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Evaluation of a variable rate controller for aldicarb application around buffer zones in citrus groves

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Abstract

Advances in precision farming technologies have facilitated controlled application of agrochemicals and documentation procedures to follow environmental regulations. This paper details evaluation of a commercial variable rate (VR) controller for preventing aldicarb applications in the buffer zones around potable water wells of citrus groves. The controller was coupled to two common drive mechanisms, a ground-driven electric clutch-engaged (GDEC) and pulse-width-modulation motor-driven (PWMM). The evaluation involved determination of dynamic performance of the VR application system through quantification of reaction times and rate transition distances and determination of appropriate "look-ahead" times for each of the drive mechanisms. Without a look-ahead (zero) setting, the mean midpoint reaction distances were about 1.8 and 3.6 m for the GDEC and PWMM mechanisms, respectively, at 7.0-km/h ground speed. For the GDEC, a look-ahead time of 1 s gave the mean midpoint reaction distances of −0.06 and 0.04 m during step-up and step-down of the rate, respectively. For PWMM, the best look-ahead times were 1 and 2 s during step-up and step-down of the rate, respectively. However, since the prototype unit could not accommodate two look-ahead times, the compromise look-ahead time for both step-up and -down was 2 s. Validation in the actual buffer zone showed that, at 95% confidence level, the buffer zone should be increased by 2.5 or 3.3 m in commercial applications using GDEC or PWMM systems, respectively.

Keywords: Granular applicator; Variable rate application; Controller; GPS/GIS; Prescription map

1. Introduction

Aldicarb, a soil-applied pesticide, is widely used to control citrus nematodes but its use around potable water wells is restricted by the "aldicarb rule" (http://www.doacs.state.fl.us/onestop/aes/pdf/FloridaAldicarbRule.pdf) set by the Florida Department of Agriculture and Consumer Services. The rule requires a 91.4 or 304.8-m buffer zone, in the normal soils or highly leaching soils, respectively. This buffer zone is more critical in the central Florida "Ridge" area where the soils are sandy, highly permeable, and average precipitation is 125–150 cm/year (http://soils.usda.gov/technical/classification/). The current monitoring application practice requires flagging the buffer zone before application. Application of aldicarb requires a special applicator's license and permits are required prior to application.

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The majority of the applicator units are ground-driven, which power their metering system through the ground wheel, sprocket-chain drives, adjustable gearbox, and electric clutch. Other units use a pulse-width-modulation (PWM) motor drive along with ground speed radar for speed compensation (Miller and Salyani, 2006). However, neither type is equipped to allow automatic detection of buffer zones or provide feedback with regard to actual application of the material. Miller and Salyani (2006) also noted that material could be saved and environmental concerns mitigated if real-time control could be used to provide zero rate application in areas of missing or small trees.

Investigations on automatic control and documentation of aldicarb application started recently as reported by Salyani and Miller (2005) and Miller and Salyani (2006). Both papers describe the instrumentation and implementation of two automatic systems to control application of aldicarb around water wells. They also provide information on the performance and limitations of the application systems. The first system comprised a DGPS antenna and a system status data logger. A second system was developed for data logging and control through a hand-held pocket PC using "Farm Site Mate" version 10.01 software (Farm Works, CTN Data Services, Inc., Hamilton, Indiana). Utilizing a test grid area, the correct-zone classification accuracy of the unit was >89%, with all misclassified points at the boundary transitions (Miller and Salyani, 2006). The above accuracy level corresponded to assumed errors of 1–5 and 0–1 m for DGPS and offset, respectively. Other factors affecting positional accuracy include sampling frequency, well-spotting location, estimate of the boundary, equipment-antenna offset, and product delivery time. Overall, RMS errors were estimated at <2.4 m while RMS errors plus absolute offset resulted in a maximum error estimate of 7.5 m. The two systems represented low- and medium-cost technologies.

The general focus of this study was to evaluate a commercial variable rate (VR) controller, which can be used for application of aldicarb in Florida citrus groves. Fulton et al. (2005) noted that most research on VRT systems has been directed towards hardware and software development and the implementation of these systems. However, work on the accuracy of application and the identification of sources of error in these systems has lagged. Anglund and Ayers (2003) noted that industry use of this new technology is ahead of scientific research that needs to support this technology. A typical VR applicator system integrates components such as a global positioning system (GPS) receiver, software, and the rate controller. The focus of their study was evaluation of a Mid-Tech® Legacy™ 6000 VR controller system for precision farming applications. In many cases, these systems have been placed into the working environment with the assumption that the technology will work properly in a prescribed setting; however, many studies have shown that certain errors exist in VRT systems (Fulton et al., 2003). GPS receivers exhibit position and latency errors, while VRT controllers have limited response time and some steady-state rate error.

Some errors in the VRT can be minimized through hardware and software corrections. For example, by adjusting the initiation time, rate transitions should occur at management zone boundaries, thereby minimizing deviations from the desired rate (Fulton et al., 2005). Anglund and Ayers (2003) noted that to improve field application accuracy, the controller will have to change the desired rate several seconds before the actual rate change position occurs. In evaluating a VR herbicide applicator, Al-Gaadi and Ayers (1999) found that the largest average reaction time was 2.2 s and the highest average application rate error was 2.0%. Most of the application errors were related to travelling from one management zone to another (during transition time). Fulton et al. (2003), investigating the effect of application amount on system response, found that application errors were not rate sensitive. In other words, none of the rate categories, between 0 and 166 kg/ha, appeared to generate larger errors than others. The resulting "as-applied" surfaces showed errors existed especially at the intersection of management zones where rate changes occurred. Variability also existed within zones requiring higher application rates. Anglund and Ayers (2003) found that the change in application rate of a ground sprayer when moving into the next management zone occurred 0.65 s on average prior to entering the zone, and the transport lag (delay time) was approximately 2 s. The advanced time change was stated as due to the 3 s look-ahead. Also, the application errors were within ±2.25%. Molin et al. (2002) reported that the response time for a particular VR fertilizer spinner spreader was 3.1 s for an increasing step rate change and 5.6 s for the decreasing step change. The spreader applied up to 27% less than the desired rate during these tests. These results indicate that different look-ahead times are required to adjust rate changes to the desired location and time. It should be mentioned that typical aldicarb applicator has much smaller material delivery capacity and requires different delay and transition times compared to granular fertilizer units. Fulton et al. (2005) conducted VR tests to quantify the rate response characteristics (delay and transition times) for various VRT applicators. Results indicated that only one applicator had consistent delay and transition times, enabling the use of a single look-ahead time for rate response time correction. The other applicators had longer transition times when decreasing the rate than when increasing it.