Development of Variable Rate System for Disinfection Based on Injection Technique

Wei Ma[1,2](✉), Xiu Wang[2], Lijun Qi[1], and Wei Zou[2]

[1] College of Engineering, China Agricultural University, Beijing 100083, China
maw516@163.com.cn, qilijun@cau.edu.cn,

[2] National Engineering Research Center of Intelligent Equipment for Agriculture, Beijing 100097, China
zouw@nercita.org.cn, xiuwang@263.net

Abstract. A variable soil pesticide injection system was developed for control of soil pesticide amount by PWM. The paper analyzed a algorithmic model of control system, and designed hardware, algorithm and control of soil pesticide, mainly software flow and a feedback control way. In the paper, the variable-rate control system was consisted of infrared sensor, speed sensor, PWM valve, and pump motor. According to the amount of soil pesticide information, controller can automatically control flow amount by adjusting solid solenoid valve and PWM valve based on working speed, which changes the pulse duty cycle to achieve the variable work. Injection experiments of soil pesticide was pre-set different dosage, the results shown that pesticide amount was precise in fact, and the errors was less than 3.2 %. The system could achieve variable rate injection of liquid pesticide into deep soil based on infrared sensor. Fitting equation of flow amount by adjusting PWM valve based on working speed could draw the R2 value of 0.935. The chip can calculate the output PWM duty cycle according to the pre-set injection of soil pesticide amount after collected the speed of tractor. The feedback control is to regulate the PWM signal duty cycle according the real liquid flow obtained by the microcontroller chip which collected the output signal of liquid sensor which fixed on pesticide pipeline.

Keywords: Crop protection · Soil-borne disease · Variable rate injection · Control system

1 Introduction

In the suburbs of Beijing in China, greenhouses for agricultural production has developed very rapidly, mainly because of the rapid urban development and the population explosion in Beijing (Wang *et al.* 2008). Many farmers have planted with a variety of tomatoes for many years in the same piece of ground. And there are a lot of similar things. Such soil diseases cause huge losses to farmers, while an enormous impact on produce planting structure of the entire region. Due to a large area of crops reduction caused by continuous soil diseases, farmers abandoned cultivation of eggplant.

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Farmers try to use pesticide on soil disinfection, taking examples as bellow: a. By the method of solution to fill the root with pesticide, but it will reduce the quality of vegetables; b. With the method of changing new soil, but it can lead to cost doubled.

Precision agriculture, is the development trend of future agriculture, and a implementation of a set of modern farming operation technology and management mode, which is supported by the information technology according to the spatial variation, positioning, timing, quantitative (Yao *et al.* 2001). Precision agriculture technology has been used to solve farmers' problems in the greenhouse bases on the outskirts of Beijing. The technology, injecting pesticide directly, makes the storage of pesticide liquid be separated from water, the pesticide liquid, which is controlled by a peristaltic pump, flow into the main water pipe quantitatively to mix with water. It solved the issue of pesticide liquid treatment and equipment cleaning (Landers 1992). Underground spay machinery need to solve the problem of soil environment. Pesticide air jet injector cultivated shovel is a kind of device to inject pesticide into the soil by high-speed air jet. No target spray causes pesticide deposition outside spraying target, it is one of the important reasons of low utilization rate of pesticide. While target spraying is a technology, which identify weeds by the use of near infrared light reflection, to spray selectively with targets through the control circuit and spray system (Cooke *et al.* 1996). It can save 60 %–80 % of pesticide by using target spraying technology (Hanks *et al.* 2009). It is feasible to separate plants and soil by using camera sensitive to near infrared wave band when they studied the reflection characteristics of plant canopy and soil in visible light and near infrared band (Guyer 1996). Fehon designed a kind of photoelectric sensor which identify soil and weeds by sensing reflectance on the weeds and background in the visible and infrared light section, its recognition rate of the soil and weeds is as high as 95 % (Fehon *et al.* 1991). Deng Wei designed an infrared detection system targets based on infrared sensor technologies, different probe group with different coding modulation pulse infrared signal, can eliminate the interference of light paths between probe groups and other light signal (Wei *et al.* 2008). Chen Zhigang measured and analyzed the different influence factors of infrared target detection effect in spray pesticide technology by actual plant, and indicated that plant appearance, light intensity, walking speed of detectors and plant spacing is relatively significant effect on the detection performance, while particularly the effects of plant shape and light intensity (Zhigang *et al.* 2009).

This paper studies the test of soil disinfection by injection technology to develop a variable control system to realize the precise control and variable regulation of soil disinfectant.

2 Experiments and Methods

2.1 Experimental Samples

Experimental crop: eggplant, Bliss tower (Rijk Zwaan seed company, Netherlands), engraftment time is August 20, 2013, planting base is Beisishang village of Da xing district of Beijing (E:116.6295498320, N:39.69441545747).

The test land was being used for eggplant planting from 2011. Using Wang Binglin method to measure the height, fresh weight (FW) and root size of eggplant, the root activity was determined by TTC method. 20 samples were collected on March 31th, 2014, and of which four are infested plant samples by root-knot nematode. The roots of normal plants and diseased plants were measured after excavation. The photograph of real object as shown in Fig. 1. There is visible difference in height and root between the normal and diseased eggplant plant. The left side in picture a is the healthy plants excavated, with large distribution root and high plant. The right side of in picture a is the plants infested by Meloidogyne, with small roots and low plant. It is easy to distinguish due to obvious difference respectively. Picture b is a comparison of roots. It is need to increase the dose for roots will stop growing after illness. Figure c is disease roots measuring. Figure d is normal roots measuring.

a. plant height compare b. root compare c. diseased roots measuring d. normal roots measuring

Fig. 1. The photograph of real object

2.2 Experimental Methods

The experiment was done in two parts according to the plant detection and precision dosage control. For the first experiment, six infrared sensors, 0.5 m, E3F3-DS50N1 (Yueqing city Gaode electric co., LTD, China), was used to get a infrared diffuse reflectance light feed with difference sensor fixed at different heights. Delayed response time is less than 2.5 ms. The part used a group spectral sensors which is to detect target crops. Six sensors was fixed to both front sides of the tractor. The mounting height of the bottom sensor was set to be 220 mm from the ground because the weeds height was not higher than 200 mm.

The second part used PC software processing signals of infrared sensor for target detection and the speed sensor, and calculating the interval of acquisition time, obtaining the data of pesticide volume for different target root and sending it to the lower control computer. PWM was applied by the controller to regulate the dose. The controller calculated out the injection start and end time to control the injection volume.

As shown in Fig. 2. The controller of fixed-point pesticide injection acquires data of target plant and adjusts different volume of pesticide for different target root injected into soil.

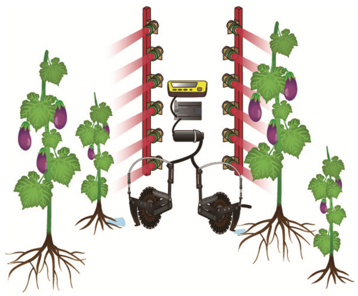

Fig. 2. Infrared sensor for target detection

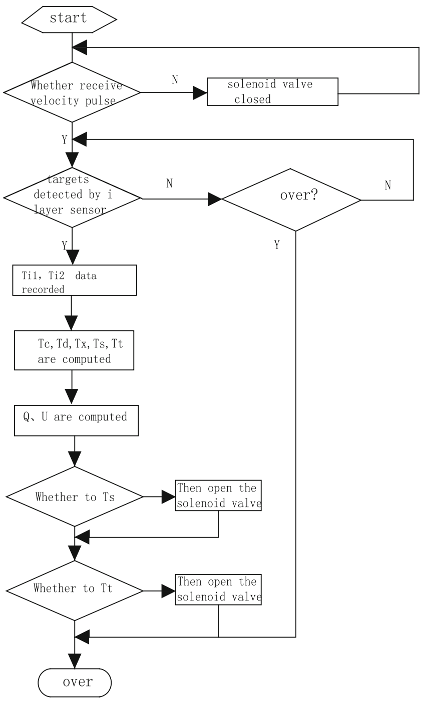

Fig. 3. The flow chart of software

A control system for the PC control software was developed by using SamDraw3.3 development platform (Shenzhen display control automation technology co., LTD). PC software issue commands to control the duty cycle of spraying pump voltage after its calculation base on the data of distance from infrared sensor to the nozzle, the correlation coefficient between the output pulse of wheel speed sensor and the vehicle speed, the transfer function between the biomass detected by infrared sensors and the duty cycle of the solenoid valve on output pipeline, the base reference dosing per plant, the acquisition of biomass signals of the infrared sensor, speed pulse signal of the vehicle speed sensor and quantitative flow rate signal of the flow sensor. The flow chart of fixed-point pesticide injection expressed the logic of control program intuitively. The dose and the injection position is computed out quickly according to this process (Fig. 3).

3 Results and Discussion

The test results were similar to Wang BingLin's results, after 30 days of inoculation, compared to normal eggplant plants, and plant height by infection of root knot nematodes decreased by 9.3 %, stem and leaf fresh weight decreased 18.21 %, and root vigor decreased 26.67 %. A solution for injection into soil of root zone is demonstrated, which is used for crop infected by Meloidogyne detected by six sets of infrared sensor. The six sets of sensors detected targets independently and obtained corresponding scanning signal to each layer separately and sent the signal to the controller. As per circuit theory to analysis, Due to the response time is less than 2.5 ms for sensor to detect the target and the computing time is less than 1 ms for single-chip, the reaction time was very fast. So only one sensor could be used to detect at the same time, interfere with each other could be avoided completely in the actual test with multiple sensors used. Soil variable injection system included disc, plow and injector, and traveled by traction in the field. The outline of the soil variable injection system could be figured out (Fig. 4).

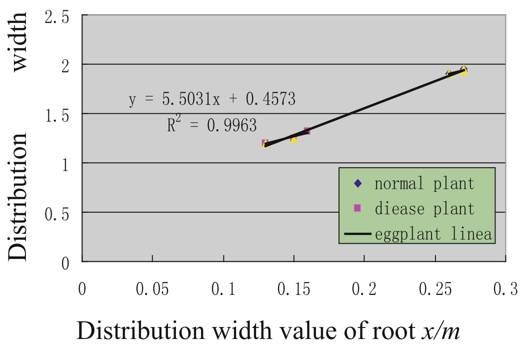

Fig. 4. The relationship between eggplant height and root

In the test, walking speed was 1 m/s, the degree of fit of the actual target signal was not less than 95 % after the signal be treated by controller model, and the relative error was not more than 3.2 % for dosing adjustment by the controller. It is linear relationship between the duty cycle for flow control and per unit of time, the linear regression equation was y = 12.163x + 7.6, where R2 = 0.935. The R^2 gives how much variance is explained by the model in term of overall variance in data. The R^2 is relative measure and is very intuitive. Fitting curve equation of duty ratio and flow linear relationship is y = 12.163x + 7.6, of which $R^2 = 0.935$, R^2 for the quadratic fitting curve equation is 0.9714 (Fig. 5).

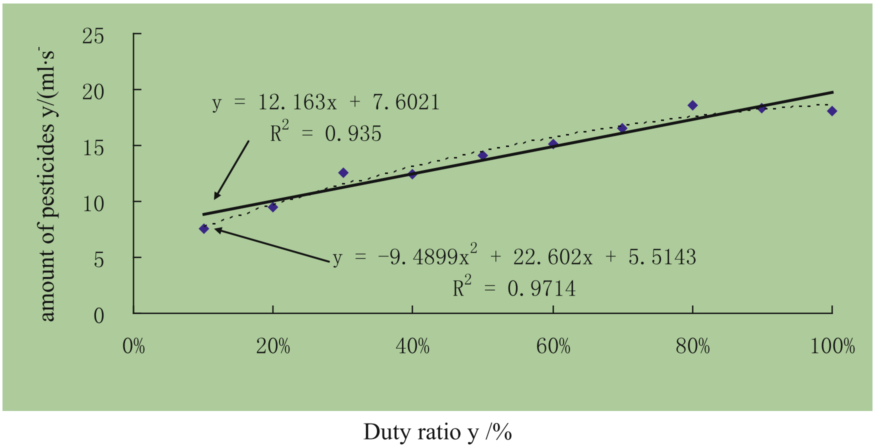

Fig. 5. Linear relationship of Duty ratio and flow

In order to test the precision of the dosing quantitative adjustment module quantitative, the pc controller software sent commands to the lower computer, the lower computer control dose automatically after receiving commands. The test data about the liquid quantitative adjustment are shown as in Table 1 with 3.2 % of maximum error of quantitative adjustment, 0.4 MPa of the maximum system pressure, 3.07 % of error after correction. Duty ratio and flow have a good linear relationship. Fitting curve equation of duty ratio and flow linear relationship is $y = 12.163x + 7.6$.

Table 1. At the pressure of 0.1 MPa, the controller controlled the injection quantity automatically according to the calculated value by PC software.

Set press/MPa	Volume of liquid/(ml)					Relative error/%
	Set volume/ml	Test value 1/ml	Test value 2/ml	Test value 3/ml	Average value/ml	
0.1	50	52.3	50.6	51.9	51.6	3.20 %
0.1	100	107.2	104.5	102.7	104.8	2.47 %
0.1	150	151.3	152.4	153.5	152.4	1.60 %
0.1	200	202	200.3	205.2	202.5	1.25 %
0.1	250	255	250.9	253.6	253.2	1.27 %
0.4	250	239.3	245.8	241.9	242.3	-3.07 %

In order to test the target crop model, time tree was set up. The detect time of start T_{i1} and end T_{i2} for each six layers, the root zone injection time of start T_s and end $T_{t,}$ and intuitive analysis of location and width of the injection zone. If the crop is tilted, the exact injection area of the root zone should be obtained relying on the model. Prediction of relative position of injection range for soil root zone is a very difficult thing. It is a certain uncertainty that the disease severity, of the underground root invaded by root knot nematode, was predicted according to the growth vigor of the target eggplant.

The problem was to be solved in two steps, the first step was to detect target and obtain the height information and position of the branches and leafs. Wherein the height of which was used to determine the prevalence of root crops and to calculate the pesticide amount need to be injected, and the position of the branches and leafs was used to build the computation model of time tree and calculate the injection width of the root and the relative benchmark time point. The second step was dynamic online adjustment of the flow and dose. Wherein the flow was calculated by controller according to the linear relationship to duty cycle, and sent commands to lower computer to realize. And the dose was obtained from the corresponding number of pulse to certain flow volume fed back by flow pulse sensor. Soil variable injection system was traction to travel in the field.

4 Conclusion

From measuring data, a linear relationship could be seen between the diseased plant height and root growth range. The relationship between eggplant height and root could be obtained by measuring the root excavated. And it is linear for eggplant with the same species and planted at the same time.

The relationship between duty and amount of pesticide is similar to linear approximation in experiment. The proposed approach is meant to be used in mathematical model for computing the relative time according to benchmark time point.

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