.0001$. These results document high correlation between weigh wagons and yield monitors for grain moisture percentage. Regression analyses for the handheld grain moisture sensor predicting combine-mounted grain moisture sensor were significant for all locations except for Wessington in 2012 (Table 5), where grain the moisture concentration range was very limited. Across environments, the slope of the linear function was lower and significantly different from the 1:1 trendline (Fig. 4). The RMSEs were 6.6 and 6.3% of overall mean grain moisture values for the handheld meter and combine-mounted sensor values. Across strip trials, unexplained variation was greater for grain moisture than for grain weight when comparing traditional methodologies with combine-mounted sensors (Fig. 4).

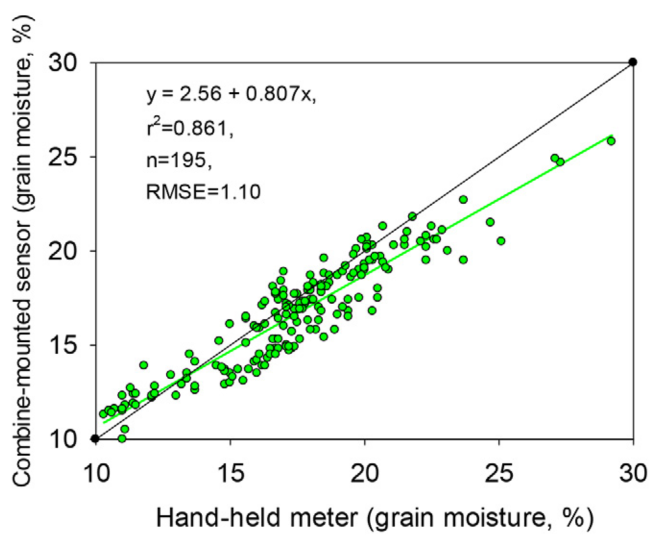


Figure 4. Relationship of grain moisture percentage between handheld moisture testers and combine monitor moisture sensors from six environments in South Dakota, 2012 to 2014.

Table 6. Minimum, maximum, and mean yield for comparing traditional moisture testers and combine-mounted moisture sensors from six locations in South Dakota.

| Location | Year | Entries | Weigh wagon yield | | | Combine-mounted yield sensor | | | Correlation |
|---|---|---|---|---|---|---|---|---|---|
| | | | Min. | Max. | Mean | Min. | Max. | Mean | *r* |
| | | | bu/acre | | | | | | |
| Wessington | 2012 | 12 | 81.8 | 95.2 | 87.1 | 80.0 | 92.8 | 84.8 | 0.989 |
| Woonsocket | 2012 | 25 | 56.1 | 107.9 | 83.9 | 42.0 | 103.0 | 73.3 | 0.910 |
| Hitchcock | 2013 | 43 | 114.8 | 207.6 | 174.5 | 119.0 | 228.0 | 187.2 | 0.964 |
| Wolsey | 2013 | 52 | 95.9 | 134.7 | 114.1 | 76.7 | 128.6 | 100.5 | 0.879 |
| Hitchcock | 2014 | 54 | 150.3 | 216.6 | 184.6 | 150.8 | 214.8 | 182.5 | 0.992 |
| Yale | 2014 | 9 | 116.4 | 147.6 | 131.9 | 116.0 | 147.0 | 128.6 | 0.976 |
| Combined | | 195 | 56.1 | 228.0 | 142.2 | 42.0 | 228.0 | 139.1 | 0.983 |

Table 7. Regression analyses for traditional weigh wagons predicting combine-mounted yield sensor yield within and across six South Dakota environments: Wessington 2012, Woonsocket 2012, Hitchcock 2013–2014, Woolsey 2013, and Yale 2014.

| Location | Year | Entries | Regression | $P > F$ |
|---|---|---|---|---|
| Wessington | 2012 | 12 | $y^{\dagger} = 4.1 + 0.925x^{\ddagger}$; $r^2 = 0.978$ | $P < 0.0001$ |
| Woonsocket | 2012 | 25 | $y = -13.0 + 1.029x$; $r^2 = 0.828$ | $P < 0.0001$ |
| Hitchcock | 2013 | 43 | $y = -10.3 + 1.132x$; $r^2 = 0.929$ | $P < 0.0001$ |
| Wolsey | 2013 | 52 | $y = -25.3 + 1.103x$; $r^2 = 0.772$ | $P < 0.0001$ |
| Hitchcock | 2014 | 54 | $y = 2.6 + 0.974x$; $r^2 = 0.984$ | $P < 0.0001$ |
| Yale | 2014 | 9 | $y = 1.3 + 0.965x$; $r^2 = 0.953$ | $P < 0.0001$ |
| Combined | | 195 | $y = -24.5 + 1.151x$, $r^2 = 0.967$ | $P < 0.0001$ |

† *y* = grain yield from yield monitor in bu/acre.

‡ *x* = grain yield from traditional calculations in bu/acre.

## GRAIN YIELD

The Pearson correlation coefficients for grain yield (weight adjusted for moisture concentration) ranged from 0.879 to 0.992 for the six environments (Table 6) with an overall Pearson correlation coefficient of 0.983 across environments, all significant at $P < 0.0001$. Results from regression analysis had $P < 0.0001$ for each environment (Table 7) and all environments combined (Fig. 5). It is interesting to note that the lowest correlations (Woonsocket 2012 and Wolsey 2013) were from the two environments with the smallest harvested area (0.20 and 0.22 acres/plot, respectively). The slope of the regression function was significantly greater than the 1:1 trendline and the intercept was significantly less than 0 (Fig. 5). The RMSEs were 6.4 and 6.5% of the mean values for weigh wagon and combine-mounted yield sensor technologies. Overall, these results indicate a strong relationship between weigh wagons and yield monitors for moisture-adjusted grain weight from corn hybrid strip trials.

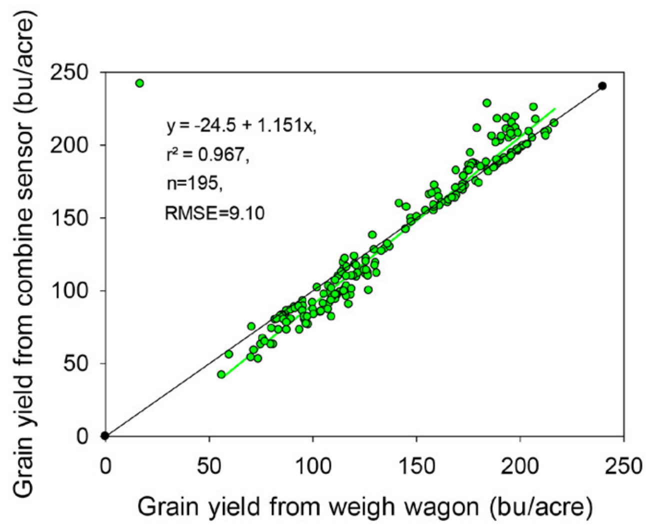


Figure 5. Relationship of moisture-adjusted grain yield between traditional weigh wagon methods and combine-mounted yield sensors from six environments in South Dakota, 2012 to 2014.

## IMPLICATIONS

Our results document that combine-mounted yield sensors can provide results comparable to traditional weigh wagon methods when used for hybrid corn strip trials. Combine-mounted yield sensors allow the use of larger areas for grain harvest. Grain moisture data can be collected at a number of points in each strip with combine-mounted moisture sensors rather than for a single sample, as typically done with handheld moisture testers; therefore, a more representative moisture concentration is determined. Despite regression analysis showing a skewed relationship between handheld and combine-mounted grain moisture sensors, relative differences between or among corn hybrids are quite similar within the range of yield obtained in central South Dakota. For instance, a 200.0 bu/acre moisture-adjusted grain yield from a weigh wagon would be a predicted yield of 203.7

from the combine yield sensor. When calculated for a 100.0 bu/acre yield with a weigh wagon, the predicted yield from a combine sensor would only be 1.6 bu/acre greater. Few published results comparing corn grain yield among hybrids or hybrid × management interactions have found significant differences within the 1.6 to 3.7 bu/acre range. A combine-mounted GPS typically would measure plot area more accurately than a measuring wheel (Nelson, unpublished data, 2012). Data collection occurs immediately and accurately with the computer, and corrections can be made with the yield monitor if incorrect calibrations are determined. The strong correlation coefficients, high coefficients of determination, and small RMSE from regression analyses document that yield monitors can be used effectively in on-farm corn hybrid strip trial evaluations with three caveats: ensure the yield monitor and moisture sensor are properly calibrated, harvest a large plot area for improved accuracy, and do not switch between using combine-mounted sensors and traditional methodology within a study.

Combine-mounted yield, moisture sensor output, and adjusted grain weight had strong correlations with traditional weigh wagon methods for on-farm corn hybrid strip trials. Many corn growers appreciate the accuracy and simplicity of yield monitors and because of this may show renewed interest in on-farm hybrid testing due to labor and time savings compared to traditional methods.

## Acknowledgments

The authors wish to thank the cooperators and sales agronomists that assisted in this 3-year study. In addition, the authors express appreciation to Monsanto Co. (St. Louis, MO) for providing seed, instrumentation, and use of data for this study.

## References

Al-Manasneh, M.A., and T.S. Colvin. 2000. Verification of yield monitor performance for on-the-go measurement of yield with an in-board electronic scale. Trans. ASAE 43:801–807.

Fulton, J.P., C.J. Sobolik, S.A. Shearer, S.F. Higgins, and T.F. Burks. 2009. Grain yield monitor flow sensor accuracy for simulated varying field slopes. Appl. Eng. Agric. 25:15–21.

Griffin, T., and B. Erickson. 2009. Adoption and use of yield monitor technology for U.S. crop production. Site Specific Manage. Cent. Newsl., Purdue Univ. http://www.agriculture.purdue.edu/SSMC/Frames/SSMC4_2009.pdf (accessed 11 Feb. 2015).

Grisso, R., M. Alley, and P. McClellan. 2009. Precision farming tools: Yield monitor. Virginia Coop. Ext. Publ. 442-502. Virginia Polytechnic Inst. and State Univ., Blacksburg.

Grisso, R.D, P.J. Jasa, M.A. Schroeder, and J.C. Wilcox. 2002. Yield monitor accuracy: Successful farming magazine case study. Appl. Eng. Agric. 18:147–151.

Krill, T.L. 1996. Effectiveness of AgLeader ® yield monitor for evaluation of varietal strip data. In: Precision agriculture. Proceedings of the 3rd International Conference, Minneapolis, MN. 23–26 June 1996. ASA, CSSA, and SSSA, Madison, WI. p. 819–825.

Reinhart, C., and B. Ganzel. 2003. Farming in the 1930s: Hybrid crops. http://www.livinghistoryfarm.org/farminginthe30s/crops_02.html (accessed 5 Dec. 2014).

Reyns, P., B. Missotten, H. Ramon, and J. de Baerdemaeker. 2002. A review of combine sensors for precision farming. Precis. Agric. 3:169–182. doi:10.1023/A:1013823603735

Risius, N.W. 2014. Analysis of a combine grain yield monitoring system. Pap. 13799. Graduate M.S. thesis, Iowa State Univ., Ames. http://lib.dr.iastate.edu/cgi/viewcontent.cgi?article=4806&context=etd (accessed 5 Dec. 2014).

SAS Institute. 2008. Release 9.2. SAS Inst., Cary, NC.

Schimmelpfennig, D., and R. Ebel. 2011. On the doorstep of the information age: Recent adoption of precision agriculture. USDA, Econ. Res. Serv. EIB-80. http://www.ers.usda.gov/media/81195/eib80_1_.pdf (accessed 5 Dec. 2014).

Taylor, R., J.P. Fulton, M.J. Darr, L. Haag, S. Staggenborg, D. Mullenix, and R.P. McNaull. 2011. Using yield monitors to assess on-farm test plots. In: Agricultural and Biosystems Engineering Annual International Meeting, Louisville, KY. 7–10 Aug. 2011. http://works.bepress.com/matthew_darr/28 (accessed 5 Dec. 2014).