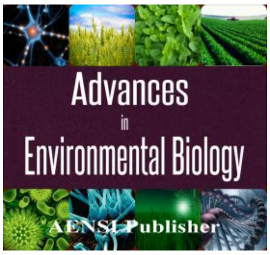
Advances in Environmental Biology, 8(21) October 2014, Pages: 1-8

AENSI Journals

Advances in Environmental Biology

ISSN-1995-0756 EISSN-1998-1066

Journal home page: http://www.aensiweb.com/AEB/



Response Time of a Variable Rate Fertilizer Applicator

[1]Morteza Sedaghat Hosseini, [2]Morteza Almassi, [3]Saeid Minaei and [4]Mohamad Reza Ebrahimzadeh

[1]PhD Graduated student of agricultural mechanization, Department of Agricultural Mechanization, Science and Research Branch, Islamic Azad University, Tehran, Iran
[2]Faculty of Agriculture, Department of Agricultural mechanization, Science and Research Branch, Islamic Azad University, Tehran, Iran
[3]Faculty of Agriculture, Department of Agricultural Machinery Engineering, Tarbiat Modares University, Tehran, Iran
[4]Assistant Professor, Department of mechanic, Shahr-e-Rey Branch, Islamic Azad University, Tehran, Iran

ARTICLE INFO

Article history:
Received 4 September 2014
Received in revised form 24 November 2014
Accepted 8 December 2014
Available online 16 December 2014

Keywords:
Response Time, Fertilizer Applicator, Variable Rate Application

ABSTRACT

Variable rate application of fertilizers can mitigate the pollution caused by their uncontrolled usage. One way to develop variable rate technologies is to convert conventional agricultural implements into variable rate implements using an electronic control system. To do so, a fertilizer application rate control system was developed and mounted on a four-row fertilizer applicator. This system included sensors for travel speed, fertilizer metering gate position, fertilizer metering gate actuators, controller and GPS receiver. This system adjusted the fertilizing rate by changing the metering device gate position. In order to increase the precision of the map-based variable rate fertilizer applicator, its response time was measured in the Farm Machinery Workshop of Imam Higher Education Center. The response is divided into two parts: the mechanical latency time and fertilizer particles fall time from the metering device into furrow. The mechanical latency was measured for application rate changes of 100, 150, 250, 400 and 500 kg/ha (at total working range of metering device) with three replications. The changes in the fertilizing rate were first performed from low to high and then from high to low. The fall delay of fertilizer particles from fertilizer metering device to furrow was measured by an impact sensor at three speed levels (5.3, 5.75 and 8 km/h) appropriate speed range for the applicator operation, in five replications. The advance distance for changing the application rate before reaching the new-rate area on the field was a function of fall delay and mechanical latency of the implement. The mechanical latency was also a function of the difference between the primary and target rates. The maximum and minimum advance distances were 10.81 and 0.46 m, respectively, for 8 and 3 km/h travel speeds

To Cite This Article: Morteza Sedaghat Hosseini, Morteza Almassi, Saeid Minaei and Mohamad Reza Ebrahimzadeh, Response Time of a Variable Rate Fertilizer Applicator. ***Adv. Environ. Biol., 8(21),*** *1-8, 2014*

INTRODUCTION

Every year, more than 2,699,920 tons of chemical fertilizers are consumed in Iran to produce agricultural products [9]. This amount of fertilizers pollutes a large portion of soil and water resources. Precision Agriculture (PA) is a method to mitigate environmental impacts from uncontrolled application of chemicals [5]. Variable rate application of agricultural inputs, as an important part of PA, is capable of minimizing over- or under-application of inputs on every zone of a field [4]. Since there is variability in soil properties (such as fertility, EC, pH, MC), variable rate management of field inputs is required. Research results indicate that soil nutrients largely change within small field areas [1], [6], [7] and [8]. Therefore, agricultural units should be on a smaller field scale, as far as possible. Since operation accuracy is more important than operation width, variable rate application of fertilizers should be incorporated in fertilizer applicators than in fertilizer spreaders.

Variable rate application of inputs can be achieved by two methods: sensor-based and map-based. The sensor-based technique is less-developed as there is a lack of required sensors [3]. The Variable Rate Technology (VRT) is required for PA development. By adding an electronic control system on conventional implements, variable rate implements can be achieved [2]. Most Iranian fertilizer applicators are equipped with a fluted wheel fertilizer metering device [9]. Accordingly, a fertilizer applicator that was equipped with a fluted wheel metering device was selected for this study. Implement response time is an important factor in determining the operation precision of variable rate implements. As the response time decreases while changing

Corresponding Author: Morteza Almassi, Faculty of Agriculture, Department of Agricultural mechanization, Science and Research Branch, Islamic Azad University, Tehran, Iran.
E-mail: morteza.almassi@gmail.com

the application rate, a shorter time period is required to reach the target application rate. In map-based VRT implements, the control unit can be set to start changing the application rate ahead of reaching the new-rate area, applying the target rate once in that area. This advance distance depends on the response time and tractor travel speed.

This study aimed at assessing the response time of variable-rate fertilizer applicator with a single-parameter control system [9] and to determine the required advance distance for field fertilizer application.

MATERIALS AND METHODS

Control System Components:

This system was developed to control the fertilizer application rate of an implement based on its effective parameters (travel speed and fertilizer metering device gate position). This system, therefore, used a number of sensors to measure these parameters and send their data to an electronic control unit, allowing the application of fertilizer based on local requirements of a field. The system consisted of the following:

1-Sensors:

A travel speed sensor and a meter's opening position sensor were used as follows.

A) Travel Speed Sensor:

Although it is possible to determine the travel speed by a GPS receiver, a separate sensor was used because of the reduced accuracy of GPS-determined speeds and the need for speed measurements under simulation conditions (a stationary implement with its ground-driven wheel rotated by an electromotor) during static laboratory tests.

A rotary encoder (model E50S8-100-3-T-24 with 12-24V DC ±5%, Autonics, South Korea) was attached to the ground-driven wheel (Figure 1).

Fig. 1: Travel Speed Sensor.

As the implement moves across the field, the travelled distance is sent as electric pulses to the control unit. The electronic control unit counts the sent pulses within 0.01s intervals, calculating the travel speed by dividing the distance travelled to its time. Since the field surface conditions affects the output accuracy of the travel speed sensor, the mounted sensor was calibrated in a corn field per 10 revolutions of the ground-driven wheel at three travel speeds (3.5, 5.75 and 8 km/h, all within the working range of the applicator) in five replications. The mean number of pulses sent from the sensor for travelling the mentioned distance was calculated. Dividing the mean travelled distance to mean number of pulses resulted in the speed coefficient of the implement which was 1.74 cm of travel per each sent pulse by the sensor. This coefficient was used in the control unit to convert the number of pulses sent by the rotary encoder into field travel distance.

B) Fertilizer metering gate Position Sensor:

A linear potentiometer (model KTC 100, linear travel of 100mm, accuracy of 0.70%, and 3.4 kΩ resistance, made by Hidromatt, Hong Kong) was used as the opening position sensor. This sensor was mounted under the hopper where the end of its axis was connected to the gate's nut (Figure 2).

Fig. 2: Fertilizer metering gate Position Sensor

The sensor's output voltage changes from zero (completely closed) to 5V (completely open) with moving its lever, allowing the control unit to determine the gate position.

2-Actuator:

This actuator features a worm gearbox and a 12V DC electromotor with a gear ratio of 1:15. This gearbox-electromotor set provided the required torque to simultaneously move all four openings (Figure 3).

Fig. 3: Opening actuator (electromotor) of fertilizer meters.

The components that transmit power from the electromotor to the fertilizer device gates included a square-section rotating shaft, four gearboxes, electromotor-shaft coupling, four connections between gearboxes and the threaded shaft of gates, and four nuts connected to openings (Figure 4).

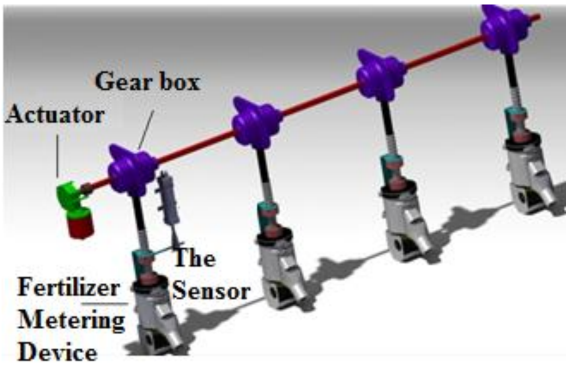


Fig. 4: Electronic Control System Components.

Electromotor power was transmitted to gearboxes through the rotating shaft where the transmission direction was changed by 90 degree. As the square-section shaft rotated, the nut on the shaft causing the gate connected to it to move forward and backward, which, in turn, opened and closed the gate of metering device. This procedure allowed to simultaneously changing the position of gates. The position of all gates where synchronized when nuts were fastened.

3-Electronic Control Unit:

This unit included an electronic board with an AVR Atmega32 microprocessor (Figure 4). Data from sensors were sent to this unit, and AVR analyzed them according to the developed application, and finally took the best decision based on working conditions.

Fig. 4: Electronic board (control unit)

4-GPS Receiver:

To determine the implement's location on the field (geographic coordinate), a GPS receiver (model NEO-5Q, made by U-blox AG, Switzerland) with 2.5m CEP (according to the manual) was used. This receiver featured a module and a magnetic antenna (Figure 5).The antenna was placed at the middle of the implement's working width. NIMEA protocol was also used.

Fig. 5: Picture of the GPS receiver module.

Laboratory Tests of System:

Fertilizer applicator simulation:

Since it is necessary to measure the properties of the variable rate fertilizer applicator (e.g. lag time) under stationary conditions (while working under actual conditions), its working condition were simulated in the workshop. A set of a gearbox and a three-phased 2kW electromotor with continuous variable output speed was replaced for the ground-driven wheel of the variable rate fertilizer applicator (Figure 6). The electromotor drove the ground wheel with a rotary speed similar to when it was moving on the field.

Fig. 6: The gearbox and electromotor collection replaced for the ground-driven wheel

During the laboratory tests and for simulating the travel speed, the rotary speed of the collection output shaft was adjusted in order for the speed sensor to displace the required speed.

Determining lag time of the implement:

The lag time of the fertilizer applicator has two components. First, the mechanical latency or the implement response time, i.e. the time interval between sending the rate-change signal to the fertilizer metering device and the moment its gate is placed in the right position. The second one is the time interval between once the gate is in the right position and the moment the metered fertilizer rate is placed on the furrow surface created by the opener.

The total time required for data processing and actuator response time can be assumed and measured as the mechanical latency, and the time period required for fertilizer particles to reach the furrow surface can be separately calculated as the fertilizer fall delay.

a) Mechanical latency:

The time interval between sending a signal from the electronic control unit to the gate actuator (during application rate change) and the moment the gate reaches the target point (position verification by the gate position sensor) can be measured as the mechanical latency. This time interval was measured for application rate changes of 100, 150, 250, 400 and 500 kg/ha (at total working range of the metering device) with three replications. The changes in the application rate were first performed from low to high and then from high to low.

```
ResT0.00 POT=63 1000
F1=200 R1=56.2  Next
F2=300 R2=82.6  Entr
665----->   440 PREU
```

Fig. 7: The electronic control unit while measuring time lag

b) Fertilizer fall delay:

Another component of the total lag time is related to the time required for metered fertilizer particles to pass the fertilizer metering device and its tube to reach the furrow surface. To measure this time interval, a tube with a magnetic gate at its end was used. This tube was placed vertically in the hopper and 10 cm above the fertilizer metering gate. A teaspoon of fertilizer was poured for each run and a piezoelectric impact sensor was mounted under the opener at 10 cm above the furrow surface (the lower edge of the opener) (Figure 8). In each run, the ground wheel shaft was rotated speeds equivalent to travel speeds of 3.5, 5.75 and 8km/h (within the working range of the applicator). The fall delay, from the hopper to the furrow, was measured through five replications.

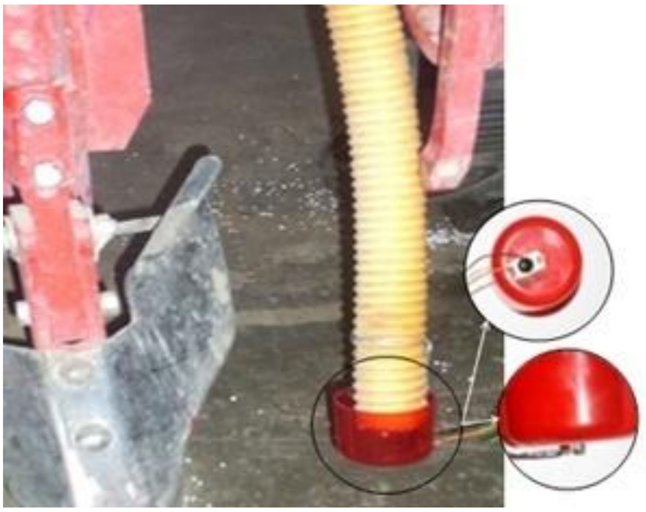


Fig. 8: Impact sensor position.

The total lag time was obtained as the summation of the mentioned two components. The regression relation between the application rate (kg/ha) and the total lag time was determined by SPSS.

RESULTS AND DISCUSSIONS

Mechanical latency:

Since the gate actuators rotate faster when closing than opening, the lag time equation of the implement was higher for the incremental rate change (Figure 9a) than for declining rate change (Figure 9b).

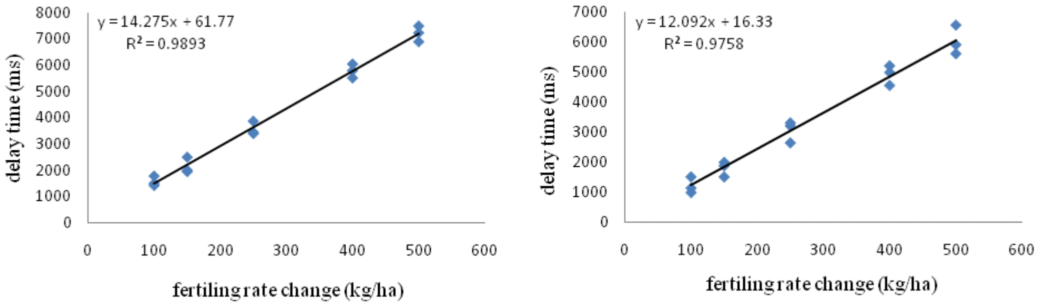


Fig. 9: The mechanical latency measured for 100, 150, 250, 400 and 500kg/ha rates a) measured for low to high rate changes; and b) measured for high to low rate changes.

Larger margins between the current application rate and the target application rate require more time to shift the gate towards the target point and thus increases the mechanical latency. The mechanical latency to change the application rate by 1kg/ha for incremental and declining states was 76.04 and 28.42ms, respectively. In these states, the distance travelled by the implement at 3km/h was 0.063 and 0.023m, respectively. When the travel speed reached 8km/h, this distance was 0.16 and 0.063m, respectively. For instance, if the application rate is to be changed from 100 to 150kg/ha, the time required shifting the gate to the target point is 775.2ms. This time period is equivalent to 0.646 and 1.72m the machine travelled distance on the field at 3 and 8km/h, respectively. When the application rate is to be changed from 150 to 100kg/ha, this distance is equal to 0.51 and 1.38m, respectively.

Fertilizer fall delay:

The mean fall delay time (from fertilizer metering device to furrow opener) was 520ms.

Total response time

The total of mechanical latency and fall delay times determine the total response time. The total response time of the implement is matched with the rate-change step.

The lag time for incremental rate change for 10 and 500kg/ha was 0.88 and 7.74s, respectively, whereas it was 720 and 660ms for the declining rate change. In comparison to results reported by Loghavi and Forouzanmehr (2010) where the reported lag time for incremental and declining rate changes was 0.22 and 0.15s respectively, the single-parameter control system took longer time to change the application rate. Their control system changed the fertilizer application rate by changing the speed of a steppermotor coupled to the fertilizer metering device shaft, resulting to faster rate changes. Note that, although the proposed control system has a large time lag, the implement can continue its operation under fixed-rate application once the electronic control unit stops working (which is an advantage).

System adjustment distance:

To ensure that the required change is made on the application rate once the implement reaches the new rate area, a signal must be sent earlier to the actuator. This advance distance depends on the total lag time and tractor travel speed. On the other hand, the total lag time of the implement indirectly corresponds to the rate-change step. The smallest required advance distance was for the 1kg/ha declining rate change at 3km/h with 0.46m, and the longest distance (9.25m) for the 300kg/ha incremental at 8km/h (Tables 1 and 2).

Table 1: The required advance distance (m) for changing the fertilizer application rate from low to high rate.

Tractor speed km/h						Application rate change kg/ha
8	7	6	5	4	3	
1.32	1.16	0.99	0.83	0.66	0.50	1
2.88	2.52	2.16	1.80	1.44	1.08	50
4.46	3.91	3.35	2.79	2.23	1.67	100
6.05	5.29	4.54	3.78	3.02	2.27	150
7.64	6.68	5.73	4.77	3.82	2.86	200
9.22	8.07	6.92	5.76	4.61	3.46	250
10.81	9.46	8.10	6.75	5.40	4.05	300

Table 2: The required advance distance (m) for changing the fertilizer application rate from high to low rate.

Tractor speed km/h						Application rate change kg/ha
8	7	6	5	4	3	
1.22	1.07	0.91	0.76	0.61	0.46	1
2.54	2.22	1.90	1.58	1.27	0.95	50
3.88	3.39	2.91	2.42	1.94	1.45	100
5.22	4.57	3.92	3.26	2.61	1.96	150
6.57	5.74	4.92	4.10	3.28	2.46	200
7.91	6.92	5.93	4.94	3.95	2.97	250
9.25	8.10	6.94	5.78	4.63	3.47	300

The required advance distance can be determined from Equation 1.

$$D = \frac{V(T_m + T_d)}{3.6} \qquad \text{(Equation 1)}$$

Where, D is the required distance for initiating the fertilizer application rate change prior to reaching the new zone (m); V stands for the tractor travel speed (km/h); Tm is the mechanical latency (s); and Td indicates fertilizer fall delay from fertilizer metering device to the furrow opener (s). This equation was embedded as part of the electronic control unit firmware. In this case, the electronic control unit determined the required distance before reaching each new-rate zone marked in the pre-imported prescription map, with regards to the travel speed and the current-target rates difference, and also signaled the actuator once the implement reached that distance.

Conclusion:

A fertilizer metering device control system was developed and mounted on a 4-row fertilizer applicator. The response time of the variable rate implement was evaluated. The required advance distance for changing the application rate depends on the travel speed, fertilizer metering device adjustment delay, control unit processing delay, fertilizer fall delay from fertilizer metering device to furrow opener, and the current-target rates difference. With each 1km/h increment in travel speed, the advance distance for changing the fertilizer application rate increased by 0.6m.

REFERENCES

[1] Dhillon, N.S., J.S. Samra, U.S. Sadana and D.R. Nielson, 1994. Spatial variability of soil test values in a typic Ustochrept. Soil Technology, 7: 163-171.

[2] Jafari, M., A. Hemmat and M. Sadeghi, 2010. Development and performance assessment of a DC electric variable-rate cotroller for use on grain drills. Computers and Electronics in Agriculture, pp: 56-65.
[3] Loghavi, M. and E. Forouzanmehr, 2010. Design, Development and Field Evaluation of a Map-Based Variable Rate Granular Application Control System. ASABE Meeting Presentation.
[4] Maleki, M.R., H. Ramon, J. De Baerdemaekerand and A.M. Mouazen, 2008. A study on the time response of a soil sensor-based variable rate granular fertilizer applicator. Biosystems Engineering, 100(2): 160-166.
[5] Morgan, M. and D. Ess, 1997. The precision farming guide for agriculturists. Moline, illinois; john Deer Publisher.
[6] Mouazen, A.M., M.R. Maleki, J. De Baerdemaeker, H. Ramon, 2007. On-line measurement of some selected soil properties using a VIS-NIR sensor. Soil Till. Res., 93: 13–27.
[7] Mouazen, A.M., M.R. Maleki, J. De Baerdemaeker, H. Ramon, 2007. Potential of visible and near-infrared spectroscopy to device colour groups utilising the munsell soil colour charts. Biosystem Engineering, 97(2): 131-143.
[8] Raun, W.R., J.B. Soile, G.V. Johnson, M.L. Stone, R.W. Whitney, H.L. Lees, H. Sembiring and S.B. Philips, 1998. Micro variability in soil test, plant nutrient and yield parameters in Bermuda grass. Soil Science Society of America Journal, 62: 683-690.
[9] Sedaghat Hosseini, M., M. Almassi, S. Minaei and M.R. Ebrahim Zadeh, 2014. Accuracy of Two Types of Fertilizer Rate Control System in a Variable Rate Fertilizer Applicator. Advances in Environtmental Biology, 8(12): 306-313.