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# PERFORMANCE EVALUATION OF AGRICULTURAL SPRAY NOZZLE UNDER DIFFERENT PRESSURE CONDITIONS BY IMAGE ANALYSIS

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## Abstract

Spray nozzles are critical components in agricultural equipment used for pest control, pollination, and so on. The liquid ejected from the nozzle is broken down into droplets due to friction with the air and pressure changes. Consequently, the nozzle performance is often defined by alternative parameters to estimate the actual operating conditions.
This study aims to determine the operating parameters of spray injection by photographing the movement of droplets ejected from a nozzle under different pressure conditions using a high-speed camera and analyzing the image analysis. In particular, the motion of droplets sprayed under different pressure conditions was recorded as a movie using a high-speed camera. Firstly, the movie was processed to remove unnecessary background, and identify the spray boundary, after which the spray angle was estimated. Secondly, we applied a temporal filtering for the entire movie to select the optimal cutoff time point. The frames at each cutoff point were stacked and the images were binarized to calculate the area covered by the droplets during spray injection. The droplet distribution area was calculated for all pressures in a similar manner. Finally, particle image velocimetry (PIV) analysis was applied to all the movies to estimate the droplet velocity variations and identify high-speed droplet area. The results enable performance evaluation of the spray nozzle.

**Keywords:** particle image velocimetry (PIV), spray angle, droplet velocity, density and size

## INTRODUCTION

Agricultural nozzles often operate for several seconds or keep a few minutes, whatever irrigate or pollination. Therefore, to study the suitable operational duration of a nozzle, it is necessary to establish baseline working parameters by testing. Many studies have also investigated nozzle performance under steady-state conditions, their behavior during the transient start-up phases lasting only a few seconds have been less explored. In this research, we tested an agricultural pesticide nozzle with a pressure setting time of 0.5 s and the pressure range of 200~440 kPa and measured this nozzle's base parameter-spray angle, droplet distribution area and droplet velocity. Our research aims to provide a suitable parameter for short duration spraying operations, to improve spray efficiency and accuracy.

## MATERIALS AND METHODS

The test system was composed of a high-speed camera, a laser sheet lighting device, and a spray unit with several sizes of nozzle. The high-speed camera was used to capture movie of the spray particle scattering characteristics in two focused targeting regions, i.e., the near nozzle (spray distance of 0–15 cm) and the flower regions (spray distance of 21–40 cm). The movies were analyzed by using MATLAB code to identify the spray boundary and calculate the time-variation of the spray angle. Time series images given by the movie were then applied to compute the droplet distribution. Finally, particle image velocimetry (PIV) was used to estimate droplet velocities and its distribution.

## RESULTS & DISCUSSION

The first result concerns the time-varying spray angle. Due to the 0.5 s pressure setting, the full system operation time exceeded 1.5 s. However, only the first 0.5 s were considered relevant for analysis, as the latter part was influenced by residual pressure in the pipeline. The time-varying spray angle data show in Fig. 1. The spray angle decreased with increasing pressure. Additionally, the time variation of the spray angle showed a different tendency at the pressure level of 300 kPa. The spray angle reached nearly constant value after 0.5 s less than 300 kPa, it increased significantly from the initial value.

Next, the sprayed droplets' distribution was analyzed from the high-speed camera images. Since the region near the nozzle was almost filled with the sprayed droplets, the analysis was focused intensively on the flower section. The results at the different cross-sections are show in Fig. 2. The droplets' velocity was assessed at different positions. To ensure that the droplets effectively reached and contacted the target, we only focused on the high-velocity ranges. Within the sprayed droplets' distribution, the maximum velocity was observed at 440 kPa and 0.87 s was 2.49 m/s. This maximum velocity enabled the spray distance over 0.4 m without damages for the flowers. At 200 kPa, the maximum velocity reached 1.26 m/s after 0.25 s. The average velocity after 0.5 s at the distance far from the nozzle part was between 1.03 and 1.58 m/s for 440 kPa, and between 0.53 and 0.62 m/s for 200 kPa.

Based on these results, the maximum value of the effective spray distance of the tested nozzle was between 31 and 40 cm for the pressure range from 200 to 440 kPa. Belong to the spray distribution, the spray system ensured over 35% coverage within the 0.1 m diameter spray range at the target distance under 0.4 m and the pressure more than 300 kPa.

## CONCLUSIONS

We investigated the spray performance for a nozzle under several pressured conditions. The sprayed angle changed from 78.6 to 27.8° after 0.5 s for the pressure range at 200–440 kPa. The sprayed distribution at 30cm far from the nozzle was less than 45% for the area. The sprayed velocity range changed from 2.49 to 0.72 m/s at the region.

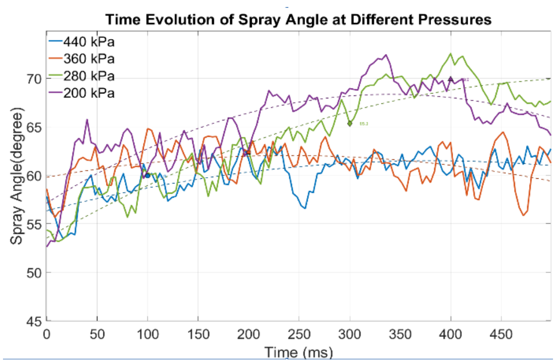


Fig. 1 Time evolution of spray angle at different pressures.

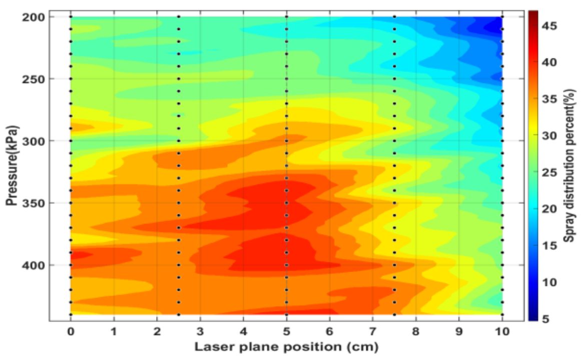


Fig. 2 Sprayed droplets' distribution at the different cross-section in 0.5s.