Research on Influence of Angle of Deflector on Air Flow in Spray Area Based on Numerical Simulation

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Abstract. The movement and distribution of the airflow field of the sprayer are very important for the distribution and penetration of the droplets. It is the focus and difficulty of the research to find the airflow field distribution of the fan outlet that matches the parameters of the canopy of the fruit tree. In order to study the influence of the angle change of the deflector of the orchard air-driven sprayer on the three-dimensional spatial distribution of the external air velocity field, this paper numerically simulated the external flow field based on computational fluid dynamics. The spray requirements of different fruit tree crown shapes were analyzed. The ICEM CFD software was used to model the external flow field. In order to improve the calculation efficiency, the model was divided into mixed grids. The k-ε turbulence model and Fluent solver are used for numerical solution. The flow fields of different deflectors are analyzed, and the influence of different positions and different sizes of deflector angles on the external flow field is determined.

1. Introduction

The air-blast spray technology uses high airflow to drive the droplets, so that the droplets can reach a long-distance target [1]. It is currently widely used in agricultural application and public health disinfection [2]. In the application of pesticides in orchards, the spatial distribution and diffusion of the auxiliary airflow field have a significant effect on the penetration and deposition of fog droplets in the canopy of different positions on the fruit tree [3].

In the traditional test method research, the application process is affected by many factors, especially the uncontrollable field natural wind, air temperature and relative humidity and other factors, so the research effect is not very good. In recent years, with the development of CFD technology, the interference of uncontrollable factors on the test results in field trials has been overcome, and various parameters have been changed as required to obtain test results under arbitrary conditions. Endalew et al. Established an orchard air-fed spray CFD model, studied the influence of sprayer wind speed and direction on spray airflow, and confirmed that the airflow reversed linear attenuation [4]. Delele et al.
Established wind field models of different types of orchard air-feeding sprayers to evaluate the performance of sprayers [5]. Dugaa et al. Established a CFD model of orchard air-fed spray field loss, which can predict and reduce the drift distance by 50% [6].

Due to the complexity of the spatial flow field and the variability of the test conditions, it is difficult to conduct on-site tests, so at present there is no research to reveal the relationship between the air flow field distribution and the outer contour of the fruit tree. Based on the above, this study uses CFD technology to establish a three-dimensional simulation space of the spray field of the new air-driven sprayer, and analyzes the distribution of the external airflow field at different angles of the upper, middle and lower deflectors through simulation. And analyze the relationship between the velocity field change caused by the angle of the deflector and the shape of the canopy, and match the airflow field caused by different angles of the deflector to the shape of the canopy. The research is helpful to guide the sprayer spray parameter adjustment, can achieve better spraying effect, save pesticides, and provide reference for precise application.

2. Introduction of air-blast sprayer and deflector

The air supply system of the air-blast sprayer is different from the traditional air supply system. It adopts the structure of a tower-type air duct. Its wind conveying device draws air from the front of the fan and enters the wind through the tower conveying device with a centrifugal fan inside the road. And automatically distribute the airflow to both sides of the air duct, there are six air outlets on each side, and a wind shield is installed for each two air outlets. In order to change the direction of airflow, a deflector with adjustable angle is installed inside the windshield at each air outlet, as shown in Figure 1. The pesticide droplets sprayed from the nozzle are transported to the leaf surface of the distant plant by the force of the wind. At the same time, after the droplets are ejected from the nozzle, they are mixed with the high-speed airflow in the air channel. The droplets are atomized again and at the same time get a higher speed, so that the droplets are sent to the target.

3. Pre-processing of numerical simulation

3.1. Simplification of the geometric model

In order to simulate the distribution characteristics of the external flow field, this study established the model in ICEM CFD software. The sprayer model has symmetry and considers the efficiency of calculation. In this paper, one side of the sprayer is selected as the simulation area. According to the actual situation of the sprayer working in the orchard, the main body of the external simulation calculation area is a cuboid with a length of 4000 mm, a width of 2000 mm, and a height of 3300 mm, as shown in Figure 2. On the side of the external simulation area is the air outlet of the sprayer, which is simplified 1: 1 according to the actual model of the sprayer.

The schematic diagram of selecting the three-dimensional cross-section of the airflow field is shown in Figure 3. The cross section is selected in three directions in the space field outside the fan to show the spatial distribution of the velocity field. Section a: vertical plane perpendicular to the air inlet
and passing through the center of the air inlet. Section b: a plane parallel to the air inlet and 2000 mm away from the air inlet. Section c: horizontal plane parallel to the ground and 2300mm away from the ground.

3.2. Deflector angle combination and mesh division
The position of the six deflectors is divided into three parts according to the distribution of the windshield, namely the upper deflector, the middle deflector and the lower deflector. There are two angles for the deflector at each position, which are $\alpha = 20^\circ$ and $\beta = -20^\circ$. In order to explore the influence of the change of the deflector angle at a single position on the external airflow field and the movement of fog droplets, we established 16 sets of geometric models according to the combination of the deflector angle, as shown in Table 1.

| Deflector position | Upper deflector | Middle deflector | Lower deflector |
|--------------------|-----------------|------------------|-----------------|
| Angle name         | $\alpha$ | $\beta$ | $\alpha$ | $\beta$ | $\alpha$ | $\beta$ |
| plan 1             | 20      | 20     | 20      | 20     | 20      | 20     |
| plan 2             | 20      | -20    | 20      | -20    | 20      | -20    |
| plan 3             | -20     | 20     | -20     | 20     | -20     | 20     |
| plan 4             | -20     | -20    | -20     | -20    | -20     | -20    |

In order to enhance the efficiency of numerical simulation, a hybrid mesh is selected for division, the wind inlet part and two calculation domains are established respectively, the mesh size of the external watershed is increased, and mesh nodes are merged at the interface of the two calculation domains. In order to enhance the quality of the grid near the deflector, a "Y"-shaped split is performed on the mesh, as shown in Figure 4.
3.3. Solution conditions
According to the airflow conditions of the fan, set the boundary conditions as follows:
1) Inlet: speed inlet, the direction is perpendicular to the air inlet, the size is 50m/s;
2) Outlet: pressure outlet, relative pressure is 0;
3) Wind shield and deflector: set as wall surface, without slip.

4. Air flow field analysis and discussion
Figure 5 shows the change in the distribution of the wind field on section a when the angle of the upper deflector changes. During the angle change of the upper deflector, under the guidance of the deflector, the air flow diffusion area becomes larger, and the directed air flow is mainly concentrated in the area directed by the deflector. When the upper deflector adjusts the angle, it has no obvious effect on the air flow in the middle and lower parts. Figure 6 shows the deflector in the middle mainly affects the distribution of the intermediate airflow field. The velocity distributions of the other three types are almost the same except for Scheme 3, which guides the airflow in the middle in both up and down directions.

![Figure 5: Influence of upper deflector changes](image1)

![Figure 6: Influence of middle deflector changes](image2)
In order to facilitate observation, we selected five straight lines (z = 1600mm, 1800mm, 2000mm, 2200mm, 2400mm) on plane \( a \) as observation lines, and observed the changes in the vertical height of the speed in the application area, as shown in Figure 7-8.

![Figure 7. Curve of upper deflector](image1)

![Figure 8. Curve of middle deflector](image2)

We can see that the velocity distribution is almost the same in the four cases. The effective velocity is mainly distributed between the effective height of 0.6m-2.7m from the ground when the interval is 8m / s-16m / s, which meets the actual needs of the orchard.

Figure 9 shows the change in the distribution of the wind field on section \( b \) when the angle of the upper deflector is changed. In the figure we can see that during the change of the upper baffle, the change of the angle \( \alpha \) will change the height of the airflow. When \( \alpha = 20^\circ \), the height of the spray will increase obviously, so this angle is suitable for a higher canopy Fruit tree. The change of \( \beta \) angle can also lead to the change of airflow height to a certain extent, but the change of index relative to \( \alpha \) angle is small. Figure 10 is the change of the wind field distribution on the section \( b \) when the angle of the middle deflector is changed. From the figure, we can see that the change of the middle deflector relative to the change of the upper deflector makes the overall velocity in the flow field increase. Except for scheme 3, the distribution of the velocity field in this direction is roughly the same, and the change of the deflector makes the velocity field in the middle decrease in width.
Figure 9. Influence of upper deflector changes

Figure 10. Influence of middle deflector changes

Figure 11-12 are the change of the distribution of the wind field on the section c when the angle of the deflector are changed. In the figure, we can see that with the change of two angles, the velocity field distribution in this direction is generally consistent. However, the change of β angle can cause the change of the horizontal speed. When β is a negative angle, the area with large speed increases significantly.

Due to the symmetry of the geometric model, the influence of the lower deflector on the wind field can be analyzed with reference to the upper deflector, which is not discussed here one by one.
5. Conclusion
In this paper, CFD technology is used to analyze the influence of the sprayer deflector on the external flow field distribution characteristics and droplet motion characteristics. When the upper deflector changes, the velocity distribution is almost the same. When the effective velocity is in the interval of 8m/s-16m/s, it is mainly distributed between the effective height of 0.6m-2.7m from the ground, which meets the actual needs of the orchard. The change of the angle will change the height of the airflow. When $\alpha = 20^\circ$, the height of the spray will increase obviously. The change of $\beta$ angle can also lead to the change of airflow height to a certain extent, but the change of angle $\alpha$ is smaller than that of angle $\alpha$. It can mainly change the velocity distribution of airflow in the upper part and the width of the variable airflow.

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