Calibration and uniformity of solid manure spreaders

Quiz Questions

1 When spreading solid manure with a rear-delivery spreader, is there more variation in manure applied across the swath or in the travel direction?

2 About how wide is the effective swath width for a rear-beater spreader to maintain relatively uniform application?

3 Narrower swath widths increase average application rate over the whole field. Do narrower swath widths increase or decrease application uniformity?

Introduction

Field experience and research demonstrate that manure nutrients can be readily substituted for commercial fertilizer. Fertilizer needs depend on soil test levels. Substituting manure at a lower cost than commercial fertilizer can result in significant savings if relatively uniform application and distribution can be maintained. The less nutrient-dense manure requires more hauling of material to the field. To take full advantage of fertilizer in manure, correct application rates and uniform application are important issues. Typical nitrogen (N), phosphorous (P), and potassium (K) contained in different manure sources are detailed in Iowa State University Extension publication, *Managing Manure Nutrients for Crop Production* (PM 1811).

The best manure application matches crop needs while considering application uniformity and soil test values. Application uniformity is not as great a concern for soils with adequate levels of P and K and that don't exhibit a significant response to N. For soils that do exhibit crop problems with nutrient deficiencies, application uniformity is important for any fertilizer application including manure.

For solid manure spreaders the application rate should be calibrated and have uniformity across the application swath similar to that of application equipment for dry granular spreaders. This publication outlines how to correctly calibrate your dry manure equipment, measure the manure distribution uniformity, and shares results of Iowa State University Extension research comparing rear- and side-delivery spreaders.

Calibration

The most common method of calibrating solid manure application is to spread one or more loads over a known area and divide the weight of manure applied by the land area to which it was applied. This assumes that the weight of manure applied by the

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spreader is known or readily approximated. If commercial scales are not available, the volume (in cubic feet) of manure in a spreader can be multiplied by the density (lb/cubic ft) of manure to approximate weight of manure in the spreader. Density of manure can be calculated by multiplying the pounds of manure in a level–full 5-gallon bucket by 1.5. For example, if the level–full bucket contains 30 lb of manure, manure density equals 30 lb multiplied by 1.5 or 45 lb/cubic ft. If the volume of manure in the spreader is 300 cubic ft, the weight of manure equals 300 cubic ft times 45 lb/cubic ft or 13,500 lb. Further details of this method including figuring the volume of various manure spreader shapes and land area of odd-shaped fields can be found in "Manure Application," lesson 3 of an *Environmental Issues in Livestock Production* home study course on the Web at **www.abe.iastate.edu/homestudy-land-application.html.**

Measuring Uniformity

Calculating manure application rates over a large area, however, does not indicate the amount of nutrients available to individual plants. For that, application uniformity at specific locations across the swath must be measured. For fields with adequate levels of P and K, or that don't have a significant crop response to N, application uniformity may be important only from an environmental perspective. However, for fields that do have a yield response to additional applications of P and K or where adequate levels of N are required for corn grain yield, application uniformity of any fertilizer is important.

To determine application uniformity, you will need plastic sheets, bucket, and scales (e.g., fishing or dairy scale with 10- or 20-pound capacity). Plastic sheets to collect manure are laid on the ground surface at uniform distances across the application swath. The weight of manure applied on these sheets can be used to calculate an application rate for that region of the swath.

Plastic sheets should be of uniform size (e.g., 1 ft × 2 ft). Place a single sheet inside a plastic bucket and obtain a tare or "empty" weight of the bucket and sheet. Record weights of several of the sheets to find an average tare weight or use individually determined tare weights for each sheet.

Next, place sheets at uniform intervals across the application swath. The suggested number of sheets required will vary depending on the distance manure is thrown by the spreader and the spacing interval between sheets. Eight to 13 sheets are typical. A common layout on cropland with 30-inch rows, using a rear-beater manure spreader that throws manure a maximum of 10 feet away from the centerline of travel is shown in Figure 1.

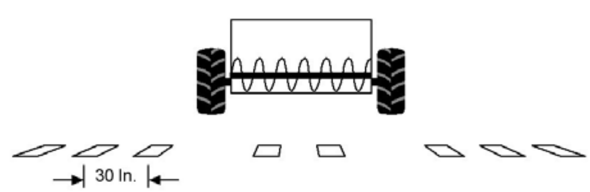

Figure 1. Common sheet layout pattern for a rear-beater spreader.

For narrow spread patterns such as this, two sheets may be used between the vehicle wheels. For wider patterns, a single sheet may be used between the wheels. When even interval spacing would result in a sheet being used in a wheel-track, omit this sheet and approximate application weight in this collection zone by averaging weights collected on either side of it.

The manure should be applied, as near as possible, parallel to the prevailing wind, and plastic sheets should be laid out perpendicular to the line of spreader travel. Wind speed should be light, less than 5 mi/hr if possible. In addition to applying a swath centered over the line of collection sheets, apply adjacent swaths at a desired swath interval because some of the manure applied on these passes will land on the plastic sheets. If manure weight on some of the sheets is too light to be measured, an additional one or two sets of passes (both center and adjacent swaths comprising one set) should be applied and manure weights reduced accordingly (e.g., reduce by half for two sets of passes) in the analysis that follows.

After the application passes, collection sheets should be individually weighed from left-to-right across the swath and weights recorded. Inspecting the range of individual weights of manure collected, without further analysis, will show the relative application amounts across the swath. Actual application rate at any single location across the swath can be determined by

$$A = (3136 \times M) / (L \times W)$$

where

A = application rate, ton/acre

M = weight of manure, lb

L and W = length and width of plastic sheet, in.

For example, if 1.0 lb of manure is collected on a plastic sheet 12 in. × 24 in., the application rate would be

$$\frac{(3136) \times (1.0\ \text{lb})}{(12\ \text{in.}) \times (24\ \text{in.})} = 10.9\ \text{ton/acre}$$

If application rate or spread pattern is not acceptable, other swath intervals, travel speeds, or manure delivery speeds by the chain or auger to the spreading mechanism may be tested. Decreasing swath interval or travel speed, or increasing chain or auger speed will increase application rates. The average application rate collected on all sheets can be used to determine the average field application. This average application can be used to approximate application across the entire field but does not measure the plant-to-plant application variation within the field.

To improve uniformity, measure application rates across the swath by a single pass of the spreader and attempt to improve the pattern by adjusting swath overlap to fill in area with low application. A typical single-swath pattern for a rear-beater spreader (Figure 2)

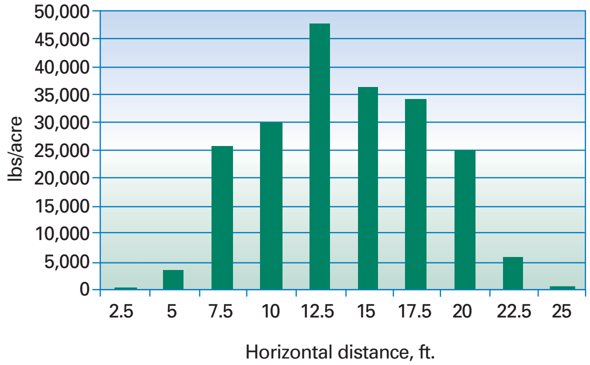

Figure 2. Typical single-swath pattern for a rear-beater spreader.

can be improved by adjusting the swath interval to equal the distance between locations in the swath pattern receiving half the maximum rate. In the case of Figure 2, half the maximum rate is applied at positions 7.5 ft and 20 ft. The distance between these two points, 12.5 ft (= 20 – 7.5) is a good starting point for an effective swath width. If the resulting application rate is too high or too low, compensate by first adjusting apron or auger delivery speed or spreader travel speed before changing swath width.

Field Results with Rear- and Side-Delivery Spreaders

Knowledge of typical solid spreader patterns helps improve distribution. Solid manure application patterns from both rear-delivery and side-delivery spreaders have been evaluated in field tests at Iowa State University. Manure used was solid semi-packed beef manure that had been stacked outside for several months. Moisture content was around 50% (wet basis). Much greater variation was observed across the swath than in the travel direction for rear-delivery spreaders if patterns were not carefully overlapped.

Observations of rear-delivery spreaders were made with both one- and two-beater shaft configurations to throw manure as well as twin vertical screws and a horizontal drum. Distribution from single-pass patterns was characteristically heavy across a zone extending approximately one row (2.5 ft) to either side of the wheelbase (Figure 2). Outside this zone application rates decreased markedly. Peak application rates near the centerline of the spreader for a single pass varied from 15 to 30 tons/acre due to travel speed and speed of the chain apron or auger delivery to the spreader mechanism.

Varying the swath overlap changes the overall average field application rate as well as the uniformity across the swath. Swath uniformity for fertilizer applicators and herbicide sprayers is often evaluated by a statistical measure, the coefficient of variation (CV). Lower CV indicates less variation across the swath and better uniformity. Figures 3 and 4 indicate overall field application rate and CV, respectively, for different swath intervals of a two-beater rear-delivery spreader that was tested. Narrower overlaps increase uniformity of distribution, but also increase application rate. As indicated with the previous example from Figure 2, using a swath width of about 12.5 feet for this type of spreader increases uniformity (by reducing CV to 45%) without greatly increasing application rate (35,000 lb/acre).

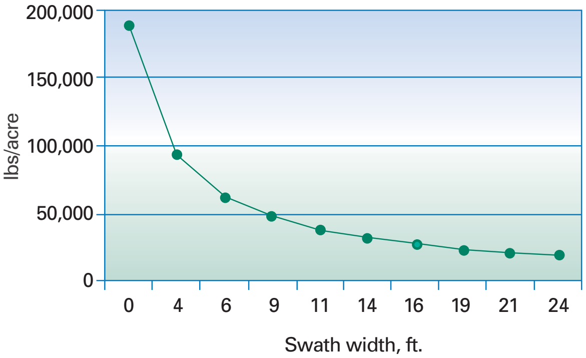

Figure 3. Application rate vs. swath width for rear-delivery spreader.

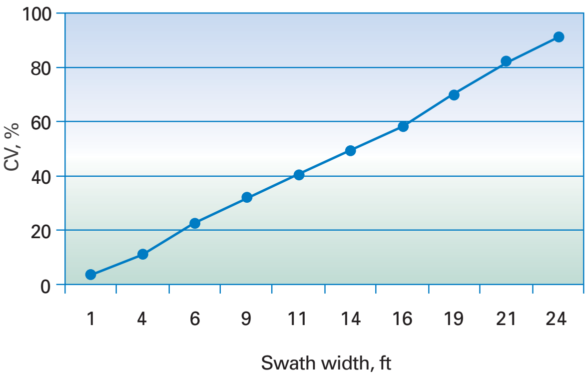

Figure 4. Coefficient of variation vs. swath width for rear-delivery spreader.

The side-delivery spreader observed used a set of rotating hammers to throw manure (Figure 5). For a single swath, peak application rates were lighter and more uniform over a wider distance than a rear-delivery spreader (Figure 6). Figures 7 and 8 indicate overall field application rate and CV, respectively, for different swath intervals of the side-delivery spreader that was tested. Similar to the rear-delivery spreader, narrower overlaps generally increase uniformity of distribution, but also increase application rate. As indicated by lower CV (20%), uniformity was

Figure 5. Side-delivery spreader.

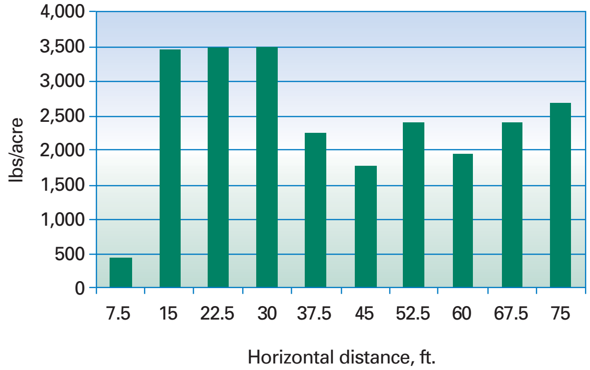

Figure 6. Typical single-swath pattern for side-delivery spreader.

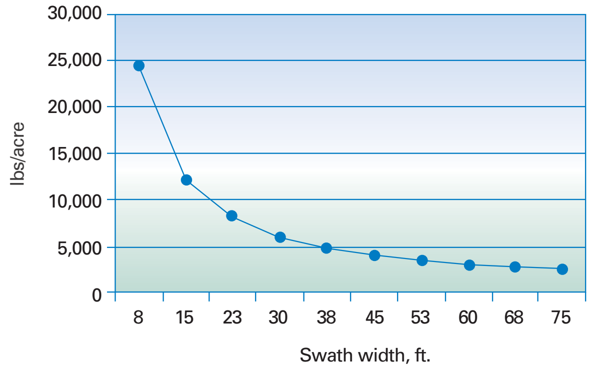

Figure 7. Application rate vs. swath width for side-delivery spreader.

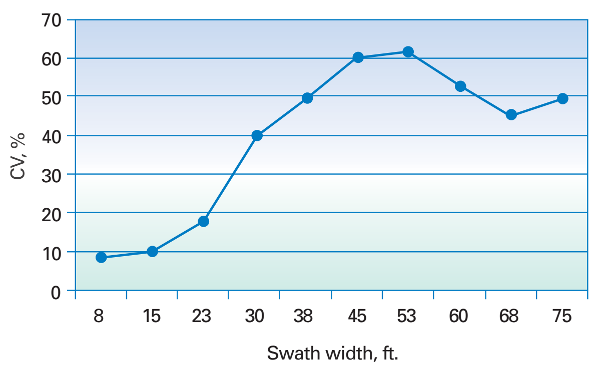

Figure 8. Coefficient of variation vs. swath width for side-delivery spreader.

Calculation of Coefficient of Variation

Coefficient of variation (CV) is a statistical measure of the amount of variation across an application swath of fertilizer. The American Society of Agricultural and Biological Engineers uses CV to measure uniformity of fertilizer or pesticide application. Lower CVs indicate better uniformity.

CV is calculated as the standard deviation of a series of application rates across the applied swath divided by the average application rate and expressed as a percentage. In mathematical terms,

$$CV = 100\% \times \text{(standard deviation of set of observations)} / \text{(average of set of observations)}$$

A formula to calculate standard deviation can be found in statistical textbooks, but it's probably easiest to use a calculator or computer with a built-in function to calculate standard deviation. If the collection areas (e.g., plastic collection sheets mentioned on pages 2–3) are all of equal area, the CV can be calculated directly from the weights of manure collected on the sheets.

Example:

The following weights of manure were collected on eight plastic sheets (all 1 ft × 2 ft) laid across the path of a manure spreader as in Figure 1: 0.3, 0.6, 0.8, 1.0, 1.2, 0.7, 0.6, and 0.4 lb. The standard deviation of this group of eight numbers (from a calculator or computer spreadsheet program) equals 0.30 lb. The average of the numbers equals 0.70 lb. The CV then would be

$$\frac{(100\%) \times (0.30\ \text{lb})}{0.70\ \text{lb}} = 43\%$$

improved at a swath width of 25 ft and application rate (8,000 lb/acre) was still considerably lower than that of a rear-beater-type spreader. Overall application rates are typically lighter with the side-delivery spreader tested than the rear-delivery spreaders tested at the same travel speed.

Although double-spinner-type spreaders were not included in these tests, measurement of spread pattern and adjustment and maintenance of these spreaders are also important. Field collections at two different sites measured heavy application directly behind the spreader from manure being carried over the spinners although this was not visually apparent before measurement. Delivery point on the spinners from the apron, flow divider and spinner vane positions, and spinner speed are all potentially important adjustments.

Conclusions

Varying spreader swath interval affects application rate and uniformity. In general, a narrower swath interval increases application uniformity, but increases overall application rate. For a rear-delivery spreader with beaters, application rates are often significantly reduced within a single row width to either side of the wheels. To obtain acceptable uniformity, it may be necessary to maintain a swath interval not much wider than this distance. Measuring both overall application rate by the spreader and application uniformity across the swath improves fertilizer distribution to individual plants.

Quiz Answers

1. Across the swath unless swaths are carefully overlapped.

2. Effective swath width for a rear-beater spreader extends only about one row to either side of the wheelbase.

3. Narrower swath widths generally increase application uniformity.

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