Development of a Graphical User Interface for Spinner-Disc Spreader Calibration and Spread Uniformity Assessment

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Abstract. *Broadcast fertilizer distribution through spinner-disc spreaders remain the most cost-effective, and least time consuming process to apply the needed soil amendments for the next crop. Spreaders currently available to producers enable them to apply a variety of granular products at varying rates, blends, and swath widths. In order to uniformly apply granular fertilizer or lime, the spreader should be calibrated by standard pan testing with any change in spreader settings, application rate, or fertilizer source. Improper or lack of calibration can result in nutrient “streaking” across the field, which is undesirable because it induces variability in crop fertility levels. The standard pan testing process includes a cumbersome technique of measuring the mass of fertilizer particles collected in each pan. Often, due to time restrictions operators cannot or choose not to calibrate their spinner-disc spreaders. An accurate and time efficient way to measure the spread pattern is required to ensure that proper calibration procedures are being adopted at an acceptable rate. Using image processing techniques, a user friendly application for graphical user interface was developed to assess the spread pattern uniformity of commercial-scale, spinner-disc spreaders. In this app, the operator captures an image of the fertilizer particles in each collection pan. Images are then analyzed in order to detect the blend of fertilizer and to quantify mass of applied fertilizer particles in the collection pan. Data from image analysis for each of the pans is then aggregated and combined with inputs from the user to generate an observed application rate across the swath and a spread pattern uniformity assessment. Results prove that the image based application is just as accurate as traditional pan testing, but less time consuming. Overall, this app will encourage calibration of spreaders while simultaneously reducing time and labor costs of operation.*

Keywords. *Spread pattern, app, fertilizer, application, image processing, calibration*

Introduction

Non-uniform applications of fertilizer can induce variability in cropping system nutrient levels, and these variabilities are known to affect yield (Tazeen et al., 2016). Precise fertilization techniques have been adopted in modern crop production that place the right rate of fertilizer, at the right time, in the right place (Bender, Haegele, Ruffo, & Below, 2013). Fertilizer applications via spinner-disc spreader are a method commonly adopted by producers throughout the United States due to low costs of implementation and high levels of field capacity. To ensure accurate and precise application, spreaders used for commercial fertilizer applications must be precisely controlled and adjusted, depending on the working conditions, the type of fertilizers and the desired fertilizer distribution (Cool et al., 2015). Uniformity of spread pattern is an important parameter to evaluate in spreader performance when applying various sources and rates of fertilizers. In order to achieve desired levels of application accuracy with spinner-disc spreaders, proper calibration is required.

A collection pan test is the standard practice used to evaluate the spread uniformity for spinner-disc style spreaders (ISO 5690, 1984 & ASABE S341.4, 2015). Traditionally, this spread pattern test utilizes standard size collection pans, spaced approximately one meter apart to collect fertilizers for further analyses. The collected fertilizers from each pan are either weighed or measured volumetrically in test tubes to quantify the amount of applied fertilizers in a known area (Figure 1). Although this method is proven to provide an accurate depiction of spread patterns, it is manually intensive and time-consuming. Additionally, if fertilizers are applied simultaneously from multiple sources, the standard pan testing procedure is incapable of assessing the distribution of each fertilizer constituent. To optimize the standard pan testing process and introduce blend quality assessment opportunities, new technologies for determining the spread patterns of the spinner-disc spreaders are required.

Figure 1. Image of standard pan collection testing. Fertilizers are applied over the pans, then mass is quantified and an assessment of spread uniformity is generated.

Opportunities exist to utilize digital image processing techniques that are non-intrusive and proven to be accurate (Igathinathane, Ulusoy, & Pordesimo, 2012). Digital image processing along with classification of various agricultural products in granular form was proven accurate by Raj et al. (2015). Ishizu et al. (2008) proposed a particle detection technique for asbestos and performed a qualitative-analysis by image processing. This technique automated particle counting in a picture. Chen et al. (2016) developed an image processing technique to identify and locate the granule impacts on the sampled foil digital images, the reconstructed particle dispersion pattern using the image processing method showed good agreement with the experimental observations. Similar image processing techniques show potential for accurate spread pattern assessment for a single fertilizer, or a blend of fertilizer constituents at greater levels of efficiency.

In this paper, we are exploring the development of accurate and time efficient methods to measure the pattern of spinner-disc fertilizer spreaders using image processing techniques. A user friendly application for smart phones is under development to assess the spread pattern uniformity of commercial-scale, spinner-disc spreaders. The operator captures an image of fertilizers in each collection pan, then it is automatically uploaded for import into MATLAB based image analysis algorithms. The fertilizer particles will be detected and mass of applied particles will be quantified for the collection pan. For blended fertilizers, each particle can be classified and resulting applied mass for each fertilizer constituent can be quantified. Data from image analysis for each pan is then aggregated and combined with inputs from the user to generate an observed application rate across the swath and a spread pattern uniformity assessment. This assessment will enable operators to adjust the spreader setup to obtain a uniform spread pattern. This work will streamline the process of spreader calibration, encouraging operators to regularly conduct calibration, resulting in greater application uniformity.

The main objective of this project is to increase the efficiency and ease of use for spreader calibration.

This objective will be accomplished by meeting the following sub-objectives:

- Establishment of an app-based intuitive process for spreader calibration.
- Accurate assessment of applied mass of fertilizers.
- Accurate assessment of proportions of blended fertilizers.

Materials and Methods

App Framework

The development process of the app involved evaluating the feasibility of performing a fertilizer spreader test using fertilizer collected in standard collection pans. Images of fertilizer particles landing on the 0.5m x 0.5m (1.64ft × 1.64ft) collection pans are captured using smart phone. A particle analysis tool is developed using the MATLAB environment to extract and analyze particle information. Combining the particle information with inputs from the user, an observed application rate and a spread pattern uniformity assessment are generated, according to which a proposal will be given for the operator to adjust the spreader setup.

Figure 2 displays the pan testing work flow.

1. User Parameter Input

- User inputs target swath width, desired application rate, fertilizer type, and fertilizer density.

2. User Image Input

- User uploads an image for each pan, images are passed on to cloud servers for analysis.

3. Image Processing

- Fertilizer mass and blend proportions are calculated through novel image processing techniques.

4. Spread Pattern Output

- Resulting spread patterns are calculated and displayed to user. Recommendations pushed to app based on spread pattern results.

Figure 2. Pan testing workflow. User input is used to dynamically adjust the image processing techniques for each pan.

App Components

1. *User Parameter Input*

Before spreading, some parameters such as target swath width, desired application rate, fertilizer type, fertilizer density and number of pans need to be known to ensure accurate calculations. The number of collection pans needed will depend on the swath width of the applicator, and the desired pan spacing. Previous research suggests pan spacing should be at least 0.76m (2.5ft) and twice the width of the target swath width in order to capture all components being spread. To determine the number of collection pans needed for another swath width, the following formula can be used:

$$\textit{Number of needed collection pans} = \left(\frac{Swath\ width\ (ft)\ x\ 2}{2.5}\right) - 2[\text{wheel tracks}] + 1[\text{center pan}] \quad (1)$$

All pans must be of identical size and shape. Pans should be shallow 2.5 cm to 6.35 cm (1" to 2.5" deep) with a collecting area of 0.03 to 0.27 m^2 (1 to 3 ft^2) each. The spacing interval between pans can be changed, depending on swath width. Based on the user parameter inputs, the current code will dynamically adjust the number of required pans, the spread pattern output, and the calculations based on the physical properties of the fertilizers. This will allow for standardization across the tests being conducted by the users of this app, as well as ensuring the proper number of pans are being used in the calibration process.

2. *User image input*

For input into the image analysis algorithms, the operator captures an image of the fertilizer particles in each collection pan. When he selects “Choose an image” in the graphical user interface, the gallery folder opens so that the operator can select the correct image from the folder. Upon selection of correct image and the image being displayed, the image is uploaded and stored in the database. This process is repeated until the number of uploaded images equals the number of needed collection pans.

3. *Image processing*

Once the image is uploaded, it is ready to be processed according to the user input information. Image processing algorithms were trained on images captured in variable lighting conditions to account for variability in illumination environments. A hue-saturation-value (HSV) thresholding method was conducted to reduce the noise effect of lighting and optimize the binary images for particle region analysis. Other algorithms in the developed MATLAB code are capable of filtering noise and extracting particle property information for further analysis. Particle properties such as area, major axis length, minor axis length, orientation, equivalent diameter and perimeter can be used to calculate the applied mass of granular fertilizers. The image processing steps are summarized in Figure 3.

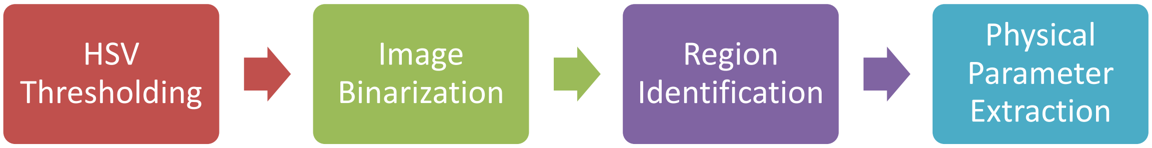

Figure 3. Image processing steps to acquiring needed information for applied mass calculations.

Mass Calculation

Fertilizer granule physical dimensions and information extracted from the image processing algorithms are in units of pixels, and need to be converted to real-world metric units of area (m^2 or mm^2). Calibration between pixels and mm^2 is achieved by placing a coin inside each collection pan prior to image capture. The coin is easily distinguished from the fertilizer particles and will be replaced by a standardized, stationary object of known dimensions in future collection pans. The conversion between pixels and mm^2 is applied to the entire image, allowing particle information such as area and major axis length to be represented as mm^2 and mm, respectively. An equation is chosen to calculate the mass of fertilizers.

$$m = 4/3 \cdot p \cdot \pi \cdot a^2 \cdot b \tag{2}$$

m —— Fertilizer mass (g);

p —— Fertilizer density (g/m^3);

a —— Minor axis length of fertilizer particle (m);

b —— Major axis length of fertilizer particle (m).

Blended product recognition

When multiple products are being applied simultaneously, the spread pattern for each constituent is desirable. To depict both products, information from the output of image processing algorithms is used to classify the blended fertilizers.

Classification is the process of finding a model (or function) that describes and distinguishes data classes or concepts, for the purpose of being able to use the model to predict the class of objects whose class label is unknown. The derived model is based on the analysis of a set of training data whose class label is known (Jiawei Han and Micheline Kamber, 2006).

In order to classify each type of fertilizer in the collection pan, a classifier was developed to utilize output information from the image processing algorithms and the RGB color value from the centroid of the particle to assign a label to every fertilizer particle. This enables the operator to know the source of each fertilizer particle collected in the pan. The trained model was able to identify the unknown fertilizer types with accuracies of over 98%. After classification, the equation above is used to calculate the mass of each fertilizer constituent and calculate the spread pattern for each applied product.

4. Spread Pattern Output

After the mass of fertilizer is calculated for each collection pan, the application rate can be calculated with the above image processing techniques. User input information of the pan interval and target swath width allow for distribution patterns to be plotted and reviewed. This enables the operator to visualize the spread uniformity and make any needed corrections to the spreader settings.

Results

An interactive graphical user interface which helps the operator to obtain spread patterns for spinner-disc, dry fertilizer applicators was developed. The operator captures or chooses an image and input the fertilizer density, the image is then processed to get the application rate. This process is the conducted for each collection pan, allowing distribution patterns to be plotted and reviewed for spread uniformity.

1. *User Parameter Input*

Fertilizer density (g/cm^3) should be measured for calculating the mass. Users will select the desired pan interval and enter target swath width to calculate the needed number of images. Once this information is obtained, the proceeding code will adapt dynamically to ensure high levels of accuracy when calculating spread pattern parameters. The target rate is the desired application rate and enables the algorithms to calculate a percent error by comparing the observed rate to the desired rate. The interface for input is shown in Figure 4.

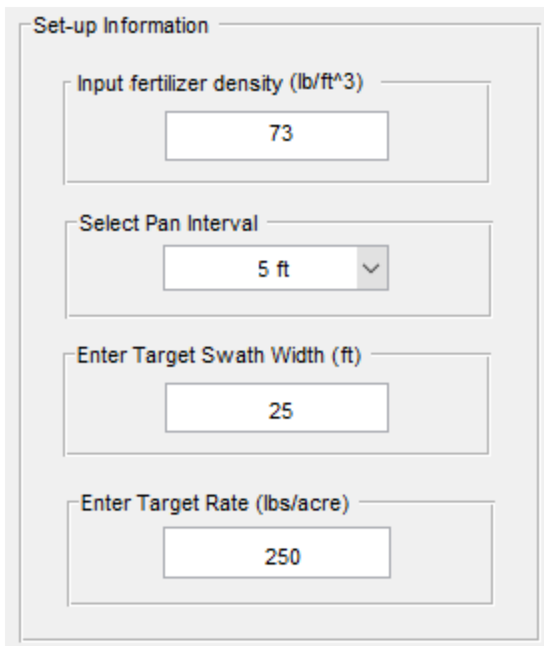

Figure 4. Input for preliminary testing parameters.

2. *User image input*

The Choose an image button allows the operator to choose an image from the gallery that was captured in the field by the operator. For single fertilizer, the operator can input the fertilizer density and click on calculate button. This action will get the application rate of the fertilizer in this image.

3. *Image processing*

The developed image processing techniques enable the images of collection pans to be analyzed at high rates of speed. The fertilizer images in Figure 5 are potash particles captured in a black collection pan. The applied masses of potash were then weighed to compare with the known application rates for each image. The maximum error for all 6 images is less than 5 percent error, this level of accuracy is deemed acceptable for this application.

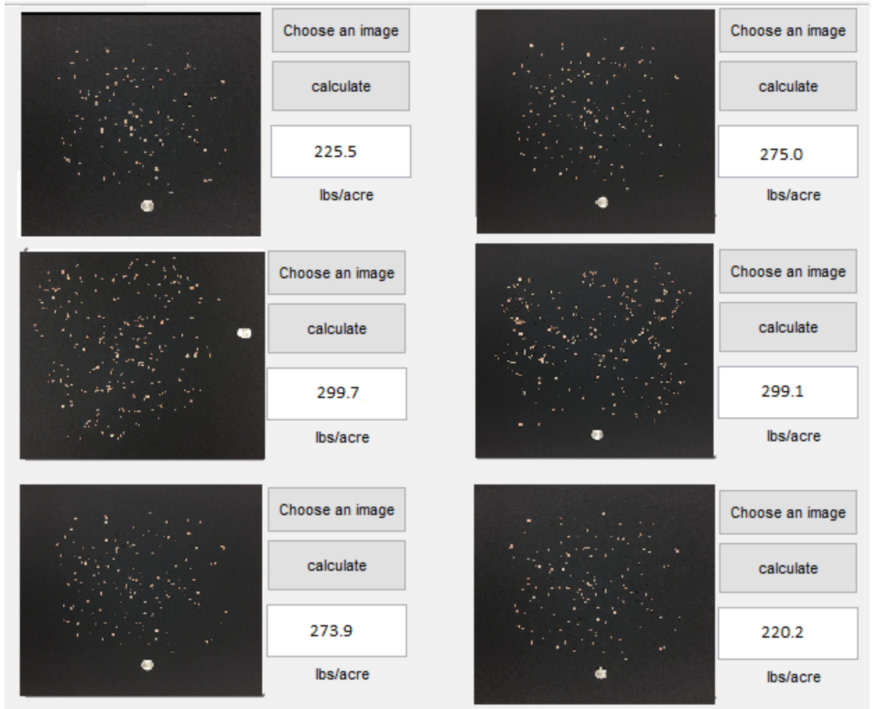

Figure 5. Output Layout displaying the Result for single fertilizer.

4. Spread Pattern Output

Spread patterns

In the determination of applied spread patterns, variations in application need to be visualized across the width of the swath. Fertilizer must be placed where intended and at the correct rate by a spreader. Spread patterns can be optimized for uniformity by using the correct swath spacing for the current spreader set-up. These patterns ensure field-scale uniformity and eliminate “streaking” across a field. The spread pattern shown in Figure 6 is generated from the calculated masses above. The blue straight line indicates the target rate and depicts where an over or under application of fertilizer occurred. This information can then be used to adjust the spreader set-up accordingly.

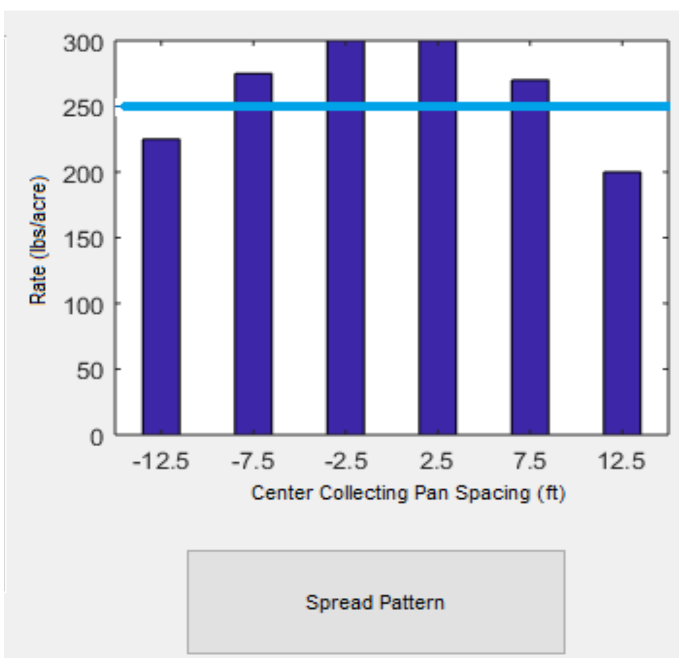

Figure 6. Output layout displaying the spread pattern for single fertilizer.

Blend Quality Assessment

For blended fertilizers, the app can recognize their source and classify them to get each spread pattern. This example shows how the GUI is capable of classifying the blended potash and DAP and form the spread pattern for each. Follow the same procedures for the single fertilizer analysis, and then push the classifier button to get the proportion and application rate for each fertilizer constituent.

The operator will select the pan interval and enter target swath width to calculate the number of images needed. Once the needed number of fertilizer application rates are calculated, then the spread pattern can be generated to acquire the fertilizer spreader pattern of both DAP and potash (Figure 7).

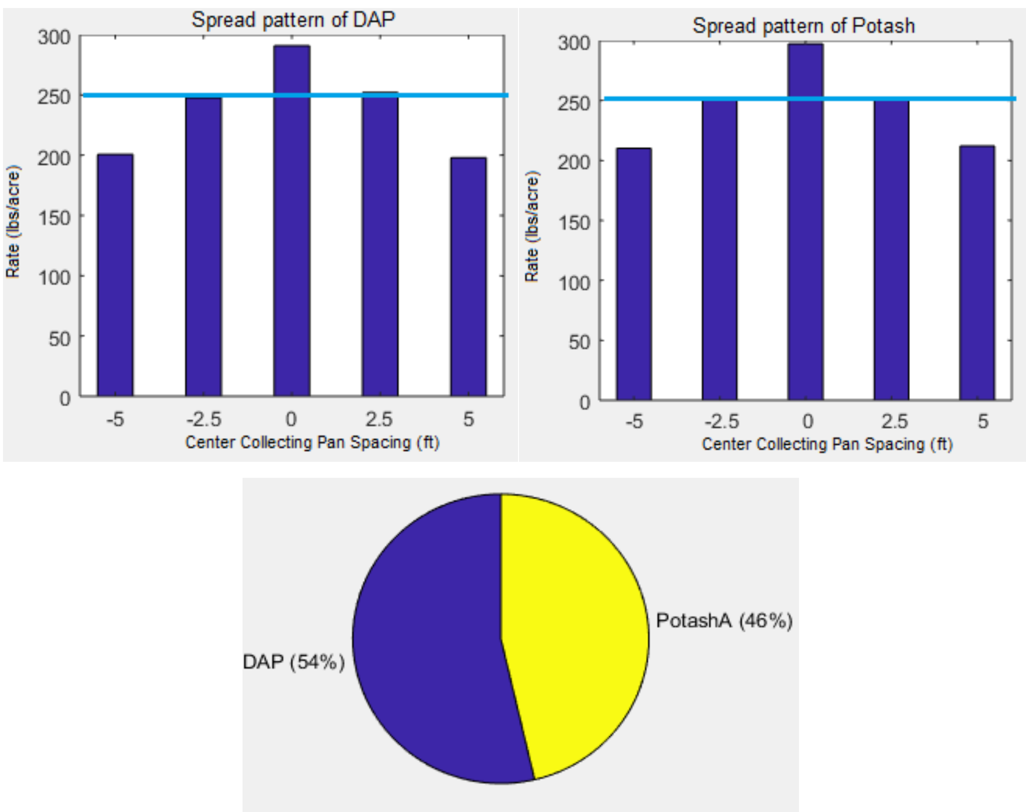

Figure 7. Output layout displaying the spread pattern for individual constituents of blended fertilizers.

Conclusion

A graphical user interface was developed to assess the spread pattern uniformity of commercial-scale, spinner-disc spreaders. The preliminary results indicated the proposed approach was successful, as it was labor-saving and less time-consuming at high levels of accuracy. This operation is easy and friendly for operators to get the spread pattern for single fertilizer or blended fertilizer application. As a part of future enhancement, the complete process can be automated so that the result can be delivered in a very short time. Additionally, these processes will be delivered to an app to enable processing of these images in the field from a smart phone.

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