2950 Niles Road, St. Joseph, MI 49085-9659, USA
269.429.0300 fax 269.429.3852 hq@asabe.org www.asabe.org

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Online Calculator to Determine Optimum Overlap from Pan Tests

Timothy S. Stombaugh
Barry Farmer
Biosystems and Agricultural Engineering
University of Kentucky
Lexington, KY

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Abstract. Increased input prices have garnered a renewed interest by producers in the accuracy and uniformity of application. It can be difficult to achieve uniform application of granular materials, particularly when using spinner spreaders. A common technique to measure the distribution of granular applicators is a pan test where multiple pans are placed transverse to the travel of the machine to collect material as the machine passes. Standards have been developed to provide validity and consistency in these tests, but no tools are broadly available to determine the optimum swath width based on data from a pan test. This paper discusses an online tool that has been developed to visualize material distribution and calculate optimum swath width based on minimization of CV across adjacent passes of granular applicators. The calculator can accommodate diversity in pan size and spacing as well missing pans because of wheel tracks. It is intended to be simple enough to be used by individual machine operators to calibrate to actual machine configurations and products.

Keywords. *Uniformity, Granular Application, Pan Test, Online Calculator, Swath Width*

Introduction

Achieving uniform application of granular materials using a spinner spreader can be a challenge. Lack of uniformity could affect the performance and profitability of the current or subsequent crops in a field. There are many factors that can affect uniformity of application. Yule and Grafton (2013) classified these factors into three broad categories of material properties (particle size, particle density, material moisture content, etc.), environmental conditions (wind speed, terrain, surface roughness, etc.), and machine parameters (design, adjustment, driving accuracy, etc.). The machine operator has specific management control over many of the machine parameters and material properties.

The recent proliferation of drone imaging technology has raised awareness of application inaccuracies that are often visible in aerial imagery. A common manifestation of application variability in fertilizer application is streaking, which is often caused by improper management of machine spread patterns and associated swath spacing. The amount of overlap required from adjacent swaths and the maximum achievable uniformity across swaths will be different for each machine's spread pattern. Knowing the optimum swath width, i.e. the distance between adjacent machine passes, for a specific machine configuration applying a particular material requires an understanding of the actual spread pattern.

A common way to characterize the spread pattern of applicators is using what is commonly referred to as a pan test. A number of standardized test protocols exist to guide the proper execution of pan tests to ensure validity and repeatability of the resulting data (e.g. ASABE Standards S341.5, S660). These standards dictate collection pan layout, dimensions, and construction as well as required test conditions. While these standards are important for comparing different machines and publishing performance data, the procedures can be intimidating to individuals who manage and operate the machines. Even though simpler versions of these tests can be conducted relatively quickly with readily available tools, the intimidation factor and perceived time commitment prevents most operators from testing their machinery.

A further complicating factor preventing operators from testing their machinery is that the data collected with pan tests will allow the user to visualize the spread pattern, but determination of the optimum swath width requires additional computation. The computation techniques can be relatively involved depending on test parameters such as pan spacing. Manufacturers and researchers typically execute these computations with relatively complicated spreadsheets or other computational software, which are often not simple to use nor accessible to most machine operators.

Because of the complexity of collecting and analyzing spread pattern data, there is more performance data available for larger machines typically used by commercial applicators than for the smaller machines commonly used by individual producers. Consequently, the application accuracy achieved by smaller machines is often quite poor. This is especially common when using machinery shared by several producers or rented from a dealer or co-op where there is a lack of knowledge and control of adjustment and maintenance.

Given the inconsistency of application equipment, a common practice recommended by extension advisors to smaller applicators has been to configure the machine to apply a half application rate of material, then double cover the field by "splitting" swaths on the second application or applying in a different orientation. While this practice might reduce the severity of the streaking, there will still be streaks, and the double application wastes energy and increases potential compaction damage to the field.

Objectives

The goal of this project was to develop an easily accessible test procedure and calculation tool that guides a user to

1. collect viable spread pattern data using a simple pan test,
2. visualize the spread pattern of the machine,
3. determine the optimum application swath width, and
4. understand the impact of varying swath width on spread uniformity.

The tool was intended to be useful to anyone involved in the use or manufacture of granular application equipment. Because of the desired broad reach of the tool, it was necessary that it be accessible from a variety of digital platforms.

Development Platform

The tool that was developed through this project was called the University of Kentucky Coverage Calculator (UKCC), which is available at uky.edu/bae/coveragecalculator. It is an interactive web application that was developed using Dash, a Python web framework that offers real-time updates and data visualization capabilities. Dash provides a wide range of built-in components such as charts, graphs, and dropdowns that enable the creation of rich and dynamic user interfaces. The application was designed with interactivity in mind, allowing for real-time updates of the displayed data based on user inputs.

The web application was deployed to a server to allow it to be accessed by anyone with an internet connection and compatible web browser. Dash web applications can be deployed to a variety of hosting services including cloud-based providers like Heroku, Amazon Web Services (AWS), and Microsoft Azure. Deploying a Dash app typically involves configuring the server environment, installing any necessary dependencies, and specifying the application's entry point. The UKCC, was initially deployed on Heroku due to its reliability and scalability.

Because the UKCC is a web application, it will run on any device that has a compatible browser installed and internet access. Due to the nature of the data input procedures and graphical visualizations, though, operation on small handheld devices such as smart phones may be impractical.

Field Data Collection

The testing group is free to choose much of the test equipment and methodology they implement during the test. Obviously, results will be better with wise choices of pan size, anti-bounce dividers in the pans, terrain, weather conditions, etc. Guidelines for best test parameters are given with a detailed user's guide for the UKCC to help ensure better success of the testing efforts.

The one test parameter that is critical to proper operation of the UKCC is the pan layout. For calculations to work correctly, all pans must be evenly spaced perpendicular to the machine path with the center pan of the array located directly at the center of the machine path (fig. 1). The same number of pans should be used on either side of the machine, which dictates that there will be an odd number of pans used. Pans should be removed from the pattern to allow clearance for machine tires, but the other pan locations must remain unaltered.

The UKCC developers recognize that depending on pan size and application rate, the amount of material collected in each pan might be quite small. Multiple passes can be utilized to increase the amount of material in each pan. The developers suggest making multiple passes in the same direction so that any systematic asymmetrical features in the spread pattern do not get masked.

After the spreading is complete, the material in each pan is collected and measured. Many different methods can be used to measure the amount of material collected in the pans. Since the UKCC does not attempt to estimate actual application rate, the critical measurement parameter is the relative amount of material in each pan. As such, the main requirement for the measurement tool used is that it has ample precision to differentiate between the amounts in each pan. The developers suggest that digital kitchen scales can be an acceptable inexpensive option.

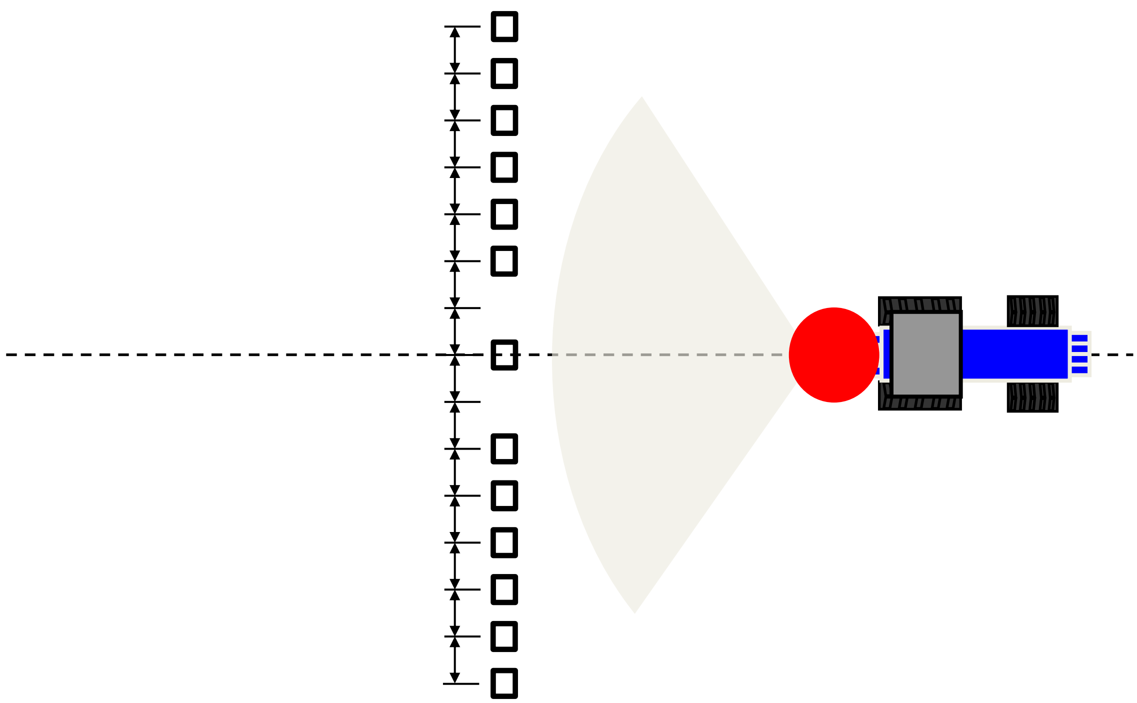

Figure 1. Arrangement of collection pans relative to the spreader. Note the uniform spacing between collection pans with two pans removed to allow clearance for the vehicle wheels.

Data Input

To input data into the UKCC input section (fig. 2), the user must first choose the total number of pans to report including pans removed for tire clearance. This is restricted to an odd number since the protocol dictates one pan at the center of the machine and an equal number of pans on either side. The user also chooses the pan spacing and units for that measurement.

An input table with the total number of pans used in the test is automatically generated. To help with orientation, the center pan will be highlighted in the table. The location of each pan relative to the center of the machine is also indicated. While the direction of numbering of the pans is not critical to the swath width calculations, the instructions direct the user to number the pans sequentially starting with the leftmost pan. In this way, negative distance numbers in the input table will indicate distances to the left of the machine, and the perspective of graphical representations will be from the rear of the machine looking forward.

The measured amount of material collected from each pan is then entered into the appropriate cell in the input table. Entries for pans that are missing from the pattern (e.g. the pans removed to accommodate the tires) are left blank or entered as zero until all the other data are entered. After the data are entered, placing a check in the box next to the missing pans causes the calculator to estimate the amount of material that would have been captured in that pan as the average of the adjacent pans. While there are no explicit data load or save functions in the calculator, pan data can be selected and copied or pasted to or from a spreadsheet or other data program. This will also allow data to be collected at a location where there is no internet access and analyzed later at a location with an internet connection.

Number of pans used: 21

Pan Spacing: 3
○ in ◉ ft ○ cm ○ meters

Place a check next to missing pans after other data are entered

Insert any notes here.

Print Report

	Pan Number	Amount in Pan	Distance from Center
☐	1	2.2	-30
☐	2	3.2	-27
☐	3	3.5	-24
☐	4	3.5	-21
☐	5	5.5	-18
☐	6	5.5	-15
☐	7	5.7	-12
☐	8	7.2	-9
☐	9	9.4	-6
☑	10	11.1	-3
☐	11	12.8	0
☑	12	10.8	3
☐	13	8.8	6
☐	14	6.4	9
☐	15	7.2	12
☐	16	5.5	15
☐	17	4.8	18
☐	18	4.6	21
☐	19	4	24
☐	20	3.5	27
☐	21	2.5	30

Figure 2. Input section from UK Coverage Calculator.

Data Analysis and Presentation

All graphs and calculations are updated continually as data are entered or edited. The first major result presented after the input section is a visualization of the spread pattern (fig. 3). This is a bar chart of the raw data collected in the pans plotted against the distance from the machine center. Users are encouraged to study the pattern and identify any adjustment or repair issues with the spreader that should be addressed. The test should be repeated if major changes are made since the spread pattern will have changed. Users should always be aware of the impact of wind speed and direction on particle travel when evaluating the symmetry of a spread pattern.

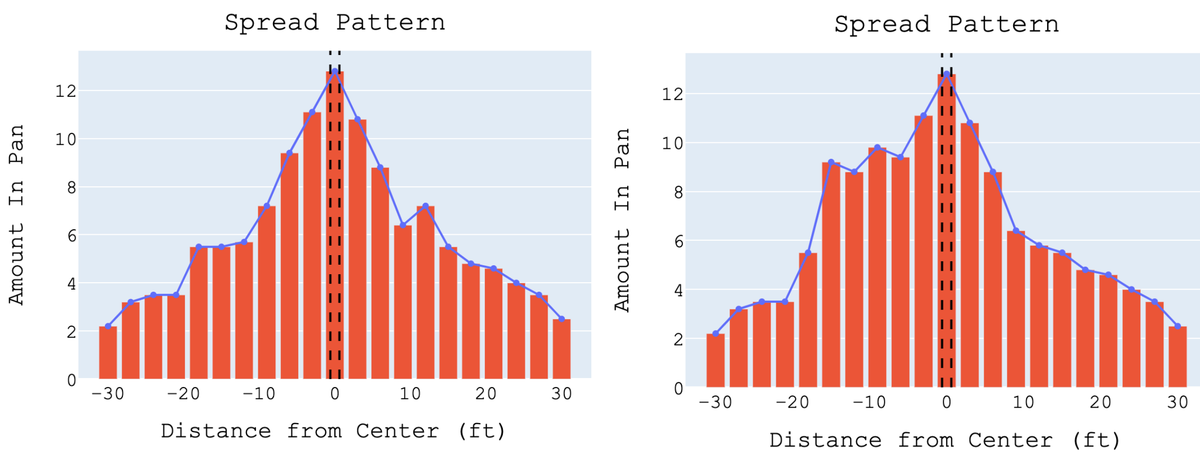

Figure 3. Example spread pattern outputs from the UKCC showing patterns from a relatively well-operating machine (left) and one with problems that should receive maintenance or adjustment (right).

If there is any asymmetry in the spread pattern, as is the case in the example shown in the right panel of figure 3the optimum spread width calculation would be dependent on the orientation of the adjacent pattern that is overlapping the original pattern. Asymmetry could cause different swath width recommendations for left or right turns at the end of a pass. To provide an implementable recommendation based on an average of the different orientation scenarios, the original data are symmetrized and normalized. This procedure involves first creating a mirror image of the original data, overlaying it with the original pattern, and averaging each individual data position. This creates a symmetrical averaged representation of the spread pattern. The data are then normalized such that the sum of all data points would be equal to one. This normalized pattern is presented graphically in the UKCC (fig. 4).

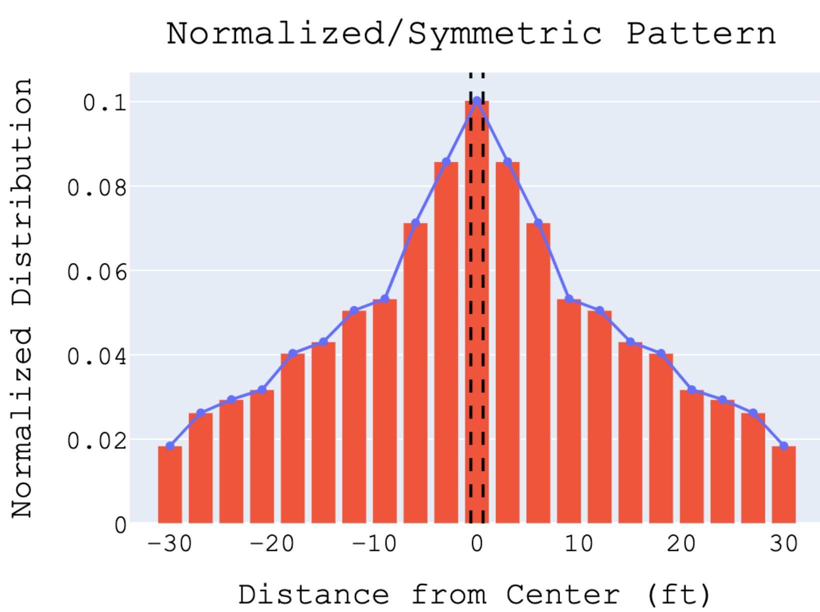

Figure 4. Example of a normalized spread pattern output from the UKCC.

The optimum swath width is defined in the UKCC as the swath width where the coefficient of variation (CV) of the expected application between two adjacent machine paths is minimized. It is identified by stepwise evaluating the CV at different swath widths. The process starts with no overlap between swaths. The swath width is sequentially decreased in increments of the pan spacing. At each step, overlapping data are added and the CV of the resulting application points from the center of one machine pass to the center of the next adjacent pass is calculated. The process continues until 100% overlap is achieved, i.e. the furthest point from one pattern aligns with the center of the adjacent pattern. The minimum CV and associated swath width are presented as optimum for the tested machine and conditions.

A graph of CV vs. Swath Width is displayed in the UKCC (fig. 5). This allows the user to visualize the sensitivity of the application uniformity to swath width and make further decisions about the best operating swath width. For instance, in the example results shown in figure 5, the optimum swath width is 11 m (36 ft), which produces an expected CV of 8.75 across swaths. At a slightly wider swath width of 11.9 m (39 ft), the expected CV would be 11.3. The user may decide that the slightly larger CV would be acceptable in terms of uniformity, and the wider swath width would allow them to make fewer passes across the field.

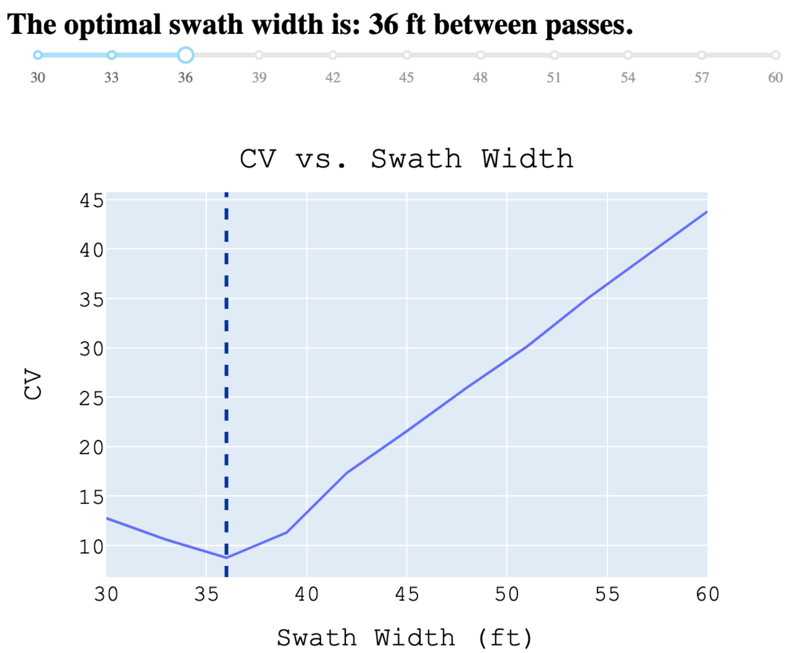

Figure 5. Example of a CV vs. Swath Width plot and optimal swath width indication from the UKCC.

The effect of different swath widths is easily visualized by using the numerical slider bar above the CV graph (fig. 5). The user can select different widths in increments of the tested pan spacing. The optimum width is still indicated above the selector bar, but the expected distribution graph and CV (fig. 6) will reflect the user's choice of swath width.

A button is provided to allow the user to quickly print a report of the calculator results to a printer or pdf file. A text box for notes is provided to allow the user to enter test conditions or other notes. These notes have no impact on calculations, but they will be printed with the report to aid in record keeping and communication.

Conclusions

The UK Coverage Calculator program that is described here is a tool that will help users of granular application equipment improve the uniformity of coverage. It is available to any internet connected device with a web browser. Program instructions outline steps to collect data representing the spread distribution of the tested machine. The spread pattern data are entered into the tool, which immediately displays the spread pattern and calculates the optimum swath width. The user is also able to visualize the effects of operating the machine at swath widths other than the optimum. Because of flexibility in pan spacing and units, the UKCC could be useful to other coverage calculations such as sprayer nozzle spacing.

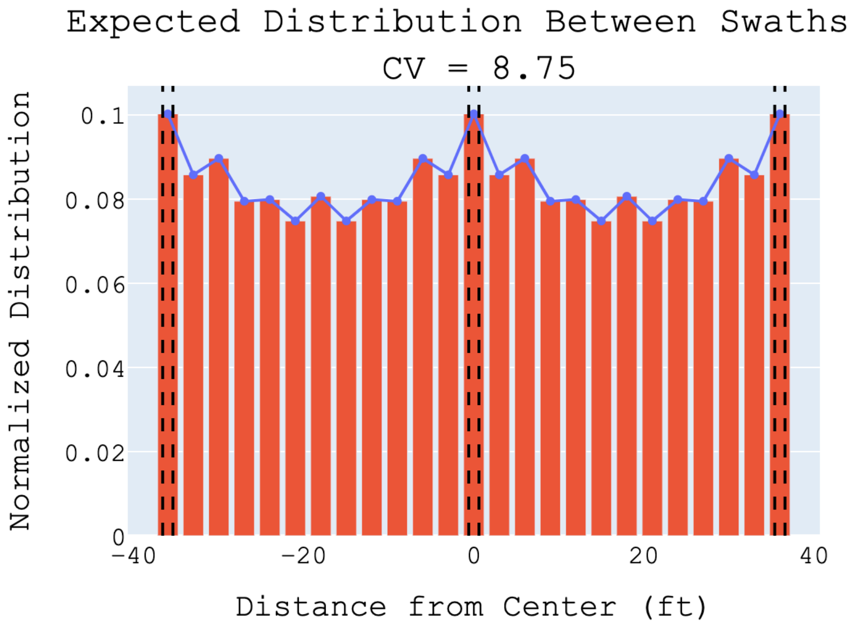

Figure 6. Visualization of resulting spread pattern and CV value across swaths as presented in the UKCC.

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