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A Case Study Concerning the Effects of Controller Response and Turning Movements on Application Rate Uniformity with a Self-Propelled Sprayer

J. D. Luck, A. Sharda, S. K. Pitla, J. P. Fulton, S. A. Shearer

Abstract. *The use of precision agriculture technologies such as automatic boom section control allows producers to reduce off-target application when applying herbicides. While automatic boom section control provides benefits, pressure differences across the spray boom resulting from boom section actuation may lead to off-rate application errors. Off-rate errors may also result from spray rate controller compensation for ground speed changes or velocity variation across the spray boom during turning movements. This project focused on characterizing application rate variation for three fields located in central Kentucky. GPS coordinates, boom control status, and nozzle pressure data (at 15 nozzle locations) were recorded as the sprayer traversed the study fields. Control section coverage areas and nozzle flow rates (calculated from the nozzle pressure with manufacturer calibration data) were used to estimate application rates. Results indicated the majority of each field received application rates at or below the target rate, as only 25% to 36% of the area in the study fields received application rates within the target rate ±10%. Spray rate controller lag time appeared to contribute to lower application rates as the sprayer accelerated and higher application rates as the sprayer decelerated as the controller attempted to compensate for changes in sprayer velocity. In addition, as boom control sections were turned off, pressure increases in the remaining sections resulted in higher application rates. Conversely, as boom sections were turned on, spray rate controller lag time may have contributed to lower application rates. Estimated application rate maps were also generated from the data to allow for a visual summary of the potential errors.*

Keywords. *Pesticide application, Precision agriculture, Spray deposition, Variable-rate application.*

Agricultural pesticide application is an essential practice on farms across the U.S. for controlling crop damage or yield loss from fungi, insects, and weed competition. The adoption of precision agriculture technologies such as map-based automatic boom section control has increased considerably in the past few years, particularly for use on self-propelled agricultural sprayers. The primary goal of these systems, when deployed on sprayers, is to reduce pesticide over-application by automatically turning off boom sections (used in conjunction with GPS) as they pass over previously treated areas or areas outside the field boundary. In central Kentucky, a study was conducted to determine the potential reduction in coverage areas for irregularly shaped fields using an automatic section control system at a resolution of approximately 1.0 m (Luck et al., 2010a). The results of this study found that coverage areas were reduced by an average of 16% compared to actuation of the entire boom as one section. In another study using fields of various shapes and sizes, an automatic boom section control system with a control resolution of approximately 6.0 m reduced coverage areas by an average of 6.2% compared to manual control (Luck et al., 2010b).

While these systems have been proven to reduce over-application of pesticides to the total field area, they may simultaneously affect application rates for the remaining boom sections. A study by Sharda et al. (2010) demonstrated that as boom control sections were turned off, pressure increases were noticed in sections that remained on. As a result, higher application rates could be expected from these boom control sections as the spray rate controller attempts to compensate for the control section actuation by reducing flow to the boom. Another finding of this study indicated that as control sections were turned on, there was a significant amount of lag time as the spray rate controller attempted to bring the spray boom up to the proper operating pressure for the desired ap-

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plication rate (Sharda et al., 2010). Reitz et al. (1997) evaluated multiple spray rate controllers and found that most systems could achieve the set application rate within 5 s after a change in operating conditions such as closing boom valves or altering speed, although some controllers required more time.

Another factor that can affect pesticide application rates during spraying operations is the amount of turning required to cover a particular field. A recent analysis of sprayer paths found that a sprayer with a 24.8 m boom could potentially over- or under-apply pesticides to substantial portions of a field when turning (Luck et al., 2010c). This study revealed that in one 35 ha field, 23% of the field area may have received off-rate applications exceeding 10% of the target application rate because of the variation in coverage areas across the spray boom during turning. While potential locations of off-rate errors resulting from sprayer turning movements were estimated by Luck et al. (2010c), a method for quantifying application rate errors would be helpful in understanding both the magnitude and geographic locations of these errors. Over-application of some herbicides such as glyphosate has been shown to reduce plant growth during post-emergence applications to glyphosate-resistant soybeans (Reddy et al., 2000; Reddy and Zablotowicz, 2003). Applying herbicides below a desired rate may lead to yield loss due to weed competition, which has been noted in corn (Cox et al., 2006) and soybeans (Shafagh-Kolvanagh et al., 2008).

The development of variable-rate pesticide application technologies has received significant attention in recent years and could provide solutions to spray application errors. Direct chemical injection is one type of variable-rate application technology that has been proposed as a potential solution for reducing errors from changes in ground speed (Anglund and Ayers, 2003; Biao and Blastreire, 2002; Luck, 2010). Pulse-width modulation (PWM) is another technology that has been studied as a potential option for variable-rate application (Pierce et al., 2001; Han et al., 2001). While sprayer control systems utilizing one of, or a combination of, these technologies are currently being developed, it is our belief that many questions remain regarding the magnitude of pesticide application errors that occur in the field today.

Geographic Information Systems (GIS) have been widely used for displaying spatial data collected from agricultural field operations. Fulton et al. (2003) used GIS tools to model dry fertilizer distribution from spreader vehicles, Giles and Downey (2003) used GIS techniques with a GPS- and sensor-based data collection system to develop quality control maps of spray application, and Lawrence and Yule (2007) created a GIS model for evaluating field application variation of dry fertilizer distribution. These investigations all demonstrate the utility of GIS for analyzing and presenting data for describing application rate errors in the field. To further develop successful technologies (e.g. direct chemical injection or PWM) for reducing application errors, more information is necessary regarding how section control, spray rate controller response, and turning movements in the field may affect the application rate uniformity. Therefore, the overall goal of this study was to demonstrate the extent of pesticide application rate variation that may occur during field application from a self-propelled sprayer with a flow-compensated spray rate controller. Specific objectives were to: (1) generate pesticide application rate maps based on nozzle pressure, boom control section status, and sprayer path GPS coordinates using GIS, and (2) quantify and characterize the estimated application rate data to provide information regarding how sprayer velocity changes, boom control section actuation, and turning movements may affect application uniformity.

Materials and Methods

Sprayer Setup and Data Collection

Data were collected from three fields on a cooperating producer's farm located in central Kentucky. This farm consists of numerous irregularly shaped fields, many of which contain unnavigable grassed waterways. The producer utilized a map-based automatic boom section control system, which eliminated application to areas outside the field boundary and within grassed waterways, and reduced over-application due to spray boom overlap. Each field received a post-emergence treatment of glyphosate to an established soybean crop during the summer of 2009.

The cooperating producer operated a self-propelled sprayer (RoGator 1074, Ag Chem/AGCO, Duluth, Ga.) with a 30.48 m wet boom comprised of 60 nozzles spaced at 51 cm. The automatic boom section control system consisted of an aftermarket control console (ZYNX X20, KEE Technologies, Sioux Falls, S.D.) and a 30-channel electronic control unit (ECU) (Spray ECU 30S, KEE Technologies, Sioux Falls, S.D.). The control console and ECU provided 30 control channels for actuating solenoid valves (TeeJet nozzle valves, Capstan Ag Systems, Inc., Topeka, Kans.) connected to spray nozzle bodies. To maintain adequate flow through the boom, the control console monitored system flow rates using a flowmeter and increased or decreased flow to the hydraulic motor that controlled pump speed. This was accomplished with a proportional hydraulic valve that could be opened or closed depending on ground speed changes or boom section actuations. Spray nozzles were mapped to individual control channels as follows: nozzles 1 through 6 at the left and nozzles 55 through 60 at the right boom ends were controlled via individual channels; nozzles 7 through 12 and 49 through 54 were controlled in pairs; the remaining 36 interior boom nozzles were controlled in groups of three (fig. 1). Effective control section widths were 51 cm for individual nozzles, 102 cm for paired nozzles, and 152 cm for nozzles in groups of three.

The control console was capable of actuating control sections every 0.2 s (5 Hz). The control console also served as the data acquisition system by recording the geographic coordinates at a rate of 1 Hz, with data collected up to 5 Hz (coinciding with boom control section actuations lasting less than 1 s). Reference coordinates were generated at 5 Hz using a real-time kinematic (RTK) GPS receiver (StarFire II, Deere & Company, Moline, Ill.) with a reported accuracy of <2.54 cm (Deere & Company, 2010). At each GPS coordinate pair, the control console also recorded a time stamp along with the control channel states (on = 1 or off = 0) as a 30-bit binary number. The control console began recording these data when any control channel state was on and stopped recording data when all channels were off. These data were stored in a tab-delimited text file.

Pressure transducers (model 1502 B81 EZ 100 PSI G, PCB Piezotronics, Inc., Depew, N.Y.) were installed at 15 nozzles across the spray boom with at least one transducer in each

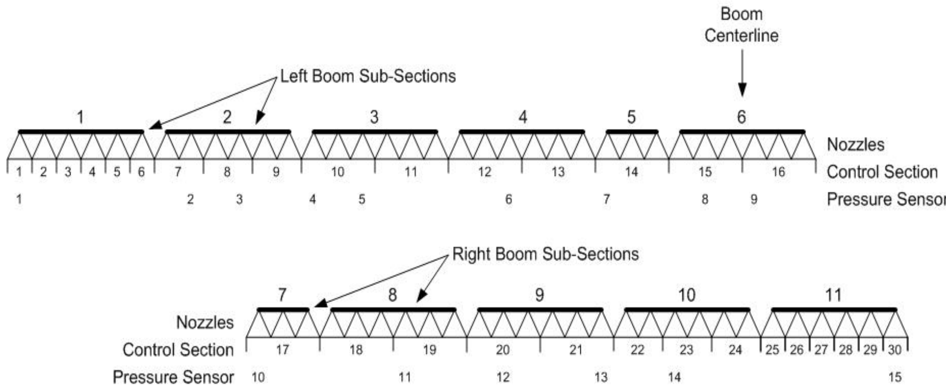

Figure 1. Sprayer wet boom sub-sections (1 to 11), automatic control section nozzle groupings (1 to 30), and pressure sensors (1 to 15).

boom sub-section (fig. 1). The transducers were connected to a data acquisition (DAQ) system for A/D conversion (9221 analog module, National Instruments, Austin, Tex.) to record the voltage output at a rate of 10 Hz for each pressure transducer. A serial module (9870 serial input module, National Instruments, Austin, Tex.) was used to read GPS coordinates (from the GGA string) provided by an additional DGPS receiver (Ag132, Trimble Navigation, Ltd., Sunnyvale, Cal.). The pressure transducer voltage values (14.5 mV kPa^{-1}) were converted to pressure readings (kPa), and these data were written to a text file using a program written in LabVIEW along with the DGPS time stamps logged at 10 Hz. The DAQ system was connected to an external PC (separate of the control console) to implement these procedures.

Data Analysis

The boom control section actuation states and RTK GPS coordinates from the control console were synchronized with the pressure data recorded by the DAQ system by matching the GPS time stamps from both data sets. The combined data set contained entries that included a GPS time stamp, RTK GPS coordinates (NAD 1983 UTM format), control section status (30-digit binary number), and the pressure values from all transducers. Based on methods outlined in detail by Luck et al. (2010c), coverage areas for each control section were calculated between successive GPS coordinates along with the turning radius (R), the turning angle (θ), and the distance traveled. It was necessary to estimate nozzle flow rates based on the pressure transducer data; therefore, calibration curves were developed from data provided by the manufacturer for the nozzle tips used by the producer (TeeJet TT11005, Spraying Systems Co., Wheaton, Ill.). The nozzle flow rate (L s^{-1}) versus pressure (kPa) is plotted from manufacturer data (Spraying Systems Co., 2010) in figure 2. The calibration curve equation (zero intercept) from these data was used to estimate the nozzle flow rate from the pressure transducer readings for the nearest pressure sensor in each control section. Standard calibration curves are typically plotted without an intercept (fig. 2); however, many pressure values below 100 kPa were recorded, and the decision was made to estimate pressure in this region by forcing the curve through the origin.

Application rates were then calculated between successive GPS coordinates by multiplying the estimated nozzle flow rate (L s^{-1}) with the time between coordinates and dividing this value by the control section coverage area (ha). Resulting application rates for each boom control section were recorded (L ha^{-1}) and plotted with the corresponding control section GPS coordinates in ArcMap using methods described by Luck et al. (2010c) to generate estimated application rate maps. Application rates were compared to the target rate (93.5 L ha^{-1}) to determine areas of the field receiving greater or less than this amount. It is important to note that boom section application rate values exceeding 1870 L ha^{-1} (20 times the target rate) were excluded from the analysis. Estimated application rates higher than 1870 L ha^{-1} typically occurred during tight turning movements (<15 m turning radius) and resulted from the estimated nozzle flow rate being divided by a very small calculated coverage area. This inflated the estimated application rates for these control sections to well above 1870 L ha^{-1}; however, this occurred at few places within the fields (primarily field 2 as a result of more turning movements compared to fields 1 and 4). Because this happened over very small coverage areas, which did not contribute greatly to the distribution of application rates versus the percentage of field covered, these values were not considered.

To illustrate the effects of boom section actuation, sprayer velocity changes, and turning movements on the estimated application rates, it was necessary to calculate additional parameters from the field data. The sprayer velocity was calcu-

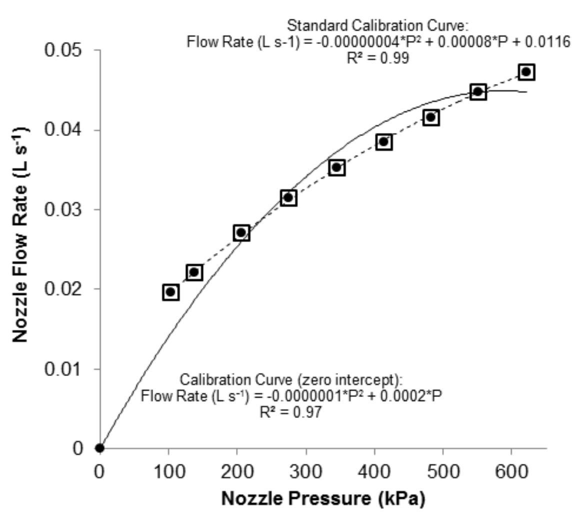

Figure 2. Calibration curve for estimating nozzle flow rates from nozzle pressure sensor data with standard calibration curve (non-zero intercept) from manufacturer data.

lated as the distance between successive GPS coordinates divided by the difference between the corresponding time stamps. Sprayer acceleration was estimated as the change in velocity (calculated at each GPS coordinate) divided by the difference in the time stamps. To quantify variation across the spray boom, the standard deviation was calculated from the estimated application rates for all boom control sections that were on at each GPS coordinate. Finally, the control section application rates and standard deviation were averaged across the spray boom for comparison with the parameters mentioned above.

To highlight the effects of spray rate controller response on estimated application rate, four scenarios were chosen for discussion. Scenarios A and B represented the sprayer decelerating and accelerating, respectively, with little or no boom section actuation. Scenario C illustrated the sprayer traveling at a constant velocity as boom sections were actuated off, while Scenario D consisted of an area where the sprayer traveled at a constant velocity as boom sections were actuated on. For each scenario, the sprayer velocity and average spray boom application rate were plotted versus time to illustrate the changes in estimated application rates.

Results and Discussion

Application Rate Distribution and Mapping

The variation in estimated application rates can be seen in figure 3 for fields 1, 2, and 4 where these data were plotted for each control section. The data shown in figure 3 highlight the locations where the estimated pesticide application rates may have been affected by factors such as spray rate controller response to boom control section actuation and ground speed changes or from sprayer turning movements. Estimated application rates were divided into five ranges to classify the variation in pesticides applied across each of the study fields. Figure 4 illustrates the distribution of the application rate versus the percentage of the field area receiving those rates. It should be noted that the target application rate set by the producers was 93.5 L ha^{-1}, and the range of 84.2 to 102.9 L ha^{-1} represented the target rate ±10%. GPS accuracy (<2.54 cm) could have contributed to an error of up to 2.5% of estimated application rates. This was based on a sampling time of 0.2 s; error would have been reduced as GPS coordinates were logged at intervals of 1.0 s. From the information contained in figures 3 and 4, it is possible to see that the majority of the field appears to receive treatments at or below the target rate set by the producer.

It was interesting to note that the highest percentage of area in field 2 (34.5%) received application at the target rate ±10%. The majority of fields 1 and 4 (36.9% and 36.4%, respectively) received application rates below the target rate

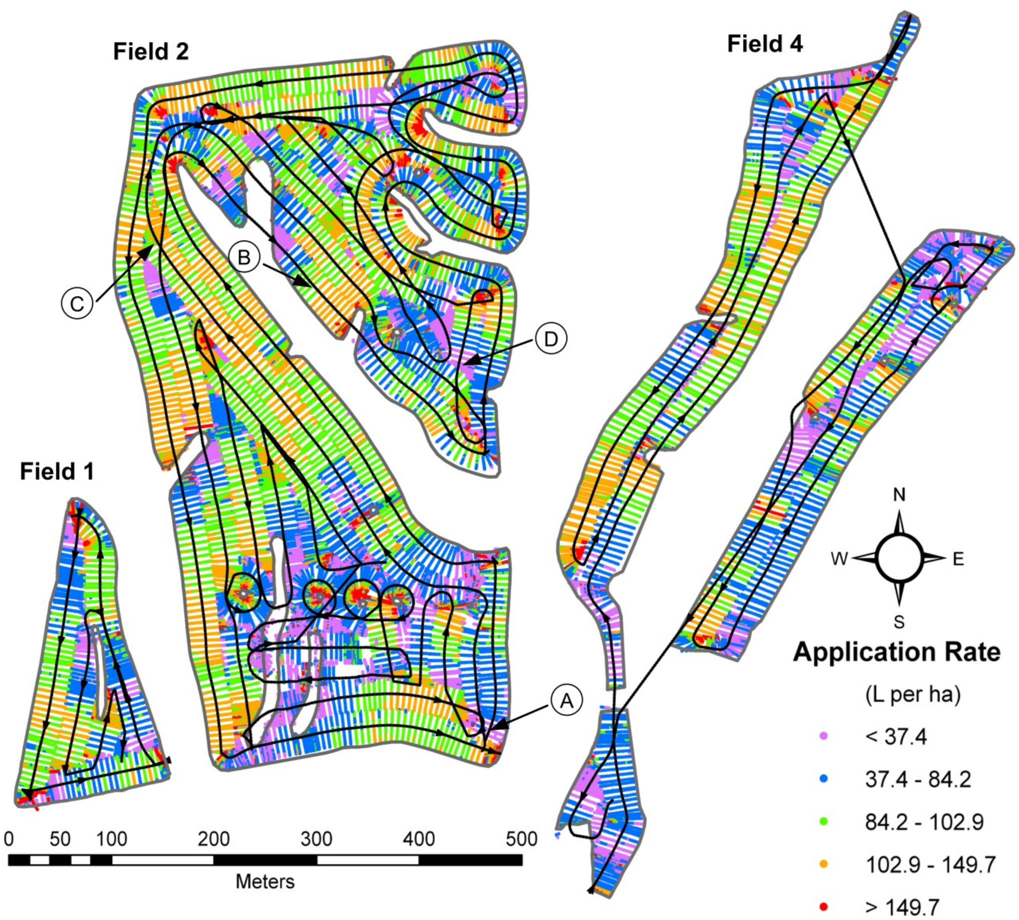

Figure 3. Estimated application rate maps based on nozzle pressure data and sprayer path analysis for fields 1, 2, and 4 with sprayer path and direction in black.

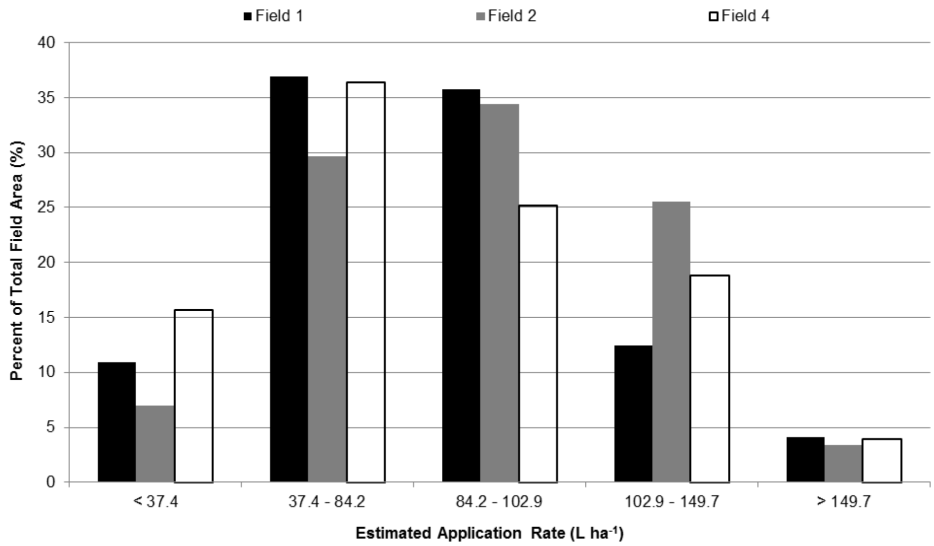

Figure 4. Distribution of field areas covered at the selected estimated application rate ranges.

(37.4 to 84.2 L ha^{-1}). The data in figure 4 indicate that for all fields, application rates were typically lower than the target rate range (84.2 to 102.9 L ha^{-1}) as opposed to higher than this range. It should be noted that over-application resulting from double-coverage (in point-row areas or other instances of spray boom overlap) was not considered in this study. Had this been included, the estimated application rate distribution would likely shift to the right, as slightly more areas of each field would have received higher rates due to spray boom overlap. As the sprayer had control section widths ranging from 51 to 152 cm, any increase would likely have been minimal and in this case (as opposed to a sprayer with larger control sections widths) would not have affected the application rate distribution to a great extent.

Effects from Sprayer Acceleration

One potential cause of application rate variation is the spray rate controller response to ground speed changes. The sprayer control system was configured to maintain the desired application rate regardless of ground speed variation. As previously mentioned, a proportional hydraulic control valve was used to control the pump speed based on feedback from the flow sensor between the pump and the spray boom. Table 1 contains a summary of the field performance data recorded during testing. The average sprayer velocity ranged between 5.0 and 5.56 m s^{-1} for the three study fields, which was likely attributed to the field size and the nature of obstacles (grassed waterways) encountered during application. Maximum error in velocity calculations was estimated at 0.127 m s^{-1} (based on GPS accuracy of 2.54 cm at the minimum sampling time of 0.2 s), which translated to an error of no more than 2.5% compared to average sprayer velocities. Also included in table 1 are the average application rates (across the spray boom) while accelerating and decelerating for all three fields. These data indicate the average application rate was higher as the sprayer was decelerating compared to accelerating across the study fields. This would seem to reinforce the idea that there is some lag time associated with the spray rate controller as it attempts to maintain proper flow to the spray boom with velocity changes.

Scenarios A and B (at locations A and B, respectively, in fig. 3) were isolated to show variation in the average spray boom application rate with respect to changes in the sprayer velocity. Sprayer velocity and average spray boom application rate are plotted versus time (t, s) in figure 5 with regression lines to illustrate the overall trend for these data. In scenario A, the spray rate controller had just achieved the target rate when the sprayer velocity was reduced from 9.0 to 6.0 m s^{-1} to enter a grassed waterway in field 2 (location A in fig. 3). As the sprayer decelerated over the next 5.0 s (with all 30 control sections on), the average application rate increased to approximately 140 L ha^{-1}, at which point the spray boom began to enter the grassed waterway. Scenario A demonstrated that there was lag time as the controller attempted to compensate for deceleration by reducing the flow to the spray boom.

Scenario B illustrates a situation in which the sprayer accelerated as the operator began application to field 2 (location B in fig. 3). As the sprayer accelerated from 3.0 m s^{-1} to just over 6.0 m s^{-1}, all boom control sections were on (with the exception of three nozzles at the right boom end, which were turned off at approximately 5 s). Figure 5 illustrates that as the sprayer accelerated, the average application rate continued to increase as the controller compensated for the increase in velocity, but the target rate of 93.5 L ha^{-1} was not achieved within this period of time. Table 1 summarizes the

Table 1. Summary of sprayer field performance data and application rates during sprayer acceleration and deceleration.

	Average Turning Angle, θ (deg)	Average Sprayer Velocity (m s^{-1})	Portion of Field Area (%)		Average Application Rate (L ha^{-1})	
			Accelerating	Decelerating	Accelerating	Decelerating
Field 1	2.5	5.00	44.7	51.8	8.75	10.64
Field 2	3.5	5.56	49.6	44.4	9.60	11.00
Field 4	2.75	5.35	51.6	45.2	8.06	9.26

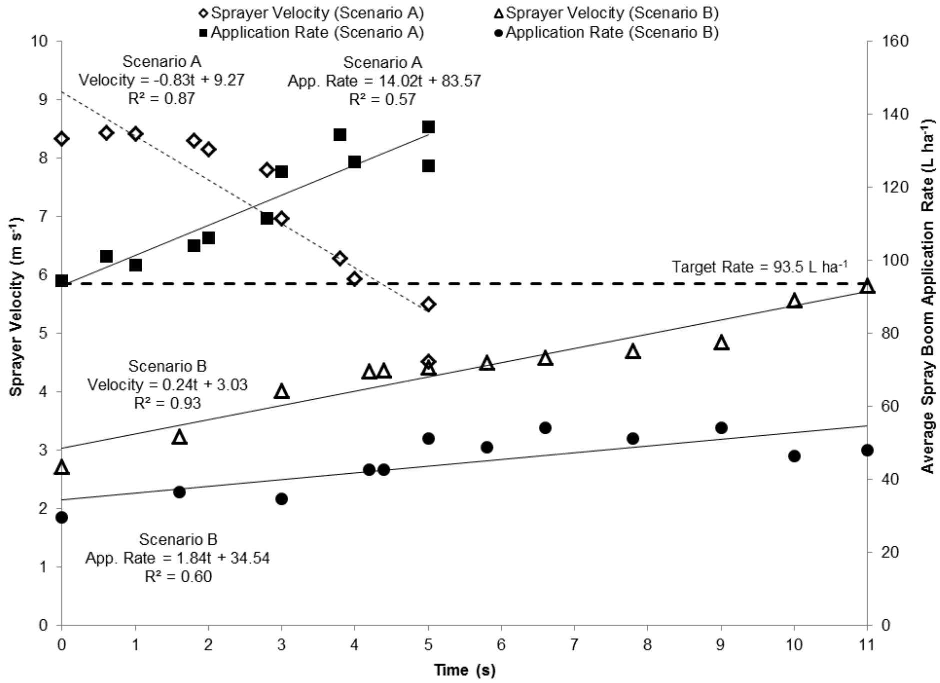

Figure 5. Effects of sprayer deceleration (scenario A) and acceleration (scenario B) on average spray boom application rate.

portions of each field that were treated as the sprayer was accelerating or decelerating and indicates that velocity changes occurred in a large portion of all of the study fields.

Effects from Boom Section Actuation

Another factor that can result in application rate variation may be boom control section actuation. Sharda et al. (2010) noted that as boom control sections were turned on, boom pressure (and therefore nozzle flow rate) dropped, and there was a delay (at times up to 15 s) before the nozzle pressures returned to the necessary operating pressure. To see if similar trends occurred in the data collected, the average spray boom application rate was compared to the cumulative amount of time that the spray boom was on. The cumulative time began any time a control section was turned on and remained on, and ended when all sections were off. When a control section was turned on again, the cumulative time started again. Average spray boom application rates were graphed versus the ranges of cumulative time that the spray boom remained on and are shown in figure 6. From these data, it is possible to see that application rates increased as the spray boom remained on for longer periods of time. In the case of fields 1 and 2, the average spray boom application rate exceeded the target rate for cumulative time greater than 15 s. This information strengthens the findings of Sharda et al. (2010), which suggested that as boom sections remain on for longer periods of time, there is a greater likelihood that the boom will return to the operating pressure to achieve the desired application rate.

In addition to the data in figure 6, scenarios C and D were isolated from the field data to observe the effects of boom section actuation on the estimated application rate (fig. 7). Scenario C (location C in fig. 3) represented the sprayer traveling at near-constant velocity (0.38 m s^{-1} variation from maximum to minimum sprayer velocity) as boom control sections were turned off. At this location, the sprayer passes into point-rows and the boom sections are turned off (from 28 sections to completely off) over a period of 6.0 s (between 3.0 and 9.0 s in fig. 7). During this time, the average pressure readings across the spray boom increased from 375 to 470 kPa. At time zero, the average application rate across the spray boom was just above the target rate. After boom sections began to actuate off, the application rate in the remaining sections increased to nearly 140 L ha^{-1}. These data indicate that boom control section actuation may lead to higher application rates resulting from pressure increases in sections that remain on as the control system attempts to reduce the flow rate to compensate for turning control sections off. This information also reinforces the findings of Sharda et al. (2010), in which nozzle pressure increases were noticed in control sections remaining on as other control sections

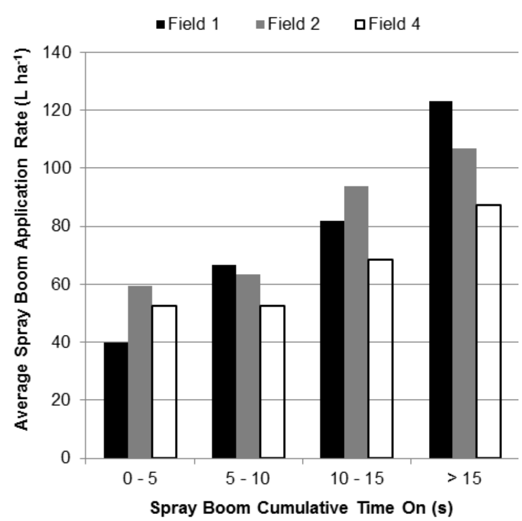

Figure 6. Average spray boom application rate versus selected ranges of cumulative time that the spray boom remained on.

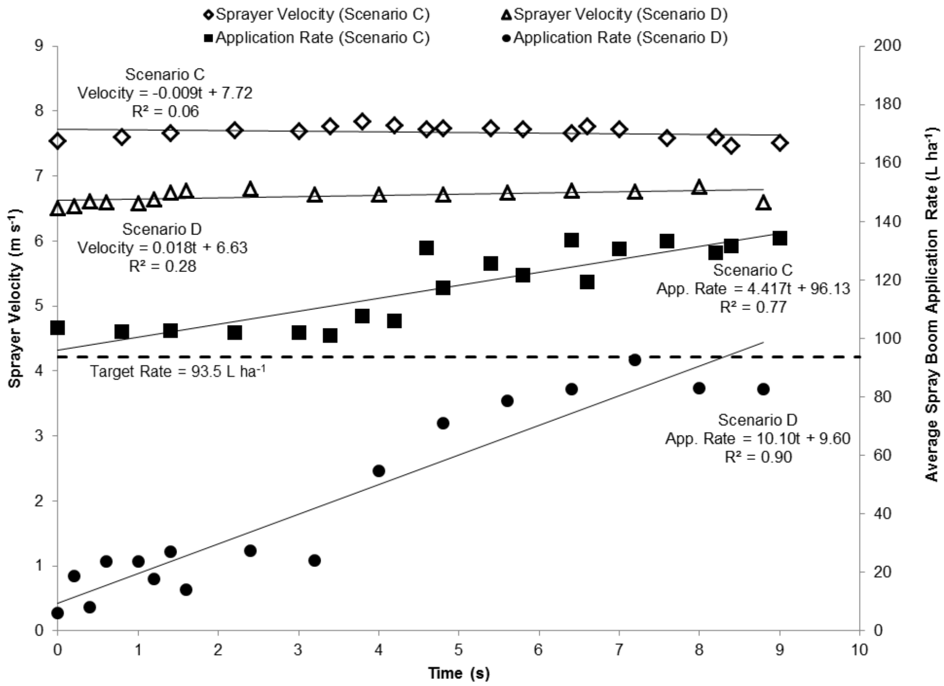

Figure 7. Effects of boom section actuation on average spray boom application rate as sections are turned off (scenario C) and turned on (scenario D).

were turned off. According to Sharda et al. (2010), the control system was able to stabilize pressure in the remaining sections after some period of time.

Scenario D was chosen to demonstrate the spray rate controller response to turning sections on. In scenario D (location D in fig. 3), the sprayer began to exit point-rows at near-constant velocity (0.33 m s^{-1} variation in maximum to minimum sprayer velocity) as boom sections were turned on. At time zero (fig. 7), six boom sections were turned on (beginning at the right boom end) and sections continued to actuate on (toward the left boom end) until 2.0 s, when 29 sections were active. The average spray boom application rate continued to increase for another 5 s, at which point the target application rate was achieved. From time zero to 9.0 s, the average spray boom pressure increased from 36 to 286 kPa. These data indicate that lower application rates may have occurred due to boom control section actuation as the spray rate controller attempted to increase the system flow rate to compensate for turning control sections on.

Effects from Sprayer Turning Movements

As noted by Luck et al. (2010c), application rate variation may occur across the spray boom during turning movements as interior sections of the boom cover less area than exterior sections. The average spray boom standard deviation data are graphed versus turning radii ranges in figure 8 to observe the effects of turning on the application rate across the spray boom. These data show that there was a large amount of variation in application rate across the spray boom for radius (R) less than 15 m (approximately half of the spray boom width). For turning radii between 15 and 30 m, application rate variation across the spray boom was still considerable, close to 40 L ha^{-1} for all three fields. As R increased, application rate variation across the spray boom decreased. The average θ (which is inversely proportional to the average R) is reported in table 1 for all three fields and indicates that field 2 (3.5°) had the most amount of turning, followed by field 4 (2.75°) and field 1 (2.5°).

The average standard deviation in application rate for each boom control section versus the respective distance to the boom centerline (d, m) is plotted in figure 9 to reveal any difference in variation across the spray boom for the three study fields. These data indicate that control section rate variation across the spray boom was more noticeable in field 2 compared to the other two fields. Fields 1 and 4 exhibited little or no increase in variation across the spray boom, which was likely due to the fact that less turning was required to cover these fields compared to field 2. This can be seen in figure 9, where data points for fields 1 and 4 are similar compared to field 2, which increases noticeably with greater values of d. As discussed by Luck et al. (2010c), turning at a constant speed could lead to more coverage at reduced ap–

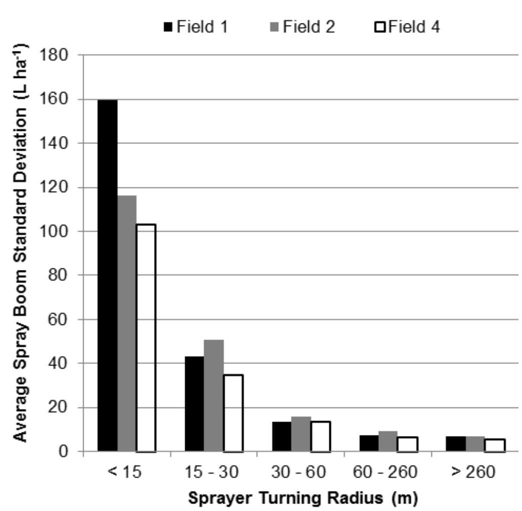

Figure 8. Average spray boom standard deviation in application rate versus selected ranges of the sprayer turning radius.

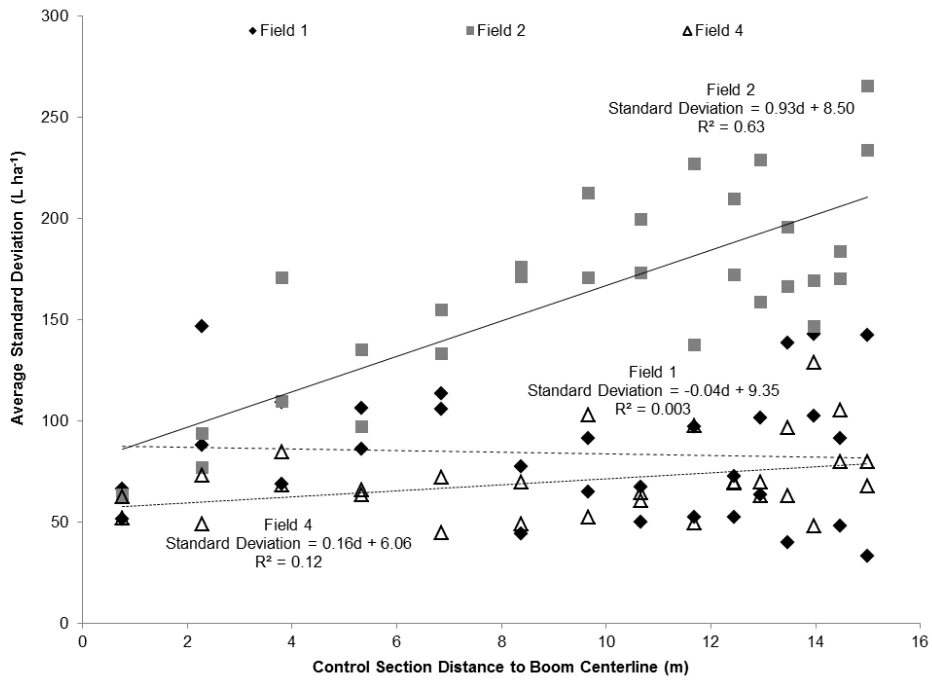

Figure 9. Average boom control section standard deviation versus distance to the boom centerline.

plication rates as the outside of the boom covers more area compared the inside portion of the boom. Based on the information presented earlier, sprayer acceleration and boom section actuation may affect this tendency. If the sprayer accelerates through a turn, application rates may be lower across the spray boom, while decelerating may lead to higher average application rates.

The data presented in this study raise important questions regarding the efficacy of the pesticide in areas where pressure variation, sprayer velocity, or turning movements occur. In Kentucky, it is common for operators to make an initial pass around a field to spray headland areas, a practice that was performed during this study. In this situation, fields with irregular boundaries or grassed waterways may require substantial turning to complete this initial pass (field 2 is a good example of this). As discussed by Luck et al. (2010c), the potential exists for greater application rate variation in fields where substantial turning is required compared to regularly shaped fields where straight, parallel passes are used. Therefore, route selection could play an important role in reducing the effects of application rate variation from turning movements. However, one should recognize that route modifications to improve application uniformity may come at a cost to field efficiency.

Maintaining proper application rates as the sprayer accelerates or boom sections are actuated is a control system function. Based on results from this study, maintaining a constant sprayer velocity would likely improve application rate variation, as the need for control system compensation would be reduced. Components of the control system that may have affected the application rate uniformity in this study would have included flowmeter resolution and type of flow control valve. Future studies into the performance of these system components are needed to better understand control system contribution to application rate errors.

Conclusions

The results from this study indicate that substantial portions of the study fields received application rates that were well above or below the target application rate because of boom pressure variations and sprayer turning movements. Only 25% to 36% of area for the three study fields received application rates within the target rate range (84.2 to 102.9 L ha^{-1}). It appeared that the majority of the fields were covered at application rates below 90% of the target rate, which likely occurred from turning movements and control system delays in adjusting boom flow to the required level, as assessed by measuring nozzle pressures along the boom. Spray rate controller lag time may have contributed to lower application rates as the sprayer accelerated and the controller attempted to adjust boom flow rates for these changes in velocity. Conversely, as the sprayer decelerated, controller lag time appeared to contribute to higher application rates. Results also indicated that the target application rate was more likely to be achieved if boom sections were active for longer periods of time.

Future testing is needed under controlled conditions to isolate the effects of sprayer acceleration and boom control section actuation on boom pressure and ultimately application rate uniformity. This study was conducted with a particular self-propelled sprayer that utilized a hydraulic control valve to control pump speed with a specific spray rate and automatic boom section control system. As other sprayer control systems are available (as well as other sprayers with different spray rate controllers), future tests should also include these systems to provide information on how they react to factors such as sprayer acceleration and boom section actuation.

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