# COMPARISON OF COMBINE GRAIN LOSS MEASUREMENT TECHNIQUES

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**ABSTRACT.** *Combine tests were conducted in commercial rice fields at Keiser, Arkansas, in 1990 and 1991. As a part of these tests, total grain yields were calculated from data collected with a commercial combine and a plot combine. Loss rates were estimated and compared using two techniques. The first technique used the total grain yield determined from the commercial combine to calculate loss rates. The second technique used the total grain yield determined with the plot combine and the amount of grain collected in the grain tank of the commercial combine to calculate loss rates. Differences of as large as 50 percentage points were observed in some test runs between the two techniques. Because of the large errors experienced in calculating loss rates when estimating total grain yield with the plot combine, it was concluded that this approach was not appropriate for estimating combine losses from test runs of approximately 6 m (20 ft) in length.* ***Keywords.*** *Combine tests, Grain loss, Combine performance.*

One of the primary indicators of combine performance is the amount of grain loss encountered while combining. Several test methods have been used to determine loss rates. Some methods use test systems to collect the entirety of the material discharged from the combine during a test run (terminology follows that is described in ASAE, 1990a, b) (PAMI, n.d.). Other methods compare the amount of grain collected in the grain tank of one combine to that collected by another combine (ASAE, 1990a).

A study was conducted to evaluate the effects of combine settings on harvest loss in rice. To quantify these effects, a test system detailed by Andrews et al. (1992) was designed and field tested on a commercial combine. The system allowed for the collection of all grain and material other than grain (MOG) discharged from the combine during a test run. Material discharged from the rotor and shoe was rethreshed in order to determine the amount of grain lost from the rear of the combine. Thus, the total grain yield of the crop could be determined assuming that shatter and header losses were negligible. This assumption was substantiated by "hand-counts" of kernels remaining on the ground after the tests were conducted. Grain loss was calculated by dividing the grain recovered from the rear discharge by the total grain yield for the test run.

Another part of the test procedure was to harvest a narrow strip, approximately 6 m (20 ft) long, of rice adjacent to each test run with a plot combine. This allowed for direct measurement of total grain yield per unit area. This yield could theoretically serve as the basis for grain loss computations.

A comparison of two loss measurement techniques is made herein. The first technique was a direct measurement of loss. This technique used the amount of grain recovered from the rethreshing of the rear discharge of the commercial combine as the amount of lost grain. The sum of the recovered grain and the grain collected in the grain tank of the commercial combine during a test run was used as the basis for loss calculation. The second technique used the total grain yield determined with the plot combine as the basis for calculating loss percentage, and estimated the amount of loss as the difference between the amount of grain collected in the grain tank of the commercial combine and the theoretical yield of the test run as determined by the plot combine. If these two techniques produced equivalent results, total grain yield for use in loss calculations could be obtained from plot combine data, thus eliminating the need for the collection and rethreshing of material from the rear of the combine. Thus, the time and labor required for conducting combine loss tests could be dramatically reduced.

## OBJECTIVES

The main objective was to compare two grain loss measurement techniques in rice with one measuring grain loss directly via a test system retrofitted to a commercial combine, and the other using an indirect approach via a plot combine. Specific objectives were to:

- Determine total grain yields using a commercial combine equipped with a test system that allowed for the collection of grain discharged into the grain tank and grain discharged from the rear of the combine.

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* Moisture contents reported herein are on a wet basis.

- Determine total grain yields using a plot combine.
- Compare loss rates using the total grain yields from the methods of the above two objectives as the bases for loss percentage calculations.

## General Description of Combines

The commercial combine was a Case IH, model 1680, axial-flow, self-propelled combine. The combine was equipped with a specialty crop rotor, a 6.1 m (20 ft) Case IH, model 1010 rigid grain header, and Case IH's short cleaning system.

The plot combine was a Suzue, machine number 1260, which used circular blades to cut the panicles from the standing rice and a sickle bar to cut the remaining crop at ground level. The panicles fell into a conventional threshing cylinder that used rasp bars to strip the rice from the panicles. Air was used to separate the grain from the chaff. The cutting width of the Suzue plot combine was 76.2 cm (30 in.).

## Experimental Design

A test system, detailed by Andrews et al. (1992), was installed on the commercial combine. The test system allowed material to be collected from the shoe discharge, rotor discharge, and the clean grain auger. For tests conducted in 1990, four field speeds ranging from 1.6 to 6.4 km/h (1 to 4 mph) were chosen for the commercial combine. Rotor speeds of 700, 800, and 900 rpm, and concave settings of 2 and 4 were chosen. Thus, there were 24 experimental combinations (4 field speeds × 3 rotor speeds × 2 concave settings) used on each test day. In addition, four randomly selected test combinations for each day were replicated, which yielded 28 test runs per day.

For tests conducted in 1991, three field speeds ranging from 1.6 to 4.8 km/h (1 to 3 mph) were chosen. Rotor speeds of 700, 850, and 1000 rpm and concave settings of 1, 3, and 5 were used, yielding a total of 27 combinations per day (3 field speeds × 3 rotor speeds × 3 concave settings). The centroid of the experimental design (field speed of 3.2 km/h, rotor speed of 850 rpm, and concave setting of 3) was replicated three times for each day of testing, which yielded 29 test runs per day. In order to avoid bias due to field variation, all test runs conducted within a given day were completely randomized within a single bay (area between levees).

Operating parameters other than forward speed, rotor speed, and concave setting were maintained at constant settings. The header lift cylinders were blocked to ensure that the header height remained constant throughout the tests. The shoe and chaffer sieves were both set at 14 mm openings. Fan speed was set at 700 rpm and the reel speed was automatically adjusted to ground speed. The settings on the plot combine remained constant throughout the entire testing procedure.

## Procedure

### Field Tests

Combine tests were conducted in commercial fields at Keiser, Arkansas in 'Newbonnet' rice, a short-statured, long-grain variety and 'Lemont' rice, a semi-dwarf, long-grain variety. The 1990 tests were conducted in 'Newbonnet' rice on three days over a five day period and the three daily average moisture contents (MCs) were 19.6, 19.1, and 17.1%. Only one day of testing was conducted in 'Lemont' rice in 1990 and the average MC was 15.4%. During the 1991 harvest, tests were conducted in 'Newbonnet' rice on four days over an eight-day period and the average MCs were 21.9, 21.6, 19.9, and 15.5%. Tests were also conducted in 'Lemont' rice on four days over a 13-day period and the average MCs were 20.5, 18.9, 16.9, and 15.5%. The tests were conducted in precision-leveled fields and each day of testing was conducted within a single bay.

A test run comprised an initialization period, a test period, and a shut-down period. The initialization period consisted of operating the combine in a test strip for at least 10 s. This allowed the operator to obtain the desired field speed and allowed the combine to reach steady state operation. After steady state conditions had been reached, the collection devices were activated. Travel of the combine between the initialization period and the test period was uninterrupted. Collection of grain from the clean grain auger and discharge from the shoe and rotor continued for approximately 6.1 m (20 ft) at which time the collection devices were deactivated. However, the forward motion of the combine continued for at least another 1.5 m (5 ft). After the test run was completed, the forward motion of the combine was stopped but the cleaning system was allowed to run until the system was empty. Complete details of the test procedure are given by Andrews et al. (1993).

Field testing began shortly after 1:00 P.M. and took approximately 4 h to complete. For each day of testing, the entire set of experimental combinations was tested. However, the order of testing the experimental combinations followed a different randomization schedule each day.

Immediately after the commercial combine had completed a test run, the plot combine was used to harvest a sample of rice adjacent to the test run area. The plot combine collected grain for approximately 6.1 m (20 ft) just as the commercial combine did. The distance over which grain was collected with the plot combine was recorded.

### Rethreshing Tests and Weighing

All material that had been collected during a test day was transported to a warehouse and weighed. The average grain MC was determined by a Shizuoka Sieki model CTR 800A individual kernel moisture meter. To determine shoe loss for the 1990 tests, the shoe discharge bags were partially cleaned in a Swanson thresher/cleaner Model B1 in which the thresher was bypassed. The partially cleaned grain samples were placed in cloth bags and subsequently transported to the Rice Processing Laboratory at the University of Arkansas where the samples were further cleaned.

To determine rotor loss for the 1990 tests, the rotor discharge was threshed with a large stationary threshing and cleaning unit. The rethresher was a conventional threshing cylinder in line with a cleaning system extracted from a commercial combine. The material from the rotor discharge was threshed twice to ensure that all kernels were threshed from the panicles. The recovered grain was weighed, placed in cloth bags, and then cleaned at a later time.

Shoe and rotor discharge were collected together in the 1991 tests, and the Swanson thresher/cleaner was not used. All the material was threshed twice using the large threshing and cleaning unit. The recovered grain was weighed, placed in cloth bags, and then cleaned at a later time.

### Lab Tests

Grain samples from the grain tank, shoe discharge, rotor discharge, and the plot combine were cleaned using a Carter-Day dockage tester. Clean grain was that which passed through a no. 28 sieve and over a no. 22 sieve.

Total grain yield from the commercial combine was calculated by summing the clean grain collected from the grain tank, the rotor discharge, and the shoe discharge for each test run and was expressed on a unit area basis. Total grain yield from the plot combine was also calculated by dividing the clean grain collected by the area over which the grain was collected. Each test run was approximately 6.1 m in length for both combines. However, the commercial combine used a 6.1 m header that harvested an area of approximately 37.2 $m^2$/test run. The plot combine had a cutter width of 76.2 cm that harvested an area of approximately 4.6 $m^2$/test run. From the standpoint of accounting for field yield variability, total grain yield derived from the commercial combine was presumed to be a more accurate indicator of the actual grain yield.

## Results and Discussion

Comparisons of the average total grain yields from the commercial combine and the plot combine for each day of testing were made. A T test was applied to the total grain yield data using PROC TTEST of SAS (1987). Table 1 shows the estimated total grain yields and associated standard deviations for each day of testing for the two techniques. For tests conducted in 1990, no statistical differences were found at the 5% significance level between the estimated total grain yields from the commercial combine and the plot combine. However, in 1991, total grain yields from the two combines were different in all cases except for one day of testing in each variety. In general, estimated total grain yields from the plot combine were slightly higher than those of the commercial combine. Standard deviations of total grain yields obtained with the plot combine were generally lower than those obtained with the commercial combine. This may be due to the average total grain yield of the commercial combine being made up of test runs conducted at several different forward speeds, which may have caused an increase in the error associated with the test system. Thus, larger variations would be found in total grain yields collected with the commercial combine.

In addition to the comparisons of estimated total grain yields for each day of testing, the average total grain yield for each variety and year were also compared. Table 2 shows total grain yield averaged across each variety and year. The only significant difference between total grain yield estimated from the commercial combine and the total grain yield estimated from the plot combine was in the 'Lemont' variety in 1991. The data suggest that there would be no difference in estimating total grain yields by the two techniques in three of the four cases. However, as will be indicated below, using the grain yield from the plot combine for calculating loss rates of individual test runs can be erroneous.

Loss rates were calculated for the commercial combine using equation 1 below. Loss rates were also calculated using the estimated total grain yields from the plot combine and the grain collected in the tank of the commercial combine (eq. 2). The first technique (eq. 1) uses only information collected with the commercial combine and involves laborious collection and rethreshing of discharged material. The second technique (eq. 2) uses total grain yields estimated from a plot combine and alleviates the

**Table 1. Average grain yield and crop conditions for each day of testing in rice**

| Crop Conditions | | | | Grain Yield* | | | |
|---|---|---|---|---|---|---|---|
| | | Moisture Content (w.b.) | | Commercial | Standard | Plot | Standard |
| | | MOG | Grain | Combine | Deviation | Combine | Deviation |
| Test Date | Variety | (%) | (%) | ($kg/m^2$) | | ($kg/m^2$) | |
| 9-24-90 | 'Newbonnet' | 71.03 | 19.6 | 1.003 | 0.11 | 1 033 | 0.05 |
| 9-25-90 | 'Newbonnet' | 68.69 | 19.1 | 0.960 | 0.09 | 1.003 | 0.08 |
| 9-28-90 | 'Newbonnet' | 66.69 | 17.1 | 1.002 | 0.13 | 0.956 | 0 09 |
| 10-2-90 | 'Lemont' | 68 02 | 15.4 | 0.754 | 0.08 | 0.743 | 0.14 |
| 9-7-91 | 'Newbonnet' | 68.08 | 21.6 | 0.944† | 0.16 | 1.046† | 0.05 |
| 9-8-91 | 'Newbonnet' | 67.05 | 21.9 | 0.954† | 0.16 | 1.058† | 0.08 |
| 9-12-91 | 'Newbonnet' | 65.23 | 19.9 | 1.135† | 0.23 | 1.039† | 0.08 |
| 9-14-91 | 'Newbonnet' | 61.34 | 15.5 | 0.882 | 0.17 | 0.914 | 0.11 |
| 9-1-91 | 'Lemont' | 66.53 | 20.5 | 0.947† | 0.17 | 1.053† | 0.13 |
| 9-2-91 | 'Lemont' | 64 27 | 16.9 | 0.938 | 0.16 | 0.995 | 0.09 |
| 9-9-91 | 'Lemont' | 63.56 | 18.9 | 0.901† | 0.32 | 1.076† | 0.07 |
| 9-13-91 | 'Lemont' | 61.88 | 15.5 | 0.809† | 0.21 | 1.000† | 0.07 |

* Grain yield is reported as 'green' weight and thus, has not been adjusted for moisture content.
† Denotes days in which there was a statistical difference between grain yield estimated from the commercial combine and grain yield estimated from the plot combine at a 5% significance level.
Grain yields were estimated using yields from a commercial combine and yields from a plot combine. Values shown in the table are the average of approximately 28 observations in 1990 and 29 observations in 1991.

Table 2. Overall average of grain yield for each variety and year

| Variety/Year | Grain Yield* Commercial Combine (kg/m²) | Standard Deviation | Plot Combine (kg/m²) | Standard Deviation |
|---|---|---|---|---|
| 'Newbonnet'/1990 | 0.989 | 0.11 | 1.007 | 0 08 |
| 'Lemont'/1990 | 0.754 | 0.07 | 0.743 | 0.14 |
| 'Newbonnet'/1991 | 0.981 | 0.21 | 1.010 | 0.10 |
| 'Lemont'/1991 | 0.899† | 0.23 | 1.024† | 0.14 |

* Grain yield is reported as 'green' weight and thus, has not been adjusted for moisture content.

† Denotes that there was a statistical difference between grain yield estimated from the commercial combine and grain yield estimated from the plot combine at a 5% significance level.

Grain yields were estimated using yields from a commercial combine and yields from a plot combine.

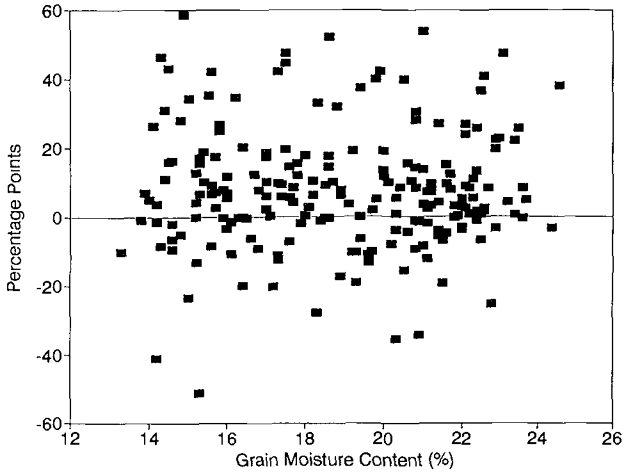


Figure 2–Difference between loss rates calculated using grain yields from a commercial combine and loss rates calculated using grain yields form a plot combine for tests conducted in 'Newbonnet' and 'Lemont' rice in 1991.

need to collect and rethresh material discharged from the commercial combine:

Technique 1 $$\%Loss = 100(GY_c - GT_c)/GY_c \quad (1)$$

Technique 2 $$\%Loss = 100(GY_p - GT_c)/GY_p \quad (2)$$

where

$GY_c$ = total grain yield estimated from the commercial combine (kg/m$^2$)

$GY_p$ = total grain yield estimated from the plot combine (kg/m$^2$)

$GT_c$ = grain collected in the grain tank of the commercial combine, expressed over the area of a test run (kg/m$^2$)

Since the commercial combine was operated at different settings for each test run, the loss rates associated with the commercial combine varied greatly for any given day. For this reason, loss rates estimated from each technique were compared for each test run. Figures 1 and 2 are plots of the difference between the two techniques plotted against the grain MC associated with each test run for 1990 and 1991, respectively. The difference was calculated by subtracting the percent loss calculated using technique 1 from the percent loss using technique 2.

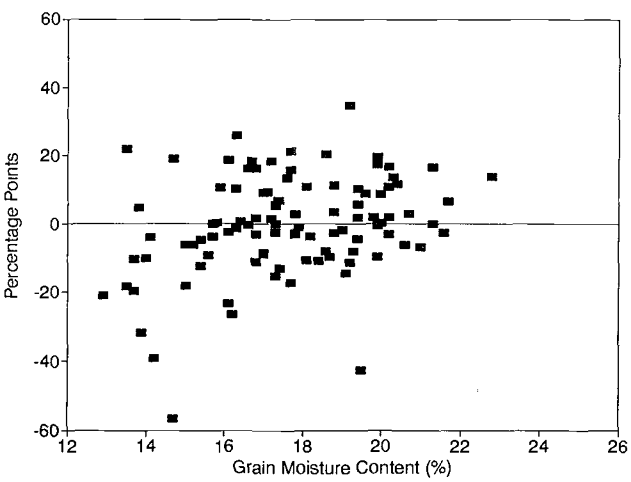


Figure 1–Difference between loss rates calculated using grain yields from a commercial combine and loss rates calculated using grain yields from a plot combine for tests conducted in 'Newbonnet' and 'Lemont' rice in 1990.

The figures show that the difference between the two techniques was as many as 59 percentage points for an individual test run. It is to be noted that loss rates were calculated for individual test runs and, therefore, showed much more variability than the average grain yields in table 1. The figures clearly indicate that loss rates calculated using technique 2 are unreasonable and do not accurately estimate loss rates, especially since the highest loss rate of the commercial combine was approximately 15%. It is also noted that technique 2 often yielded negative loss rates that resulted from the grain yield in the grain tank of the commercial combine being greater than the total grain yield from the plot combine.

Technique 2 was slightly modified to use the average estimated total grain yield from the plot combine for a given day when computing loss in equation 2 instead of the estimated total grain yield for each individual test run. Although the variability did decrease somewhat, the difference in the loss rates calculated using the two techniques remained above 30 percentage points for many of the test runs. It was determined that the variability of the grain yield was such that accurate combine loss rates over short test runs similar to those specified by ASAE (1990a) could not be determined using estimated total grain yields from the plot combine in the manner described. Further investigation revealed that even when daily average total grain yields from the commercial combine were used in computing loss rates in equation 1, differences from the actual loss rates were similar to that of technique 2.

## Conclusions

In general, total grain yields estimated using a commercial combine test system tended to be slightly less than total grain yields estimated using a plot combine. The estimated total grain yields from the plot combine were within ±10% of the estimated total grain yields from the commercial combine. When grain yields from the two techniques were averaged over each day of testing, differences between the two techniques were found to be significant at the 5% probability level for approximately 50% of the test days. When comparisons were made using averages across all harvest MCs from each variety for each year, there were no differences except in one instance between estimations of total grain yield from the commercial combine and the plot combine.

Loss rates calculated using the estimated total grain yields from the plot combine tended to have much higher variability and were inconsistent when compared to those calculated using the estimated total grain yields from the commercial combine. Differences of as large as 50 percentage points were observed in some test runs between the two techniques. Because of the large errors experienced in calculating loss rates when estimating total grain yield with the plot combine, it was concluded that this approach was not appropriate for determining combine losses for test runs of approximately 6 m (20 ft) in length.

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