Bulgarian Chemical Communications, Volume 48, Special Issue D (pp. 340 – 344) 2016

Effect, comparison and analysis of pesticide electrostatic spraying and traditional spraying

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Received February 14 2016, Revised April 6 2016

The plant protection effect takes up 20% of high yield factor in the practice of agricultural production, wherein the use of pesticide is an extreme important means in the agricultural production. The pesticide spraying technique and level have a direct bearing on the effective utilization of pesticide. This paper drew a conclusion from the contrast experiment of electrostatic and traditional spraying that: electrostatic spraying decreases the droplet diameter and droplet spectrum and at the same time, it increases the droplet evenness. The electrostatic spraying could also increase the blade droplet coverage rate, especially on the obverse side of target crop blade, where the coverage rate is relatively obvious. The coverage rate on the reverse side is also increased, its level is limited.

Key Words: Plant protection, Electrostatic spraying, Traditional spraying, Droplet diameter, Droplet spectrum.

INTRODUCTION

China's pesticide application technique has suspended on the traditional high-capacity and large-droplet spraying technique level [1]. Few pesticide are stuck to the surface of plants and the vast majority of them may flow or scatter on the ground [2-6]. It causes the effective utilization of pesticide to be 20%~30% and less than 1% pesticide would be actually sprayed inside of the pest body [7-10].

The effect of sprayed pesticide depends on three factors: the redistribution of droplet or powder on the plant surface and inside of the plant canopy, activity habits of pests (whether they are exposed to pesticides) as well as the physical properties of pests. As a result, improving the effect of spraying pesticides has an important realistic meaning to reduce the costs (manpower, pesticide, energy, time), improve the prevention effect, cut down the loss of pesticides (to the ground) and lessen the environmental pollution [11-12]. The spraying effect is determined by the atomization quality and sedimentary characteristics.

Utilizing the electrostatic spraying for prevention of crop diseases and pests is a novel technique in the modern plant protection spraying, which well solves the problems in the process of traditional spraying. This paper made some comparisons of electrostatic spraying and traditional spraying through the atomization quality and the sedimentary characteristics.

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CONTRAST EXPERIMENT OF ATOMIZATION QUALITY

The two parameters mainly investigated by the atomization quality: droplet diameter and droplet evenness.

Experimental device

The experimental devices and equipment materials are: Wuxing 3JWB-16A knapsack electrostatic sprayer, Chunshou 3WBS-16A ordinary knapsack hand sprayer, sampling paper, dye, microscope and digital camera.

The purposes of main equipment materials are shown in Table 1.

Experimental process

The reagent this experiment used is a mixed solution of tap water and red ink without impurity.

The sample was collected by the sampling paper underneath of 0.5m away from the sprayer. Wuxing 3JWB-16A knapsack electrostatic sprayer was used for spray sampling first, then came Chunshou 3WBS-16A ordinary knapsack hand sprayer and each test was made for twice. This paper coducted the experimental records and photographing immediately it finished.

Matters needing attention during the experimental process:

1) the sampling speed must be strictly controlled. If the speed is too slow, there would be severe superposition and agglutination phenomenon and poor accuracy of reflected atomization property. If the speed is too fast, the droplets collected may not be enough and lead to an incomplete representation;

Table 1. The purposes of main equipment materials

Equipment Materials	Purpose
Wuxing 3JWB-16A knapsack electrostatic sprayer	Atomization and charged droplets
Chunshou 3WBS-16A ordinary knapsack hand sprayer	Atomized droplets
sampling paper	Sampling for droplets
dye	Dying of droplets for better observation
microscope	Measurement for droplet diameter and droplet coverage rate
digital camera	photographing of experimental results

2) The electrostatic sprayer needs to be charged before the experiment and ensured to be in the turn-off state when completed.

Measurement and calculation of droplet diameter

The droplet diameter is a critical parameter reflecting the sprayer atomization quality, which is because it has something to do with the droplet adsorption and sedimentation capacity. If the droplet diameter is much larger, it could prevent the drift, is beneficial to capture the target crops as well as obtains a better sedimentation capacity, but it has poor coverage evenness and most droplets may fall down into the soil, causing a bad spraying effect and low pesticide efficacy. If the droplet diameter is much smaller, it may be evenly covered on plant surfaces and thus to take full advantage of pesticides. However, the long floating time for some smaller droplets may lead them to be easily drifted with the wind and causes the environmental pollution. For these grounds, the appropriate droplet diameters need to be selected as per the different objects within an optimum particle size range. In this way, the quantity of droplets captured by targets could reach up to a maximum number and thus achieve the optimal control effect. For this reason, it is of great significance to measure and delve into the droplet diameters. Considering that there has no mature theoretical model to calculate droplet diameters at present, so experiment is still a common means to determine the droplet diameters.

This experiment adopted the electrostatic copy paper for sampling. The sampling time was strictly, but the droplets would be diffused to some extent. As a result, in order to close to the actual value of droplet diameter, this paper multiplied the measured data after the diffusion by a coefficient in the process of data analysis. Again, there would be some certain errors when measuring by a microscope, so this paper should use the mean value of several measurements. The trace of droplet on the sampling paper is a roughly circular, so it shall be corrected as the diameter of a sphere. The calculation should be made according to the formula (1) as below:

$$d = kD \tag{1}$$

In the formula,

- d is droplet diameter after the correction, μm；
- D is reading number under the microscope, μm;
- k is correction coefficient.

The correction coefficient was determined by comparing the standard particle value of common spraying droplet and its measurement value.

Calculation of droplet evenness

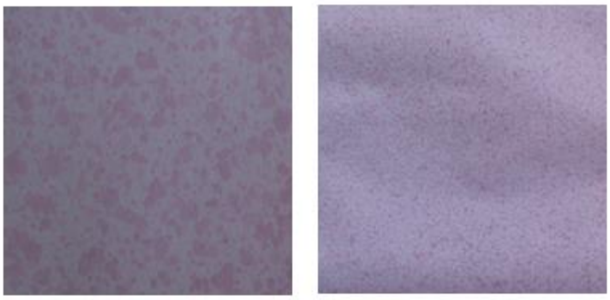
As known as the diffusion ratio, the index of droplet evenness DR is used to represent the degree of dispersion for droplet population size, which is also an important index to measure the atomization quality. DR is the ratio between NMD and VMD, which is given in formula (2):

$$DR = \frac{NMD}{VMD} \tag{2}$$

The closer the droplet evenness value is to 1, the more even the droplet partical size is. If DR is lower than 0.6, it would mean that the droplet partical size generated by the spraying machine is not even and has poorer coverage density and penetrability on the crops. If DR is higher than 0.6, it would be deemed as a relatively optimal evenness.

EXPERIMENTAL RESULTS AND ANALYSIS

Figure 1 presents the samples collected by these two sprayers under the experimental conditions:



a. common spraying b. electrostatic spraying

Fig. 1. Samples collected by these two sprayers experimental conditions.

The conclusion can be intuitively arrived at from Figure 1 that the droplet diameter for electrostatic spraying is smaller than that for common spraying on the average and it also has better droplet evenness. The common spraying may have the phenomenon that the droplets would be converged to greater droplets.

Following the experimental steps, this paper conducted 3 groups of sampling on each sampling paper by the common spraying with 100 points for each time and totally 300 points.

The actual diameters of 300 sampling droplets of common and electrostatic spraying were calculated by employing the measurement method. This paper used Excel to draw the droplet spectrum of common spraying and electrostatic spraying, as shown in Figure 2:

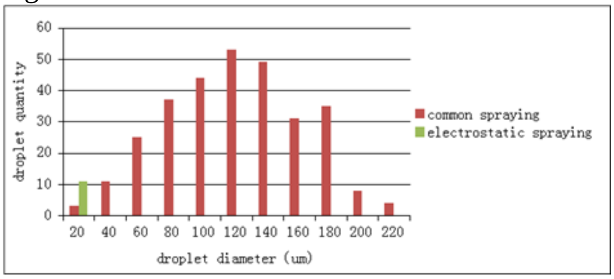


Fig. 2. Droplet spectrum of common and electrostatic spraying.

This paper used Excel to draw a percentage map for the droplet quantity within each diameter level accounting for the total droplet quantity under the common spraying and electrostatic spraying, as shown in Figure 3:

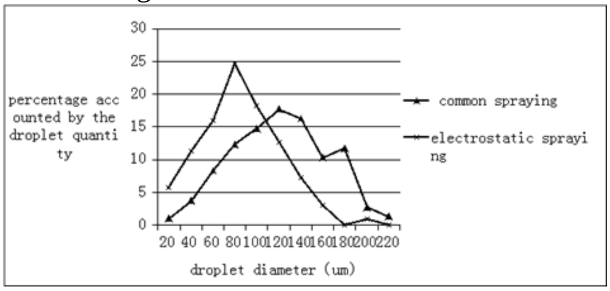


Fig. 3. Droplet percentage of common and electrostatic spraying.

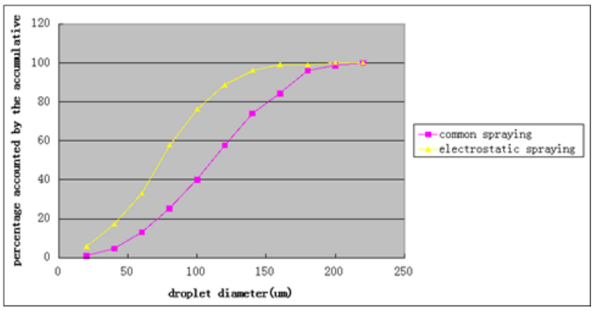


Fig. 4. Solving graph of mean diameter for droplet quantity.

The arithmetic mean droplet diameter d is the mean diameter value of 300 sampling points. Multiplying the summation for diameter values of 300 sampling points by the sampling number is the final arithmetic mean value. The solving graph of mean diameter for droplet quantity is shown in Figure 4.

The accumulative droplet volume was solved by the graphing method as the droplet diameter of 50% of the total volume, which was also the mean diameter of the droplet volume in the experimental device. The solving graph of mean diameter for droplet volume is shown in Figure 5.

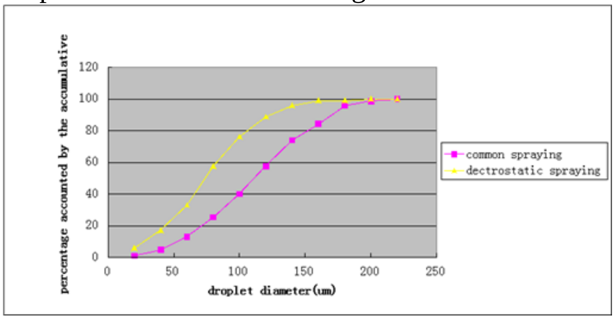


Fig. 5. Solving graph of mean diameter for droplet volume.

The evenness of droplet diameter was calculated according the formula (2), which was also recorded in Table 1.

The concrete data such as the arithmetic mean diameter, quantity mean diameter, volume mean diameter and evenness of all the sampling droplets can be seen in Table 2.

Table 2. Experimental results.

Spraying mode	Arithmetic mean diameter (μm)	Quantity mean diameter (μm)	Volume mean diameter (μm)	Evenness
Common spraying	121	112	165	0.68
electrostatic spraying	85.6	75	104	0.72

CONCLUSIONS

1) By contrast experiment, this paper found that the size of common spraying droplets varies significantly and there are lots of large droplets; while the size of electrostatic spraying droplets varies insignificantly, spraying droplets are distributed more evenly and there are increased droplets with smaller diameters.

2) Through the comparison of droplet spectrums, the electrostatic spraying tends to be narrowed down. For the common spraying, it has droplet distributed at the diameter of 20μm～220μm, while the electrostatic spraying droplets are mainly distributed at the diameter of 60μm～120μm. The droplet quantity would be quite few when the droplet diameter exceeds 160μm. The narrowing droplet

spectrum indicated that the diameter of electrostatic spraying is shrinking and more even.

3) It can be analyzed from the percentage of droplets that, by comparing the peaks for these two curves, the quantity of electrostatic spraying droplets reached to the highest level at 80µm, while common spraying droplets reached to the highest level at 120µm. It indicated that diameters of electrostatic spraying droplets were narrowed down and both of them mainly kept in a normal distribution, i.e. there were many droplets with mean diameter values and few droplets with diameter values of too large or too small. The common spraying curve is smoother than the electrostatic spraying curve, which indicated that the diameters of common spraying droplets are distributed in each level of diameters with fewer differences in the droplet quantity. However, the electrostatic spraying curve was rather pointed at the highest point 80µm, representing that 80µm aggregates its main diameters, wherein such evenly distributed diameters of droplets are required in the spraying process.

4) It can be concluded from the final experimental results in Table 3-2: the arithmetic mean diameters of common spraying droplets and electrostatic spraying droplets are 121µm and 85.6µm, respectively; the quantity diameters of common and electrostatic spraying droplets are165µm and 104µm, respectively; it indicated that the diameters of electrostatic spraying droplets are reduced. The diameter evennesses for common and electrostatic spraying droplets are 0.68 and 0.72. The diameter evennesses for the electrostatic spraying droplets are increased, and the closer the diameter evenness is to 1, the narrower difference the whole droplet is and the better the atomization quality performance is. In a word, the electrostatic spraying has a better atomization quality than the common spraying.

CONTRAST EXPERIMENT OF SPRAYING SEDIMENTATION CHARACTERISTICS

Contrast experiment for the coverage rates of common and electrostatic spraying

This experiment is designed to delve into the coverage rates of common spraying and electrostatic spraying by designing a contrast experiment for spraying sedimentation characteristics.

The coverage rate refers to the coverage ratio between the droplet and target, which is represented by number of droplets per unit area. The formula to calculate the coverage rate is shown in the following (3).

$$CR = \frac{N}{S} \tag{3}$$

In the formula,

CR is coverage rate of droplets, number/cm^2;

N is number of covered droplets;

S is area of sampling paper, cm^2.

Experimental design

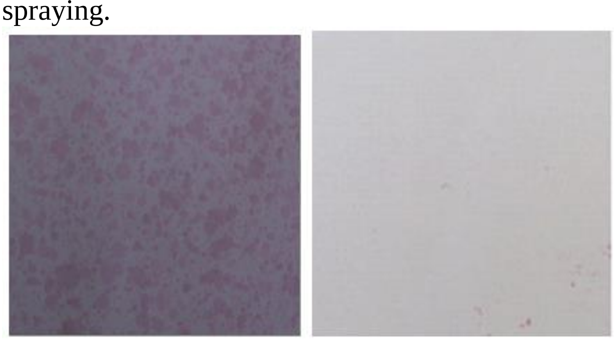
This experiment used the model shown in Figure 6. The number of droplets sprayed on the leaves in the model cannot be easily calculated, so this paper replaces leaves by rectangles cut by the electrostatic copying paper.

The sampling method in this experiment: rectangular copying papers were fixed to the model to represent the both sides of a plant leaf and moved fast at 50cm on the model by a sprayer for sampling during the spraying process.

Fig. 6. Experimental model.

Experimental result of coverage rate

This paper took photos for droplets on the copying papers by a digital camera as soon as the experiment was finished. Figure 7 is the sampling situations of the both sides under the common spraying. Figure 8 is the sampling situations of the both sides under the electrostatic spraying. Figure 9 is the effect of the both sides under the electrostatic spraying.



a. The obseverd side b. The reverse side

Fig. 7. Effects of both sides under the common spraying.

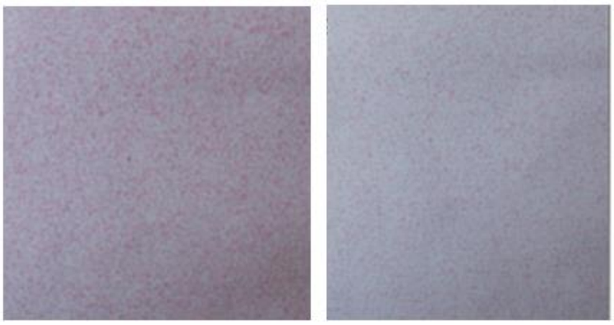


Fig. 8. Effects of both sides under the electrostatic spraying.

Fig. 9. Effects of both sides of a leaf under the electrostatic spraying.

This paper observed the number of droplets on each sampling paper (area of 15 cm^2) with a microscope at the moment the photos were took and recorded the experimental results of the droplet number by sampling groups in Table 3.

Table 3. Droplet coverage rate under common and electrostatic spraying.

Spraying mode	Unit	The obverse side	The reverse side
Common spraying	Number of droplets (droplets)	795	0
electrostatic spraying		1080	165
common spraying	coverage rate (droplet/cm^2)	53	0
electrostatic spraying		72	11

Analysis for experimental results of coverage rate

It can be seen from Table 3 that, under the common spraying, there were 795 droplets on the obverse side and no droplet on the reverse side of the copying paper; under the electrostatic spraying, there were 1080 droplets on the obverse side and 165 droplets on the reverse side of the copying paper. By comparing with the common spraying, the droplet number on both sides of electrostatic spraying was aincreased. At the same time, concering the increase of coverage rate on both sides, the electrostatic spraying was significantly increased on the obverse side, from 53 droplets / cm2 to 72 droplets / cm2, an increase rate of 26.4%, while the coverage rate on the reverse side was added from 0 to 11 droplets / cm2. However, compared with 72 droplets / cm2 coverage rate on the obverse side by electrostatic spraying, it still has a larger difference of 84.7%. Again, the droplets of electrostatic spraying were sedimentated on the reverse side.

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