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# Variability in Volume Metering Devices

Leonard L. Bashford
*University of Nebraska-Lincoln*, lbashford1@unl.edu

Abdeljabar Bahri
*University of Nebraska-Lincoln*

K. Von Bargen
*University of Nebraska-Lincoln*

Michael F. Kocher
*University of Nebraska-Lincoln*, mkocher1@unl.edu

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# Variability in Volume Metering Devices

**L.L. Bashford**
**A. Bahri**
**K. Von Bargen**
**M.F. Kocher**

*Department of Biological Systems Engineering*
*University of Nebraska-Lincoln*
*Lincoln, NE*

## ABSTRACT

The inherent variability of seed and fertilizer application from volumetric metering devices is not readily recognized. The Canadian Prairie Agricultural Machinery Institute (PAMI) suggests a maximum coefficient of variation (CV) of 15% among outlets for seeding grain or applying fertilizer. PAMI does not report down-the-row variability of individual outlets. Parameters that influence variability of volumetric measuring external fluted wheels such as rotational speed of the metering wheel, product delivery rate, seed size, and cell collection lengths were examined.

In the first study, external fluted wheel meters on four grain drills were tested for seed delivery variability for wheat and soybeans, both among the metering outlets and down-the-row for individual meters. Tests on two additional drills, one an air drill and the other with external fluted metering, used two sizes of soybean seeds and two travel speeds. For wheat, down-the-row CV ranged from 12.5 to 22.5% and the CV among metering units ranged from 12.5 to 21%. For soybeans, the CV ranged from 15.5 to 41.5% with the air drill having the lower CV. A faster travel speed gave a lower CV for both drills metering soybeans.

In a second study, when metering wheat, the seeding rate variability due to cell size and seeding rate were evaluated. Each meter was evaluated with cells 0.48 or 0.96 m in length and seeding rates of 60, 80, 90, and 100 kg/ha. The down-the-row CV ranged from 10 to 28% with 0.48 m length cells, and from 4 to 22% with 0.96 m length cells. Some of these CVs may be too high for a metering mechanism such as the fluted wheel to be used in SSCM.

## INTRODUCTION

Site specific crop management (SSCM) is a technique used in precision agriculture when a product is applied to a field based on requirements of subunits of the field instead of an average over the whole field. The utilization of application technology to site specific farming requires knowledge about the application variations inherent in metering mechanisms.

The Canadian Prairie Agricultural Machine Institute (PAMI) has published a number of reports on their evaluation of seeders and the coefficient of variation (CV) as related to the delivery rate of the drill. PAMI accepts 15% as the maximum



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acceptable CV in the seeding rate for their evaluation of seeders. The significance of the variation in metering can be stated very simply. As specified in ASAE S341.2 DEC92, a 15% CV means that at a setting of 100 kg/ha (89 lb/acre), the actual application rate would be expected to range between 85 and 115 kg/ha ( 76 to 102 lb/acre) on 68% of the area. This range of CV may not be acceptable when integrated into a SSCM program.

The delivery devices for precision planters have been modified over the years to eliminate the problems encountered with seed size variation. Air metering devices are independent of seed size and more adaptable to utilization of irregular shape and size seed.

The precision for drills will be more difficult to define as drills do not singulate seed but deliver a volume of seed. There have been some changes and developments in drill metering devices. However, the most common types of metering devices still use external flutes and opening gates to control the application rate.

The objective of this research effort was to evaluate the variation in the metering capabilities of external flute metering mechanisms on drills. Specifically, data were obtained to evaluate performance criteria as follows:

1. the ability of the drill to deliver the same volume of seed from each metering unit, and
2. the ability of each metering outlet to deliver a consistent number of seeds per unit row length (down-the-row).

## METHODS AND PROCEDURES

There are no specific standards that define individual metering outlet evaluations on drills. In general, calibration of drills is based on the seeds delivered from all outlets. For precision planters, individual seeds are captured on an artificial adhesive surface. The seed spacing can then be easily measured. However, an adhesive surface is impractical for evaluation of volumetric meters.

### Study 1

Bashford (1993) discussed a system consisting of a moving table with six rows of 15 catch boxes, or cells used to catch seed from individual metering units. The catch boxes were 102-mm by 102-mm (4-in by 4-in) and mounted on the moving table adjacent to each other in six rows, Figure 1. The seeds metered from each of six outlets were collected in the catch boxes. The catch boxes were attached to a chain driven by an electric motor through a variable speed gear box. This permitted the catch boxes to be pulled underneath the outlets to capture seed. A table speed of approximately 1.6 km/h (1 mile/h) was used for all tests. To eliminate any variation caused by the seed drop tubes, they were removed prior to the tests. Therefore, the moving table was set up immediately underneath the metering mechanisms.

The drill was driven by a treadmill. The operating procedure was to start the treadmill turning the drill wheels, and then start the moving table. As the boxes passed beneath the metering units, the seeds were caught in the catch boxes. After

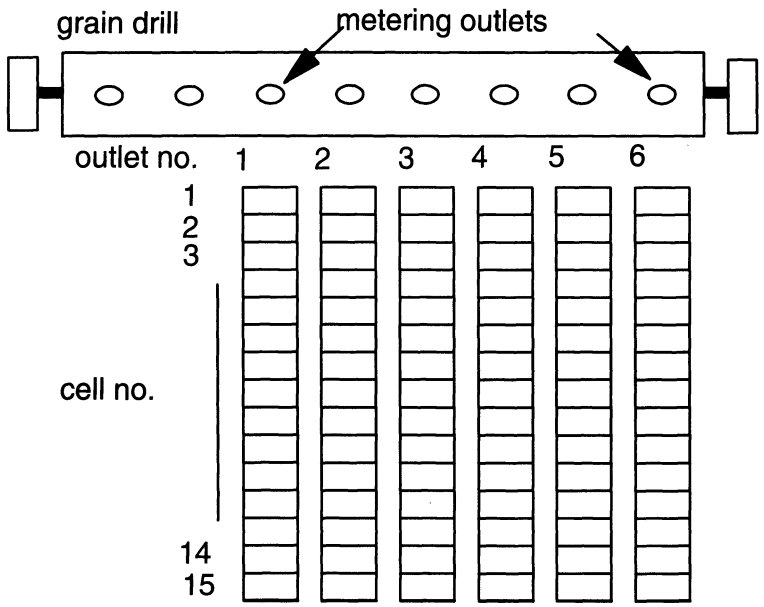


Figure 1. Stationary drill driven by a treadmill with the moving table of 15 rows of boxes (cells).

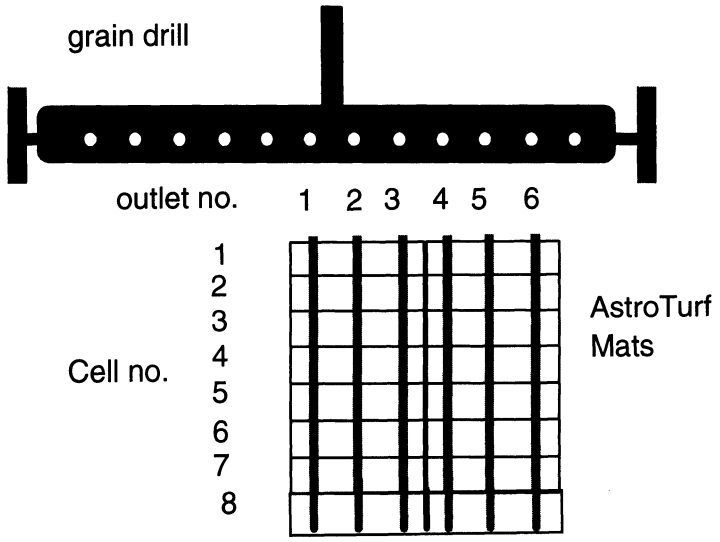


Figure 2. Drill pulled over two rows of eight mats (cells).

all boxes passed beneath the outlets, the table was first stopped and then the treadmill. The number of seeds in each box was then counted.

The first series of tests were accomplished on four drills, identified as 1, 2, 3, and 4. These tests were run at a simulated travel speed of 7.8 km/h (4.8 mile/h) for all drills. Wheat and soybean seeds were used for the tests at application rates of 67 kg/ha (60 lb/acre) and 117 kg/ha (105 lb/acre), respectively. The drill settings closest to the desired seeding rate as printed in the owner's manuals were used. No effort was made to verify the calibration. Four replications of each test were made. Seeds were used only once and discarded.

A second series of tests were run with two additional drills, identified as 5 and 6, and two different size soybeans. Jacques 201 was the larger bean and Jacques 245 the smaller. The seeding rate used for these tests was 112 kg/ha (100 lbs/acre). Three simulated forward speeds were used on an air metering drill, drill 5, and on an external flute metering drill, drill 6. The speed of the treadmill was set to simulate forward travel speeds of 5.8 km/h (3.6 mile/h), 7.0 km/h (4.3 mile/h), or 9.6 km/h (5.9 mile/h).

### Study 2

Bahri (1995) presented a procedure developed to determine the seed metering performance for different rate settings and different collection length cell sizes. A single drill with external flutes was run outdoors over AstroTurf doormats. These mats, or cells, were 0.48 x 0.74 m, with 'hair' about 16 mm high. The mats were oriented with the 0.48 m side in the direction of travel. The mats were placed in line on a paved parking lot. The drill was then operated over the test course at 6.4 km/h (4 mile/h). Seeding rates were 60, 80, 90, and 100 kg/ha. Sixteen collection mats, or cells, were placed in two rows to collect the seeds from six metering units, Figure 2, for seed counts from each metering outlet.

## RESULTS AND DISCUSSION

### Study 1

Down-the-row variability for four drills with external flute meters was based upon the number of seeds captured in each of 15 boxes (cells) per row, Table 1. Each cell represents 0.49 m (19.2 in.) of row length at the simulated travel speed of 7.8 km/h (4.8 mile/h). The most uniform down-the-row delivery was achieved by drill 3 with an average CV of 13.73% and a range from 12.55% to 14.88%. Among outlet variability for six outlets based upon the seed delivered to each box varied from an average CV of 14.96% for drill 3 to 19.06% for drill 4, Table 2. Drill 3 had the lowest average CV of 14.96% while drill 4 had the lowest CV range of 3.75%. Combining among the outlets and down-the-row observations resulted in overall CVs of 18.76, 19.06, 15.20, and 19.05% for drills 1, 2, 3, and 4, respectively.

Illustrated in Tables 3 and 4 are the results for metering soybeans. Drill 1 had the lowest average down-the-row CV, 17.20%, and the smallest CV range,

Table 1. Coefficients of variation for down-the-row variability at each of six outlets on four different drills metering **wheat** seed at 67 kg/ha.

| | Outlet Number | | | | | | |
|---|---|---|---|---|---|---|---|
| Drill | 1 | 2 | 3 | 4 | 5 | 6 | Average |
| 1 | 19.47 | 19.79 | 18.47 | 18.07 | 16.56 | 18.67 | 18.51 |
| 2 | 17.25 | 19.05 | 18.21 | 22.50 | 18.53 | 18.05 | 19.93 |
| 3 | 13.18 | 13.21 | 14.59 | 12.55 | 14.88 | 13.99 | 13.73 |
| 4 | 17.95 | 21.56 | 17.85 | 19.99 | 16.99 | 19.76 | 19.02 |

Table 2. Fifteen observations of the coefficient of variability among the outlets of each of four different drills metering **wheat** seed at 67 kg/ha.

| | Drill | | | |
|---|---|---|---|---|
| Cell Number | 1 | 2 | 3 | 4 |
| 1 | 21.11 | 19.65 | 14.12 | 18.49 |
| 2 | 19.72 | 16.64 | 12.51 | 19.17 |
| 3 | 17.93 | 21.69 | 16.45 | 20.15 |
| 4 | 18.69 | 20.41 | 17.42 | 19.51 |
| 5 | 20.31 | 19.86 | 16.00 | 17.76 |
| 6 | 17.76 | 18.86 | 15.16 | 21.26 |
| 7 | 16.94 | 15.66 | 14.37 | 18.26 |
| 8 | 18.81 | 20.38 | 14.42 | 17.93 |
| 9 | 15.33 | 16.50 | 15.41 | 17.02 |
| 10 | 19.50 | 18.67 | 14.81 | 19.45 |
| 11 | 20.15 | 18.05 | 14.71 | 20.06 |
| 12 | 18.26 | 14.02 | 13.44 | 17.51 |
| 13 | 19.04 | 19.51 | 15.51 | 18.78 |
| 14 | 18.15 | 19.34 | 15.20 | 19.53 |
| 15 | 16.07 | 20.15 | 14.89 | 21.04 |
| Average | 18.52 | 18.63 | 14.96 | 19.06 |

Table 3. Coefficients of variation for down-the-row variability at each of six outlets on four different drills metering **soybean** seed at 117 kg/ha.

| | Outlet Number | | | | | | |
|---|---|---|---|---|---|---|---|
| Drill | 1 | 2 | 3 | 4 | 5 | 6 | Average |
| 1 | 17.48 | 18.34 | 18.29 | 17.10 | 16.51 | 15.53 | 17.20 |
| 2 | 26.51 | 22.71 | 22.05 | 25.19 | 22.38 | 22.06 | 23.48 |
| 3 | 29.73 | 24.01 | 20.39 | 23.28 | 25.45 | 22.43 | 24.22 |
| 4 | 41.59 | 37.78 | 40.22 | 40.21 | 36.16 | 37.88 | 38.97 |

Table 4. Fifteen observations of the coefficient of variability among the outlets of each of four different drills metering **soybean** seed at 117 kg/ha.

| | Drill | | | |
|---|---|---|---|---|
| Cell Number | 1 | 2 | 3 | 4 |
| 1 | 18.18 | 21.45 | 22.36 | 37.95 |
| 2 | 13.98 | 20.11 | 30.34 | 43.92 |
| 3 | 18.83 | 23.49 | 18.46 | 30.26 |
| 4 | 18.41 | 26.82 | 27.10 | 39.61 |
| 5 | 19.20 | 24.24 | 27.07 | 35.87 |
| 6 | 17.89 | 25.37 | 22.77 | 36.16 |
| 7 | 20.07 | 22.69 | 24.72 | 37.51 |
| 8 | 18.11 | 22.84 | 26.65 | 41.42 |
| 9 | 15.56 | 23.07 | 29.53 | 36.73 |
| 10 | 16.96 | 23.49 | 31.03 | 39.84 |
| 11 | 14.51 | 22.96 | 18.07 | 43.20 |
| 12 | 17.61 | 16.43 | 21.22 | 47.77 |
| 13 | 16.91 | 27.02 | 20.98 | 38.93 |
| 14 | 17.46 | 23.81 | 24.18 | 32.46 |
| 15 | 15.49 | 26.25 | 28.00 | 37.33 |
| Average | 17.28 | 23.34 | 24.83 | 38.60 |

2.81%, Table 3. Drill 3 had the largest down-the-row CV range of 9.34%. Drill 4 had the largest average down-the-row CV of 38.97%. Drill 1 maintained approximately the same average down-the-row CV for wheat, 18.51%, as for soybeans, 17.20%. The average down-the-row CV change from metering wheat to metering soybeans for drill 2 was 19.93 to 23.48%, for drill 3 was 13.73 to 24.22%, and for drill 4 was 19.02 to 38.97%, respectively. Therefore, seed characteristics do have a profound effect on metering capability of some drills. Combining among outlets and down-the-row observations resulted in overall CVs of 17.60, 23.58, 25.24, and 38.96% for drills 1, 2, 3, and 4, respectively. Drill 1 had a lower overall CV for soybeans than for wheat. The average down-the-row CVs, Table 4, illustrate the same response as Table 3 for each of the four drills, with drill 1 having the lower CV and drill 4 the higher CV.

When metering two different sizes of soybean seeds, the down-the-row CV for drill 6 was 27.16% for the larger seed and 27.70% for the smaller seed, Table 5. Because the simulated travel speed was similar to that used for the drills in Table 3, the results are comparable to the drills in Table 3. Drill 5, the air drill, had much lower CVs of 11.21% and 12.23%, than drills 1 through 4 and 6. The CV ranges for drills 5 and 6 were narrower than for drills 1 to 4 as tested with soybeans. The CVs across all bean sizes and observations were 15.93 and 28.62% for drills 5 and 6, respectively.

Illustrated in Table 6 are the CVs for the two drills, each operating at two forward speeds and metering two sizes of soybean seed. Simulated down-the-row cell lengths were approximately 0.37 m (14.4 in.), 0.44 m (17.2 in.), and 0.60 m (23.6 in.) for simulated forward travel speeds of 5.8 km/h (3.6 mile/h), 7.0 km/h (4.3 mile/h), and 9.6 km/h (5.9 mile/h), respectfully. The CVs are based on observations across all outlets and cells. Bean size seemed to have little significance on the variability in metering of both drills. The CV for the two drills had a tendency to decrease as the simulated travel speed increased.

## Study 2

Among outlet variability for six outlets on a drill observed over eight cells 0.48 m in length and four different seeding rates is illustrated in Table 7. Illustrated in Table 8 are the CVs for down-the-row variability for each of six outlets on a drill as influenced by four different seeding rates using eight cells 0.48 m in length. Illustrated in Tables 9 and 10 are results similar to Tables 7 and 8, respectively, except the cell lengths were 0.96 m in length. It can be observed that the longer cell lengths result in lower among outlet and down-the-row variability. The overall CV was 27.82% for the 0.48 m cell length, 23.76% for the 0.96 m cell length.

It is obvious that the CV for seed delivery was less than PAMI's recommended maximum of 15% in very few instances. In the context of SSCM and the desire to accurately meter seeds, this type of metering mechanism may have too much inherent variability to obtain a CV less than 15% for small cells, while on a larger scale, CVs may be less. The CV for volume metering units may be in excess of the range of product application rate required. If the desired application rate is 100 units/area using a meter with a CV of 15%, the application rate will range from 85 to 115 units/acre over 68% of the area and will exceed this range

Table 5. Coefficients of variation for down-the-row variability at each of six outlets for two different drills metering two different sizes of **soybean** seed at 7.0 km/h.

| | | Outlet Number | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Bean Size | Drill | 1 | 2 | 3 | 4 | 5 | 6 | Average |
| Larger | 5 | 9.20 | 10.78 | 13.26 | 11.22 | 13.09 | 9.69 | 11.21 |
| | 6 | 26.42 | 31.94 | 24.52 | 25.10 | 28.25 | 26.71 | 27.16 |
| Smaller | 5 | 10.47 | 11.99 | 13.62 | 12.96 | 13.31 | 11.01 | 12.23 |
| | 6 | 26.73 | 28.53 | 33.29 | 29.34 | 25.20 | 23.12 | 27.70 |

Table 6. Coefficients of variation for two drills, each operating at two different forward speeds and metering two different sizes of **soybean** seed. The CV for each drill represents the combination of the observations among outlets and down-the-row variations.

| | Simulated Forward Speed, km/h | | | |
|---|---|---|---|---|
| Bean Size | Drill | 5.8 | 7.0 | 9.6 |
| Larger | 5 | 13.20 | 11.30 | |
| | 6 | | 27.30 | 23.40 |
| Smaller | 5 | 13.20 | 12.40 | |
| | 6 | | 28.20 | 21.70 |

Table 7. Coefficients of variation among six outlets of a single drill with eight 0.48 m cell lengths and four different seeding rates metering **wheat**.

| | Seeding Rate, kg/ha | | | |
|---|---|---|---|---|
| Mat Number | 60 | 80 | 90 | 100 |
| 1 | 22.80 | 15.75 | 35.24 | 14.63 |
| 2 | 24.82 | 28.62 | 15.08 | 13.17 |
| 3 | 15.13 | 26.88 | 12.95 | 24.01 |
| 4 | 20.52 | 18.11 | 19.50 | 11.04 |
| 5 | 20.12 | 20.76 | 8.18 | 11.23 |
| 6 | 14.63 | 7.71 | 27.06 | 21.71 |
| 7 | 29.68 | 26.02 | 21.98 | 17.31 |
| 8 | 21.45 | 12.60 | 10.49 | 22.18 |
| Average | 21.14 | 19.55 | 18.81 | 16.91 |

Table 8. Down-the-row coefficients of variation for each of six outlets on a single drill as influenced by four different seeding rates using eight 0.48 m cell lengths metering **wheat.**

| | Seeding Rate, kg/ha | | | |
|---|---|---|---|---|
| Outlet Number | 60 | 80 | 90 | 100 |
| 1 | 23.77 | 10.57 | 21.70 | 15.72 |
| 2 | 17.54 | 18.62 | 12.41 | 22.47 |
| 3 | 22.72 | 22.96 | 14.74 | 17.08 |
| 4 | 24.97 | 22.05 | 12.75 | 8.11 |
| 5 | 23.42 | 15.04 | 18.09 | 13.71 |
| 6 | 30.93 | 28.99 | 21.00 | 21.77 |
| Average | 23.89 | 19.70 | 16.78 | 16.48 |

Table 9. Coefficients of variation among six outlets of a single drill with four 0.96 m cell lengths and four different seeding rates metering **wheat.**

| | Seeding Rate, kg/ha | | | |
|---|---|---|---|---|
| Mat Number | 60 | 80 | 90 | 100 |
| 1+ 2 | 14.21 | 17.72 | 22.44 | 10.89 |
| 3+4 | 10.86 | 19.63 | 9.13 | 14.46 |
| 5+6 | 13.10 | 16.74 | 13.93 | 15.14 |
| 7+8 | 23.06 | 15.30 | 13.15 | 15.31 |
| Average | 15.30 | 17.35 | 14.66 | 13.95 |

Table 10. Down-the-row coefficients of variation for each of six outlets on a single drill as influenced by four different seeding rates using four 0.96 m cell lengths metering **wheat.**

| | Seeding Rate, kg/ha | | | |
|---|---|---|---|---|
| Outlet Number | 60 | 80 | 90 | 100 |
| 1 | 21.34 | 8.80 | 5.93 | 10.82 |
| 2 | 7.32 | 12.39 | 3.69 | 18.45 |
| 3 | 14.49 | 22.63 | 13.33 | 7.47 |
| 4 | 19.53 | 15.53 | 5.46 | 4.55 |
| 5 | 17.95 | 14.36 | 14.06 | 13.41 |
| 6 | 8.00 | 13.59 | 6.46 | 15.92 |
| Average | 14.77 | 14.55 | 8.15 | 11.77 |

over 32% of the area. If the desired application rate is changed to 90 units/area, the application rate will range from 76 to 103 units/area over 68% of the area Therefore, it is likely that the original and new application rates will not be different.

A drill with a 15% CV will not provide reasonable precision in product application for development of SSCM recommendations. Application rate recommendations for SSCM obtained from studies involving equipment with these magnitudes of CV would likely be erroneous. There is a real need to establish an acceptable CV and develop metering mechanisms that can meter with acceptable uniformity. Obviously, the CV cannot be zero, but the influence of variability in any product delivery system must be identified and factored into the development of SSCM recommendations and decision support systems.

## CONCLUSIONS

Not all outlets on a drill with volumetric external fluted metering units will deliver a consistent volume of seed among outlets or down-the-row. Delivery differences were observed when metering wheat and soybeans. The outlet CV's for wheat ranged from 13.18% to 22.50% and for soybeans from 15.53% to 41.59% and suggests that external fluted metering devices are not adequate for SSCM. How variability in seed or fertilizer application affects yield variability or other evaluation criteria are not known. This type of variability in a SSCM protocol cannot continue to be ignored.

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