Comparison of Variable-Rate Granular Application Equipment

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Abstract. The popularity of variable-rate technology (VRT) has grown but limitations and errors of this technology are generally unknown. Therefore, uniform and variable-rate (VR) tests were conducted to characterize distribution patterns at various rates and quantify rate changes for assessing the application accuracy of 3 VRT granular applicators (2 spinner spreaders and 1 pneumatic applicator). The characterized single-pass patterns demonstrated consistent shapes but deviated slightly from the desired patterns for two applicators at all rates. The simulated overlap multiple-pass summary statistics indicated that the three applicators performed satisfactorily with all but one of the CV’s less than 20%. A majority of the CV’s were less than 15%. The average application rates for 2 applicators were less than the desired levels for all tests. The third applicator under-applied at the low rate, over-applied at the high rate, but equaled the desired level at the medium rate. The overlap patterns for the spinner spreaders showed consistent peak levels at the center of the pattern, valleys on either side, and then tails on the ends that exceeded the desired levels. The pneumatic applicator overlap patterns indicated a problem with under-application at its center. The most uniform application occurred at the lower application tests for all applicators. Rate changes were much quicker for the two newer VR control systems. These results showed distribution plots are required along with CV’s to calibrate applicators and correctly assess patterns while new technology has improved response time on VRT equipment.

Keywords. Precision agriculture, spinner disc spreader, Gandy Orbit-Air, Newton Crouch, New Leader, modeling, fertilizer and lime, potash, distribution patterns.
Introduction

The popularity of variable-rate technology (VRT) is growing since the advent of precision agriculture (PA). One area farmers are tending to focus on is nutrient management of granular fertilizers and agricultural lime. Fertilizer dealers and custom applicators are providing VRT services to farmers, which usually come with an additional cost due to the added equipment and software to perform variable-rate (VR) application. The notion behind VRT is only applying what is needed based on local soil conditions and crop requirements. This assumes that fertility or soil variability exists and the traditional blanket application tends to over- and under-apply. Thus, VRT provides a method to reduce or make better use of granular inputs. While VRT seems to be a viable option for managing granular inputs, application errors associated with VRT equipment needs to be understood. Quantification of these errors will help establish whether VRT offers an effective way to apply products when compared to blanket application and determine VRT limitations. There is also the concern whether this technology actually pays for itself?

The two main technologies for granular material application are spinner discs spreaders and air-boom applicators. Spinner spreaders still tend to be the most popular type of granular applicators found in the Midwest since they provide a cheap application method. However, air-boom applicators are becoming popular among custom applicators. One concern about granular materials is product variability in terms of material density, particle size, and moisture content. This variability poses an issue for any type of granular applicator especially with deposition or application consistency of product(s) across the application width of the machine. Many believe that air-boom technology offers more uniform product distribution across the boom than spinner spreaders. In either case, deposition variability exists due to the nature of granular products but in most cases is unknown especially with VRT equipment. Manufacturers and producers have acknowledged the existence of deposition variability. However, producers continue to utilize the equipment despite the errors.

This investigation is a continuation of research being conducted at the University of Kentucky looking at methods to assess granular applicators equipped with VRT. Additionally, the research is focusing on developing methodology for generating ‘as-applied’ maps (Fulton et al., 2002) that represent the actual distribution of materials across fields to assess VRT equipment. This assessment is from the engineering and economic standpoint to better assist management and make comparison between uniform and VR application of products to determine what pays. The intent is not to compare different manufacturer products but determine trends, limitations, and errors of granular VRT equipment. The goal of this investigation was to quantify the variability of different VRT applicators in terms of distribution patterns and rate change response. The specific objectives were:

1. Characterize distribution patterns from various granular applicators.
2. Quantify rate changes with the different VR control systems.

Background

Precision agriculture (PA) has brought a new technique for managing agricultural land. Many believe that the use of PA practices allows for better nutrient management by applying only what is required for crop growth thereby possibly providing agronomic, economic and environmental advantages over the traditional approach of treating a field as a single unit. While VRT has become a widely accepted method in the agricultural community for varying the
application rate of various inputs, potential errors with this technology along with proper calibration and operation is critical to ensure accurate application of inputs.

ASAE standard S341.2, Procedure for Measuring Distribution Uniformity and Calibrating Granular Broadcast Spreaders (ASAE S341.2, 2000), provides a uniform procedure for testing, assessing the performance, and reporting the results of broadcast spreaders. The standard outlines a methodology by which to assess the distribution pattern of a broadcast spinner using a 1-D row of trays. While the standard addresses uniform application, it does not include the testing of broadcast spreaders equipped with VRT. Therefore, Fulton et al. (2001) modified ASAE S341.2 to include a 2-D array of collection pans to assess VR application of granular products assist in testing VRT granular applicators. The modified plot layout provided means to characterize distribution patterns while also evaluating distribution patterns and rate response during rate changes.

The coefficient of variation (CV) provides a means to quantify application variability and accuracy. ASAE S341.2 requires CV's to be reported when testing applicators while manufacturers and custom applicators have adopted CV calculations when talking about application accuracy. Lower CV's indicate uniform distribution patterns. Spinner spreaders tend to exhibit CV’s varying from 5% to 10%; however, terrain irregularities can greatly increase CV's to the upper 20's or lower 30's (Parish, 1991). Sogaard and Kierkegaard (1994) reported that CV's in the range of 15% to 20% are typical of field tests for spinner spreaders.

Application errors occur due to over- and under-lap with adjacent parallel. Dorr and Pannel (1992) reported that 10% of a field had either over- or under-lapping patterns. This result indicates that operator pass-to-pass consistency is important and can be costly if the correct swath width is not maintained. Marchenko and Chernicov (1977) determined swath width varied for spreaders under normal operation. Similarly, vehicle speed (Parish and Chaney, 1986 and Parish, 1987) and rough terrain (Parish, 1991) affect the performance of a spreader. Parish (1991) showed that the CV increased from 10% to 30% when moving from operating on a smooth surface to a rough surface. Thus, several factors influence application quality of spinner spreaders under traditional blanket application.

A procedure for testing variable-rate granular applicators was outlined by Fulton et al. (2001). They modified ASAE S341.2 to include a 2-D array of collection pans to assess both uniform and VR application. The 2-D matrix of pans permitted the characterization of distribution patterns along with the ability to capture distribution patterns during rate changes. Capturing rate changes within the test matrix also allowed for quantification of system latency for VRT equipment. Quantifying the VRT system latency allows the “look-ahead” feature provided in most software packages to be properly set.

Fulton et al. (2001) demonstrated distribution variability at different rates from a spinner spreader by performing fixed and VR application of muriate of potash. They cited that distribution variability could compound application errors when moving to variable-rate application with spinner spreaders. Additionally, pattern shifts during rate changes (Fulton et al., 2001; Olieslagers et al., 1997) plus the existence of system latency (Fulton et al., 2001) causing delayed rate changes creates other sources of application errors for VRT equipment. The problem with pattern shifts is not as easily rectified but needs to be addressed to maintain distribution uniformity at various application rates. Potential solutions involve modification of the spreader hardware, i.e. adjustment of divider position simultaneously with apron chain speed adjustments, to maintain the desired distribution pattern.
Overview of Applicators

The three granular applicators tested for this research were a Newton Crouch, a New Leader L3020G4, and a Gandy Orbit-Air. The first two applicators utilize spinner disc technology to distribute material. The Gandy Orbit-Air a pneumatic applicator using airflow to convey material from the metering units to distributors along the boom. The spinner spreaders rely on pattern overlap from adjacent passes to properly apply material. They throw material further than their effective swath width to achieve the pattern overlap from adjacent parallel passes. The Gandy-Orbit-Air does not rely on overlap except for the outside two distributors on adjacent passes. The theory behind pneumatic applicators is that material is being metered uniformly through the distributors along the length of the boom. Thus, no overlap is required.

Fulton et al. (2001) provided a full description of the Newton Crouch bed and control system. However, current system differences include using the software package AgView by GIS Solutions (AgView, 1999) instead of Agris’s FieldLink and using a Trimble 132 DGPS receiver. The New Leader L3020G4 bed and control system was purchased in 2002 and has a 18.3 m effective spread width. The control system is a simplified Rawson controller and hydraulic drive manufactured for New Leader’s spinner spreaders. A computer, the software package AgView (AgView, 1999), and a Trimble Ag132 DGPS receiver were used to implement the VR capabilities on this spreader. Table 1 provides additional characteristics for these spreaders.

Table 1. Applicator characteristics.

<table>
<thead>
<tr>
<th>Applicator</th>
<th>Test Speed (km/hr)</th>
<th>Spread Width (m)</th>
<th>Control Valve</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newton Crouch</td>
<td>20.4</td>
<td>16.0</td>
<td>Source Fluid Power</td>
</tr>
<tr>
<td>Gandy Orbit-Air</td>
<td>9.2</td>
<td>12.2</td>
<td>Rawson</td>
</tr>
<tr>
<td>New Leader</td>
<td>14.5</td>
<td>18.3</td>
<td>Rawson (G4)</td>
</tr>
</tbody>
</table>

Figure 1 shows the Gandy Orbit-Air applicator assembled by the Biosystems and Agricultural Engineering Department at the University of Kentucky. The hopper was mounted on a pull-type sprayer frame. A boom was fabricated to mount the 24 distributors or deflector plates (fig. 1). The deflector plates are located uniformly along the boom at 50.8 cm spacing providing a 12.2 m effective spread width (Table 1). Twenty-four fluted rollers meter material from the centrally located storage hopper into individual air tubes through which the airflow conveys material to each deflector plate individually. A single, hydraulically driven centrifugal fan produces airflow for all the air tubes. A Rawson hydraulic drive was mounted on the frame to drive the fluted metering rollers. A John Deere 6220 was used to pull the applicator and provide hydraulic power. A computer with the program AgView (AgView, 1999) installed, Rawson controller, and Trimble Ag132 DGPS receiver were mounted on the tractor to provide VR capabilities for the Gandy Orbit-Air.
Methodology

Four application rates were selected for testing the New Leader and Gandy Orbit-Air. The rates selected were 56, 112, 224, and 336 kg/ha. These application rates are based upon looking at the maximum application rates for murate of potash from the University of Kentucky's Lime and Fertilizer Recommendations (AGR-1, 2002) along with the Tri-State Fertilizer Recommendations for Corn, Soybeans, Wheat, and Alfalfa (Tri-State, 2000) for various crops. For murate of potash, there are instances were more than 336 kg/ha is recommended especially for alfalfa. Further, a high percentage of the granular fertilizer application in the Midwest occurs with blended products such as murate of potash and phosphate. With blended fertilizer, application rates can be well above 336 kg/ha. Therefore, it was decided that the 112, 224, and 336 kg/ha would be representative of the range of application rates for murate of potash in the Midwest and plus be somewhat representative of the amount of material applied for blended fertilizers. The low application rate of 56 kg/ha was chosen to see if these applicators could maintain their distribution pattern and correct application rate. Many spinner spreader manufacturers do not recommend application rates below 112 kg/ha. However, farmers implementing VRT on these applicators will apply under 112 kg/ha. Therefore, the New Leader and Gandy Orbit-Air were calibrated at 224 kg/ha since it was the medium rate between the 112 kg/ha and 336 kg/ha.

All three applicators were calibrated before performing any of the tests. Fulton at al. (2001) provides details about calibrating the Newton Crouch applicator. The New Leader and Gandy Orbit-Air applicators were calibrated at 224 kg/ha using murate of potash. A 1-D row of pans was used for calibration. Adjustments were made according to manufacturers' literature until the desired application rate (224 kg/ha) and distribution pattern were achieved.

The collection pan matrices for the New Leader and Gandy Orbit-Air were developed based on the 2-D pan matrix used by Fulton et al. (2001). Figures 2 and 3 contain the pan matrices for the New Leader and Gandy Orbit-Air, respectively. The width of the pan layouts was based upon the application width. The New Leader had an 18.2 m spread width therefore requiring a 36.6 m width or double the effective spread width (ASAE S341.2, 2000). In the case of the Gandy Orbit-Air, it has a 12.2 m effective spread width but an additional column of pans was added (fig 3) to catch material dispersed beyond the spread width by the deflector plates. The 0-m transverse distance represents the pans that were straddled by each of the applicators during a test run. The applicators were permitted enough area to get up to operating speed and use before entering the testing area at the 0-m longitudinal distance. A 4.5 m and 0.99 m longitudinal pan spacing was used for the New Leader and Gandy Orbit-Air, respectively. Twelve longitudinal rows were used to provide 12 replications for characterizing the distribution patterns at each of
the 4 constant application rates. Similarly, the 12 longitudinal rows were used to quantifying the rate response for these two applicators when changing rates from 112 kg/ha up to 336 kg/ha. Therefore, a total of 5 tests were conducted for each applicator: 4 constant rate and 1 rate change.

![Figure 2. New Leader collection pan matrix for single-pass tests.](image1)

![Figure 3. Gandy Orbit-Air collection pan matrix for single-pass tests.](image2)

The rate change tests (112 kg/ha to 336 kg/ha rate change) for the New Leader and Gandy Orbit-Air were conducted by developing two polygons, which intersected at the 0.0-m longitudinal row of pans (figs. 2 and 3). The polygon to the left or negative distance of the 0.0-longitudinal row represented the 112-kg/ha application rate while all the rest of the pans were in the 336-kg/ha polygon. These two polygons represent management zones and provide a means for characterizing rate changes when moving between management zones that require different application rates. Therefore, a prescription map was developed and loaded into AgView on each applicator to perform the rate change tests. Thus, the overall system latency or rate change
response will be captured and quantified if the rate change to 336 kg/ha occurs before exiting the test pan area.

Upon completion of each test, muriate of potash collected in each pan was placed in individual plastic bags, sealed, and labeled. All samples were weighed back in the lab. The weights were recorded to characterize the distribution patterns for the constant application rate tests and generate surface plots for all test cases. The distribution pattern at each constant application rate was determined by computing the mean along each transverse pan position. The standard deviation was also computed for each transverse pan position for all constant rate tests. The characterized distribution patterns were then used to generate the simulated overlap distribution patterns, using the progressive method outlined in ASAE S341.2 (2000), to assess application uniformity at each of the four application rates for the New Leader and Gandy Orbit-Air. Similarly, the three characterized distribution patterns at 56, 112, and 168 kg/ha for the Newton Crouch spreader (Fulton et al., 2000) were used to generate its simulated overlap distribution patterns. Although only two of the rates used for the simulated overlap analysis for the Newton Crouch were equal to the 4 used for the other two applicators, they still indicate trends and potential errors for the different VR applicators. Finally, surface plots for the New Leader and Gandy Orbit-Air were generated for quantification and compared to the rate change plot reported by Fulton et al. (2001) for the Newton Crouch.

Results and Discussion

The single-pass statistics for the Gandy Orbit-Air and New Leader are provided in Tables 2 and 3 respectively. These tables provide the average distribution patterns for all four rates along with the standard deviation. As expected, the standard deviation on the outside tends to exceed the average since these pans usually only capture a small amount of material, if any at times, especially for the New Leader. Therefore, the addition of a particle or two tends to escalate the standard deviations for the outer pans. The 56 kg/ha for the New Leader showed that the outer two pans on the left side (−18.3 and −16.0 m positions) did not receive any material at all for all 12 replications whereas the outer two right pans received only a small amount of material. The standard deviations tended to increase with an increase in application rate for both applicators.

The 224-kg/ha test for the Gandy Orbit-Air surprisingly produced the highest standard deviations. This surprise exists since the Gandy was calibrated at 224 kg/ha. The standard deviations for the Gandy Orbit-Air did not tend to vary much when looking at the 11 inner pans at all four application rate tests. The consistency in the standard deviations should be expected since it is a pneumatic applicator. The 0.0 m transverse position average for this spreader was lower when compared to the 5 pans on either side of it. This difference occurred for all the tests.

Overall the characterized distribution patterns’ standard deviations for these two applicators were similar to those reported by Fulton et al. (2001) for the Newton Crouch. Fulton et al. (2001) also saw an increase in standard deviation with an increase in application rate. Overall, the standard deviations seem to be within an acceptable range for granular applicators, especially considering the variability of granular fertilizer.

Table 2. Single-pass summary statistics for Gandy Orbit-Air.
<table>
<thead>
<tr>
<th>Transverse Position (m)</th>
<th>56 kg/ha AVG (kg/ha)</th>
<th>Std Dev</th>
<th>112 kg/ha AVG (kg/ha)</th>
<th>Std Dev</th>
<th>224 kg/ha AVG (kg/ha)</th>
<th>Std Dev</th>
<th>336 kg/ha AVG (kg/ha)</th>
<th>Std Dev</th>
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<tr>
<td>-18.3</td>
<td>0.0</td>
<td>0.0</td>
<td>0.2</td>
<td>0.4</td>
<td>0.3</td>
<td>0.6</td>
<td>0.1</td>
<td>0.3</td>
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<td>-16.0</td>
<td>0.0</td>
<td>0.0</td>
<td>2.1</td>
<td>4.1</td>
<td>0.7</td>
<td>1.3</td>
<td>2.1</td>
<td>2.7</td>
</tr>
<tr>
<td>-13.7</td>
<td>6.4</td>
<td>4.7</td>
<td>6.0</td>
<td>6.0</td>
<td>9.1</td>
<td>6.4</td>
<td>25.4</td>
<td>8.3</td>
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<tr>
<td>-11.4</td>
<td>17.5</td>
<td>6.3</td>
<td>29.95</td>
<td>10.6</td>
<td>52.2</td>
<td>21.1</td>
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<td>-9.1</td>
<td>31.4</td>
<td>10.0</td>
<td>60.1</td>
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<td>18.0</td>
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<td>-6.9</td>
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<td>24.1</td>
<td>327.7</td>
<td>25.8</td>
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<td>2.3</td>
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<td>12.8</td>
<td>94.3</td>
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<td>13.8</td>
<td>118.4</td>
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<td>2.0</td>
<td>3.9</td>
<td>0.9</td>
<td>1.5</td>
</tr>
</tbody>
</table>

An easier means for viewing the characterized distribution patterns is by plotting the average patterns for each test. Figure 4 and 5 depict the distribution patterns for the Gandy Orbit-Air and New Leader, respectively. One similarity in these figures is that symmetry exists about the center of the patterns. This evenness is desirable from the standpoint that the same distribution is occurring on both sides. The New Leader does show slight variation on the left side, compared to the right side, especially at the 112-kg/ha rate. But for the most part, the distribution patterns show consistency from side to side.

![Figure 4. Characterized distribution patterns for the Gandy Orbit-Air.](image)

![Figure 5. Characterized distribution patterns for the New Leader.](image)

A problem exists for the Gandy Orbit-Air at the center (0.0-m position) of its patterns. This problem can be seen at the 56 kg/ha and only escalates with an increase in application rate. The exact problem has not been identified but could a result of a restriction in the air tube or feeding problem of material into the fluted rollers for these deflectors at the center of the boom. This applicator also shows peaks occurring at the ±1.4 m and ±4.8 m positions with a valley existing between these locations on each side. This reason for this outcome is unknown but
could be contributed to the actual location of collection pans relative the deflector plate location along the boom. The deflector plates are positioned with a 50.8 cm spacing, which was not, the same spacing used for the transverse pan positions. Therefore, some pans were located directly beneath a deflector plate and others some distance from the center of a deflector when traversing the test area. This concept was not investigated for this manuscript to determine whether pan position relative to the center of deflector plates has an effect on characterizing the distribution pattern from the Gandy Orbit-Air but will be studied. If pan position does influence the pattern outcome, then this would indicate that a boom height adjustment or another modification is required to ensure that the distribution of material is equivalent between deflector plates as directly behind them.

The four distribution patterns from the New Leader showed similar trends in terms of consistency as the Gandy Orbit-Air. More material was distributed at the center of the pattern except at the 112-kg/ha rate. This peak at the center becomes more prevalent as the application rate increases. However, there just seems to be a slight shift in the pattern peak of the pattern for the 112-kg/ha test. The two higher rate tests, the –9.1 m position developed a peak causing the patterns to become slightly irregular from side to side. These patterns could be described as triangular in nature, which is a desirable characteristic since with the correct effective swath width, the overlap of a triangular pattern would generate a uniform distribution of material across an area.

The most noticeable difference between the distribution patterns produced by the New Leader and Gandy Orbit-Air compared to the patterns collected from the Newton Crouch (Fulton et al. 2001), is pattern consistency at the different rates. The Newton Crouch demonstrated pattern shifts (Fulton et al., 2001) while the shape of the distribution patterns for these other two applicators were similar at different rates. Pattern shifts are hard to remedy with simple adjustments of the applicator hardware. However, similar shaped patterns from an applicator could be fixed with an easy adjustment for all patterns. More simply, an applicator pattern shifts will require simultaneous adjustments of the hardware during rate changes (Fulton et al., 2001 and Olieslagers et al., 1997) to maintain the desired pattern whereas distribution irregularity with an applicator demonstrating consist pattern shapes could be rectified with no simultaneous adjustments, rather possibly a one time adjustment.

Simulated overlap distribution patterns provides a better method for assessing the application accuracy these applicators. These overlap patterns provides a means to observe how single-pass distribution pattern variations effects real field operation of these applicators. These were created using the effective swath width reported for each applicator in Table 1. Using these swath widths does not indicate that this would be the optimal swath width for each applicator and at different rates. Figure 6, 7, and 8 provide the simulated overlap patterns for the New Leader, Gandy Orbit-Air, and Newton Crouch, respectively. In theory, the overlap data should produce a horizontal line indicating uniform distribution of material during spreading. The desired application rates are indicated with a since, dashed line in each figure. The desired application level supplies a visible way to observe spread deviations.

Figures 6 demonstrates how with the increase in the amount of material at the center of the pattern for the New Leader causes a peak at the center. However, this peak does not exceed the desired application level for any of the four test rates. The New Leader overlap data shows more deviations from the desired levels with an increase in application rate. The 56 and 112 kg/ha overall patterns are fairly horizontal with slight irregularities for the 112 kg/ha pattern. However, the 224 and 336 kg/ha overlap patterns show peaks at the center with tails on the outside that surpass the desired application level. It is only beyond the ±6.86 m positions that the pattern is greater than the desired level for these two tests. These results indicate that an adjustment at required to the New Leader bed to produce a more uniform application.
Figure 6. Simulated overlap distribution pattern for New Leader.

The results for the Gandy Orbit-Air in figure 7 shows much more uniform distribution of material than the New Leader over all the test rates. The overlap pattern at all four rates tends to center about the desired application level except at the center of the pattern and at the far right. The problem at the center of the overlap pattern was found in the single-pass tests. Correcting the under-application at this point would produce impressive overlap data except for the slight deviation on the right side. The lower two tests seem to produce most uniform results which more variation at the higher two rates.

Figure 7. Simulated overlap distribution pattern for the Gandy Orbit-Air.

Similar results were observed for the Newton Crouch (fig. 8) as with the New Leader. Peaks formed in the middle with tails exceeding the desired level on the outside for the two high rates. These results could indicate trends with spinner spreaders that need to be corrected to provide a more uniform distribution of material. The peaks occurring at the center of the pattern do meet
or exceed the desired application levels for the higher two rate tests for the Newton Crouch unlike what was found with the New Leader. The 56-kg/ha test produced the best results with very little deviation from the desired level.

Figure 8. Simulated overlap distribution pattern for Newton Crouch.

Table 4 presents the overlap data statistical summary. The overall average and CV are reported. The CV’s are all within an acceptable range (< 20%) except for the 168-kg/ha test from the Newton Crouch. A high percentage of the CV’s are below 15%. These CV’s specify an acceptable spread by these applicators. The overlap plots (figs. 6, 7, and 8) tended to show more variation than the CV’s meaning that the CV’s can be used to quantify distribution variability but overlap plots are needed to make good conclusions about the quality of spread. The New Leader and Gandy Orbit-Air applied at slightly lower rates than the desired application level, which can be seen in figures 6 and 7. The under-application with the Gandy can be attributed to the low application at the center of the single-pass distribution patterns. The Newton Crouch under-applied at the 56 kg/ha rate, applied at the desired 112 kg/ha rate, but over-applied at the 168 kg/ha. Therefore, the results indicate that all three applicators need adjustments to improve application uniformity and bring the average application rate closed to the desired level.

Table 4. Simulated multiple pass summary statistics (progressive method).

<table>
<thead>
<tr>
<th>Desired Rate</th>
<th>Gandy Orbit-Air</th>
<th>New Leader</th>
<th>Newton Crouch</th>
</tr>
</thead>
<tbody>
<tr>
<td>AVG (kg/ha)</td>
<td>CV (%)</td>
<td>AVG (kg/ha)</td>
<td>CV (%)</td>
</tr>
<tr>
<td>56 kg/ha</td>
<td>55.2</td>
<td>13</td>
<td>54.2</td>
</tr>
<tr>
<td>112 kg/ha</td>
<td>105.4</td>
<td>12.3</td>
<td>106.1</td>
</tr>
<tr>
<td>168 kg/ha</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>224 kg/ha</td>
<td>212.5</td>
<td>10.2</td>
<td>214.3</td>
</tr>
<tr>
<td>336 kg/ha</td>
<td>320.6</td>
<td>11.6</td>
<td>318.6</td>
</tr>
</tbody>
</table>
The final analysis of this investigation was to quantify the rate change response from these applicators. Figures 9 and 10 present the rate response surfaces from the New Leader and Gandy Orbit-Air, respectively. One note is the test speed of these two applicators (Table 1). The actual time for the rate change was not computed for this investigation. Fulton et al. (2001) reported on the rate response of the VR system on the Newton Crouch. The main conclusion to draw for the New Leader and Gandy Orbit-Air is that the rate response is quick. The Gandy Orbit-Air appears to produce the quickest rate change but its test speed was much slower. However, the rate change response for both applicators is much quicker than the VR system for the Newton Crouch (Fulton et al., 2001). This could be contributed to the much newer hydraulic control valves (Rawson) on the New Leader and Gandy Orbit-Air. The Source Fluid Power control valve was purchased in the late 90’s while the two Rawson systems only a year old. This might not be the full reason for such a difference in response time but newer technology in hydraulic control valves should help minimize time to change hydraulic flow (application rate).

Figure 9. Rate change application surface for the Gandy Orbit-Air (rate change from 112 to 336 kg/ha).

Figure 10. Rate change application surface for the New Leader (rate change from 112 to 336 kg/ha).
Conclusion

Distribution patterns were characterized from three different VR granular applicators at various application rates in order to assess application uniformity. The single-pass, constant rate tests resulted in different patterns from the three applicators. The New Leader produced triangular shaped patterns at all test rates unlike the pattern shifts observed from the Newton Crouch (Fulton et al., 2001). The Gandy Orbit-Air, a pneumatic applicator, produced a fairly uniform pattern except at the center where under-application occurred. The reason for the under-application at the center of the distribution pattern is unknown but needs to be investigated for pattern correction. All the distribution patterns were symmetric about their center with slight pattern irregularities occurring at the higher application rates.

Simulated multiple-pass overlap distribution patterns were developed to better assess application uniformity. The overlap patterns represent field application assuming the operator maintains the specified swath width for each applicator. Spread variability occurred with the spinner spreaders (New leader and Newton Crouch). However, similar patterns occurred with peaks occurring at the center of the overlap patterns for the higher rate tests and tails exceeding the desired application level on the outer edges. The Gandy Orbit-Air produced a relatively uniform overlap patterns expect for the under-application at the pattern center. Slight under-application also occurred on the right side. Summary statistics for the simulated overlap data showed that the Gandy Orbit-Air and New Leader under-applied at all rates. On the other hand, the Newton Crouch slightly under-applied at the 56kg/ha rate, applied correctly at the 112-kg/ha rate, and over-applied at the 168 kg/ha rate. All the calculated CV’s were less than 20% except for the Newton Crouch at the 168-kg/ha test where a CV of 27% was computed. A majority of the CV’s were less than 15% indicating a satisfactory quality of spread or performing at an acceptable level. The calculated CV’s seemed to contradict the overlap plots in terms of spread quality for these applicators. Hence, distribution plots should accompany the calculated CV’s to assess application quality during calibration and any field tests. These results indicate that each of the spreaders needs to be adjusted and recalibrated to improve distribution uniformity and ensure the actual application rate is close to the desired rate.

Rate response tests showed that VR systems on the New Leader and Gandy Orbit-Air were quick. The rate changes for these two applicators occurred much quicker than the VR system on the Newton Crouch (Fulton et al., 2001). One reason for the quicker response time can be attributed to the newer control valves on the New Leader and Gandy Orbit-Air. Future advancements in hydraulic controls should provide even better rate changes for VRT equipment in terms of rate response time.

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