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A systematic method for quantitative diameter analysis of sprayed pesticide droplets

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Abstract. In this study, a new systematic method for quantitative diameter analysis of sprayed pesticide droplets was developed. This method adopts the screw motion with precision motor and uses the vibration frequency of the precision control technology. With this method, the bubbles contained in the pesticide droplets were eliminated and the generated droplets are no longer adhere to the tip. The accuracy of this method is significantly improved compared with the previously manually operated device. The results indicated that with the calibration coefficient, the error between of the actual droplet size and the preset droplet size value was 97.2%. This newly developed method is very valuable for future studies of droplet distribution over crop leaves for reducing the amount of pesticides sprayed on the crops.

Keywords: quantitative diameter analysis, pesticide droplet, droplet spreading, droplet evaporation, microsyringe

1 Introduction

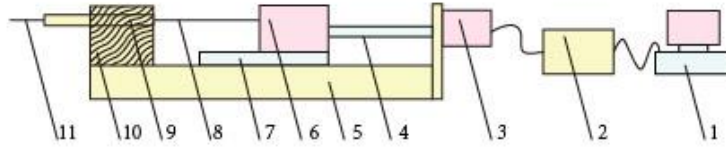
Pesticides are widely used in crop fields as an effective means of pest control for crop growth [1]. However, with extensive use of the chemicals, there are serious consequences. For example, soil compaction due to overuse of pesticides could reduce the fertility of soil to a certain extent, and bring yield loses of the grains. Also, atmospheric and water pollutions from pesticides could have serious impact on the health of humans and animals [2]. After years of studies worldwide, it can be determined that the off-target drift of pesticides has become one of major sources of the issues mentioned above [3]. The studies have been conducting to characterize the pesticide droplet micro behavior on plant leaf surface to reduce the stress caused by

the spray drift. How to precisely determine droplet size is one of the research focuses by scientists and engineers of application technology. How to remove bubbles in the spray liquid drops is an issue to impede the study. At present, there is no instrument capable of generating pesticide droplets with specified particle size. There is no report that the instrument can remove the dissolved air bubbles in the liquid drop either [4]. The droplets are mostly still generated manually [5-9]. Because of the limited experimental means, the research accuracy about the diffusion of the pesticide droplets and the evaporation of the single droplet in practice for crop production management is limited. [10-14]. This paper is mainly to explore a kind of systematic method for quantitative diameter analysis of sprayed pesticide droplets. Specifically, this study developed a device for generating sprayed pesticide droplet with specified diameters with the method for quantitative diameter analysis of sprayed pesticide droplets to address the issues mentioned above.

2 System and Method

2.1 Experimental Device

Fig. 1 is the structural diagrammatic sketch of the device for generating the sprayed pesticide droplets with specified diameters. Because there is no instrument capable of generating pesticide droplets with specific particle size and the studies about the diffusion of the pesticide droplets and the evaporation characteristics of the single droplet have not been developed in practice for crop production management, this study developed a device for generating sprayed pesticide droplets with specified diameter with a sliding component positioned on a track and capable of sliding along the track. One end of the slider is connected with one end of a piston. The other end of the slider is connected with a driving motor through a lead screw. The other end of the piston can move in a droplet generator along with the sliding of the slider and the droplets in the droplet generator are released by a guided pipe. The droplet generator is clamped on a supporting structure. A vibration unit for removing bubbles in the droplet generator is further arranged on the structure. The vibration unit includes an eccentric counterweight module and a buffer module connected with the eccentric counterweight module. The eccentric counterweight module rotates to generate high-frequency vibration, and the vibration is slowed down to the overflow frequency of the bubbles through the buffer module. The buffer module is made of rubber. The minimal propulsion precision of the piston is 0.2mm.



1: control center; 2: driver; 3: driving motor; 4: lead screw; 5: base; 6: sliding device; 7: track; 8: piston; 9: droplet generator; 10: support; 11: guided pipe.

Fig. 1 Illustrative diagram of the device for generating the sprayed pesticide droplets with specified diameters.

The device further contains a control center and a driver. The driver is used for receiving and obtaining instructions of the control center and controlling the driving motor according to control instructions.

The mathematical equation for specifying droplet diameters is:

$$0.2NS_n = \alpha \Pi D_g^3 \quad (1)$$

where N is the moving distance of the piston; S_n is the cross-sectional area of the extrusion droplet piston and D_g is the diameter of the droplets.

2.2 Experimental Procedure

The method developed in this study can be summarized as the procedure in the following steps:

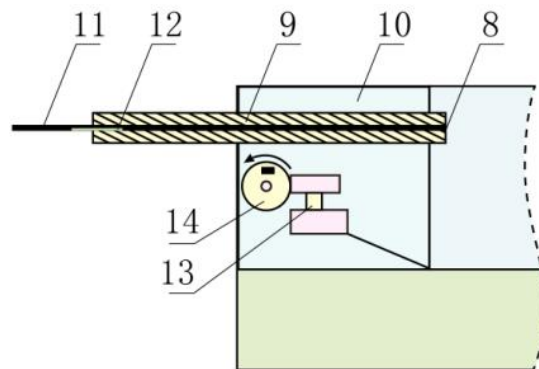
1. Inject chemicals into the droplet generator;
2. Switch on the driving motor for the lead screw to rotate and release one droplet from the droplet generator through a guided pipe;
3. Determine the diameter of the released droplet and calculate the liquid correction coefficient through the mathematical equation (1) with the corresponding diameter of the droplet; and
4. Generating the next droplet with the specified diameter.

Compared with the method of generating droplet by the precision metering pump, this method is based on the spiral movement. The developed device and method in this study have the following advantages:

1. Step motor receive a certain number of driving pulse signal from the control center, and drives the lead screw to rotate;
2. The lead screw drives the slider to a designated position on the guiding track;
3. The exact sizedroplets are generated using adjustable vibration to eliminate bubbles. So research accuracy is improved for diffusion law and evaporation property of plant leaves droplets .

Fig. 3 is the schematic diagram of the developed vibration unit with the enlarged view of the part of the developed droplet generator. Fig. 4 is the work flow of the system.

In the experiments the testing liquid used was rhodamine-B self modulated (concentration is 0.1%). The solution reported in the literature was used to replace the pesticide. Sodium chloride salt solution (2ml packaging, 10%, Guangzhou Pharmaceutical Factory, Guangzhou, China) was used as a calibration..



- 8: piston; 9: droplet generator; 10: support; 11: guide pipe; 12: calibrated scale; 13: buffer module; 14: eccentric counterweight module.

Fig. 3. A schematic diagram of the vibration unit with droplet generator.

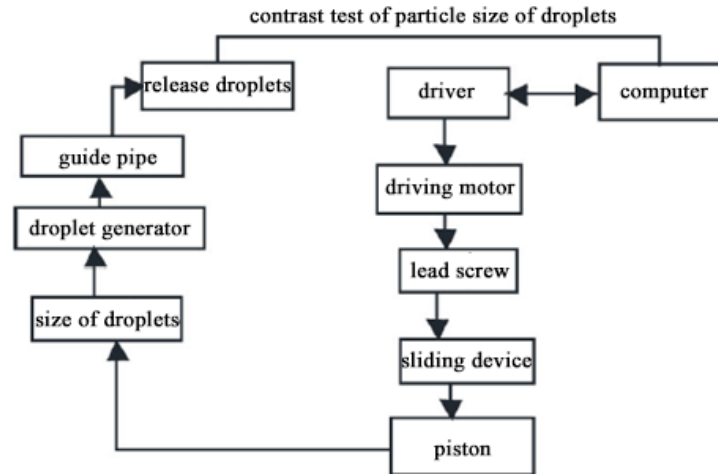


Fig. 4. System work flow.

3 Results and Discussion

3.1 Droplet Generation

The driving motor is connected with the control center through the driver. The driver is used for receiving instructions of the control center and controlling the driving motor to operate according to the control instructions. The control center is a control computer. The computer is connected with the driver through a 232 serial port and used for converting a numerical value of the diameter of the droplets, which is input from the computer, to machine instructions of the device. The instructions are sent by the computer, and the minimal propulsion precision of the piston is 0.2mm.

As shown in Fig.7, single droplet generation can be precisely controlled by the computer, and the precision error is less than 1.5%. The droplets of different particle sizes are continuously generated quickly in the sequence with the rate up to three droplets per second.



(a) Single droplet generation (b) Continuous droplet generation

Fig. 7. Droplet generation

3.2 Accuracy Assessment

The droplets measuring instrument is Oxford Laser Imaging Division VisiSizer N60 (Oxford Lasers, Inc., Shirley, MA, USA). The vibration unit can ensure that one droplet released by the device does not contain bubbles, and the droplets can be released one by one with ensured experimental precision. If bubbles are found in chemicals in the operating process, the vibration unit can be used with an exhaust function, and the bubbles in the droplet generator can be automatically removed by extrusion and vibration. In this way the bubbles contained in the droplets can be prevented from affecting the experimental precision. As shown in Fig.8, the relationship is linear between diameter of the droplets and the pulses of controller driver motor rotation.

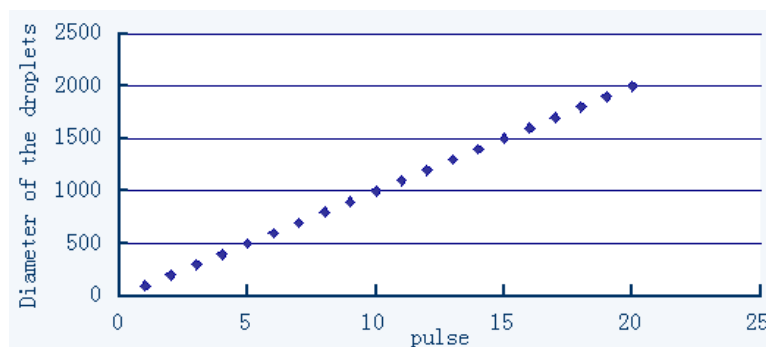


Fig. 8. Relationship between diameter of the droplets and the pulse.

After a user sets the size and the number of the droplets, the computer will send these parameters to the driver through the serial port, and the driver further completes the next two steps:

1. Automatically calculate the volume of the droplets, which corresponds to the diameter of the droplets;
2. Convert the volume into the extrusion distance required for producing the droplets from the droplet generator.

The control instructions are generated after calculation, and the instructions are sent to the driving motor. The driving motor rotates to drive the slider to move on the track. According to the instructions of the driver, the slider drives the piston to be slowly inserted into the droplet generator, and the insertion distance is precisely controlled.

The piston of a probe needs to advance 1mm to generate the droplets of 200he. Generally, the minimal advancing precision of the piston is 0.2mm.

Preferably, a calibrated scale is further arranged on the droplet generator. In the volume movement of the chemicals, whether the bubbles exist or not, other problems can be observed very conveniently through scale marks on the calibrated scale. If the bubbles exist, the bubbles can be automatically removed through the operation of the vibration unit, and then the bubbles contained in the droplets can be prevented from affecting the experimental precision.

3.3 Method calibration

The system interferences and the error due to bubbles would affect the experimental precision. The droplet is calibrated by continuous generation from large to small droplets, every 3 seconds to generate a different size of droplet. In the different sizes of droplet dripping down the moment, droplet size has been measured by the droplets measuring instrument. And then, in accordance with the droplet size from big to small order by reverse and regression method, the same number and size of droplets were generated. The results of the test can be drawn in Figure 9. Our study indicated that if the control algorithm is calibrated, the system can be with an improved control accuracy up to 97.2%.

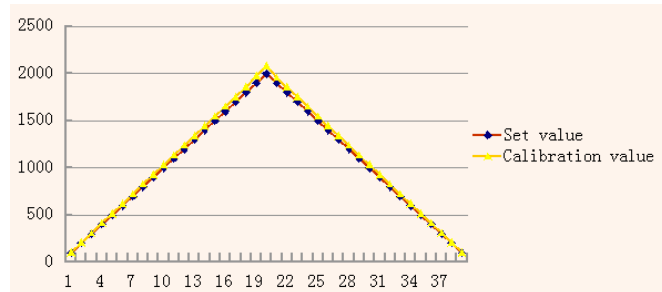


Fig. 9. Comparison of the calibration measurement value and set value

4 Conclusions

In this study, a computer-controlled mechanical compression device is used to generate pesticide droplets with specified sizes. The system performance of eliminating air bubbles in extrusion-accurate diameter droplets of pesticide was studied with a large amount of calibration data. Through this study the main conclusions are drawn as follows:

(1) The best value of the driving motor screw feeder controlled by a center motor rotation is 0.2mm. (2) The movement of the piston is affected by the vibration frequency of eccentric counterweight module. The slower the piston moves along with the sliding device, the smaller the error is.

(2) The experimental results indicated that high frequency vibrations were helpful to generate extruded non-stick droplets. Mainly because of the droplet adhesion to the tip, the module can make it fall.

So the method could be better used for studies on droplet evaporation in the tests using water-sensitive paper and other tests of the properties of the pesticides with broad application prospects.

Acknowledgment

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