CFAES

DEPARTMENT OF FOOD AGRICULTURAL AND BIOLOGICAL ENGINEERING

# Air-pinch PWM valve: An alternative to implement variable rate pesticide spray applications

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## INTRODUCTION

### Canopy variability

Specialty crops have great intra-plot variability, with different shapes, canopy dimensions and foliage densities.

This variability makes it difficult for farmers to make the right decision on the amount of pesticides to be applied.

### Intelligent sprayer

The sprayer using laser scanning technology can recognize the variability and adjusts the amount of pesticide as needed for each tree in real time[1].

To regulate the flow rate in real-time, the sprayer uses pulse width modulation (PWM) valves.

### PWM valves

Regulates the flow rate in real time with little change in the liquid pressure and the droplet size by opening and closing the valve, usually at frequencies of 10 Hz and at certain duty cycles (DUCs). DUC is expressed as a percentage of valve opening time, being 100% totally open and 0% close.

Potential problems: Some parts of PWM valves become clogged or moving parts malfunction when spraying some pesticides.

Figure 1. Principal troubles of PWM valves when in direct contact with specific pesticides: interface cap clogged by wettable powder (left), stuck plunger (center), and dirty gasket blocking the closure (right).

### New approach: Air-pinch PWM valves

These valves isolate the internal components of the PWM valve from pesticides by flowing the pesticide through a tube bypassing the valve. The flow rate modulation is processed through pinching the tube with a rod controlled by the PWM valve at certain frequency and DUC.

The maintenance and replacement of the tubes is more user-friendly and economical than those of conventional PWM valves.

## OBJECTIVE

To determine the potential of using the air-pinch PWM valve as an alternative to electric PWM valves for variable rate pesticide spray applications by investigating the flow rate modulation capability and droplet size distribution of hollow-cone nozzles controlled at different duty cycles and operating pressures.

## MATERIALS AND METHODS

### Air-pinch PWM valve

- Made by Spartan Scientific, composed by a solenoid operator and an air spring operated (Fig. 2)
- 12V DC normally-closed valve
- Silicone tube for liquid (OD: 6.4 mm; ID: 3.2 mm)
- Min. air pressure: 414kPa; max. liquid pressure: 827kPa

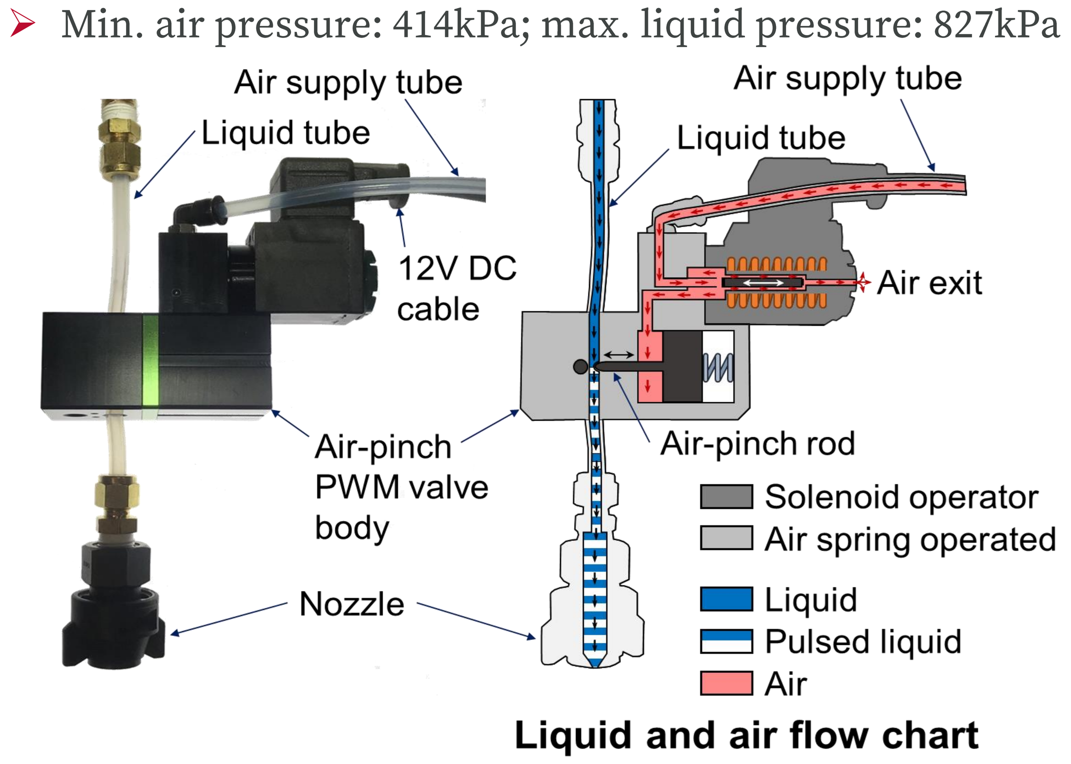


Figure 2. Air-pinch PWM valve: Image (left) and flow diagram (right).

### Electric PWM valve

- Made by Spraying Systems Co. (Fig. 3)
- 12V DC normally-closed valve
- Five concentrically distributed inlets (Ø2.3 mm) and a central outlet (Ø3.1 mm)
- Originally designed for chemical and fertilizer applications at a max. pressure of 689kPa

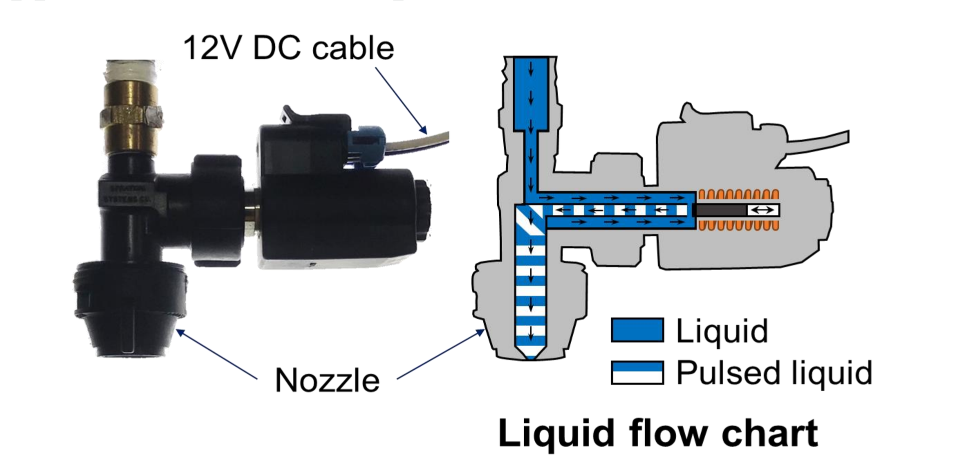


Figure 3. Image (left) and flow diagram (right) of the electric PWM valve.

### Test conditions

- Tested nozzles: TeeJet D2-DC25, D4-DC25, and D5-DC25
- DUCs ranging from 10% to 100% at intervals of 10%
- 10 Hz frequency
- PWM excitation voltage: 14.5 V
- Air operating pressure: 414 kPa
- Liquid operating pressures: 414 and 827 kPa

### Flow rate measurement

- 60L water tank placed over a digital scale with a 1 g resolution (Fig. 4).
- Determination of the flow rate from the difference between the initial and final weight measured during 60 seconds.
- The flow rate at each DUC was normalized as the percent ratio ($R_Q$) to the flow rate at 100% DUC.
- The root mean square error (RMSE) was calculated to evaluate the level of similarity between the $R_Q$ values and the target flow rates.

Figure 4. Water tank over the digital scale.

### Droplet size measurement

- Laser particle droplet image analysis (PDIA) system (Fig. 5).
- Measurement along the spray pattern until 10,000 effective droplets were analyzed.
- Obtaining the $D_{V0.1}$, $D_{V0.5}$, and $D_{V0.9}$.
- Droplet size classification following ASABE S-572.3 standard[2].

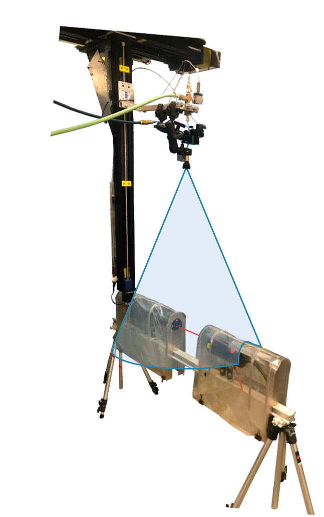

Figure 5. PDIA system.

## RESULTS AND DISCUSSION

### Flow rate modulation capability

- Flow rates mostly increased linearly as DUC increased (Fig. 6), as in other studies using flat fan nozzles[3].
- At 10% DUC, the air valve was not able to control the nozzle flow rate, and at 90% DUC both PWM valves had the flow rates very close to those at 100% DUC.

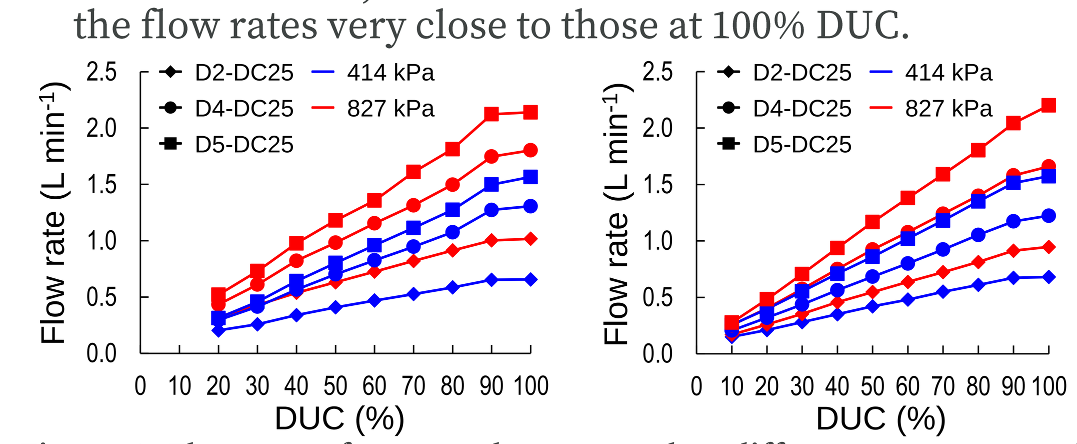


Figure 6. Flow rates from nozzles operated at different pressures and DUC with air-pinch valve (left), and electric valve (right).

- RMSE's decreased as nozzle size increased for both valves except for nozzles D4-DC25 and D5-DC25 with the air valve at 827 kPa (Fig. 7).
- With the air valve the lowest RMSE's were at 414 kPa while with the electric were at 827 kPa.

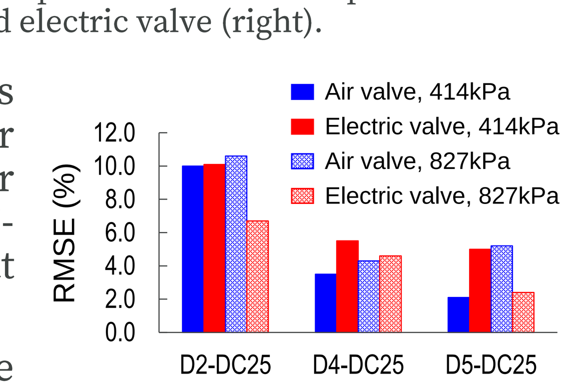


Figure 7. RMSE from valves at different pressures.

### Droplet size classification

- The droplet size classifications (Table 1) generally tended toward fine when the pressure changed from 414 to 827 kPa for all nozzles with either PWM valve.
- Droplet size classifications generally remained unchanged across the DUC range from 20% to 100% while PWM valves were manipulating flow rates of hollow-cone nozzles, as shown in other studies with flat fan nozzles[3].

Table 1. Droplet size classifications, following the ASABE S-572.3.

| Pressure (kPa) | Nozzle | PWM valve | Droplet size classification [a] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% | 100% |
| 414 | D2-DC25 | Air | N [b] | F | F | F | F | F | F | F | F | M |
| | | Electric | M | M | M | F | F | F | F | M | M | M |
| | D4-DC25 | Air | N | F | F | F | F | F | F | F | F | M |
| | | Electric | F | F | F | F | F | F | F | F | F | F |
| | D5-DC25 | Air | N | F | F | F | F | F | F | F | F | F |
| | | Electric | F | M | F | F | F | F | F | F | F | F |
| 827 | D2-DC25 | Air | N | F | F | F | F | F | F | F | VF | F |
| | | Electric | F | VF | F | F | F | F | F | F | F | F |
| | D4-DC25 | Air | N | VF | F | F | F | F | F | F | VF | F |
| | | Electric | VF | VF | VF | F | F | F | F | F | F | F |
| | D5-DC25 | Air | N | VF | VF | VF | VF | VF | VF | VF | VF | VF |
| | | Electric | VF | VF | VF | VF | VF | VF | VF | VF | F | F |

[a] VF – Very Fine, F – Fine, and M – Medium for droplet size classifications.
[b] Air-pinch PWM valve remained closed at 10% DUC.

## CONCLUSIONS AND FUTURE WORK

- The air pinch valve performed the flow rate modulations and droplet size distributions and classifications similar to the electric PWM valve, indicating that air pinch valve might be an alternative to electric PWM valve.
- The longevity and durability of the pinched tube to handle the amount of pinching actions must be tested during the spraying operation.
- The air-pinch valve must be tested with pesticides in real farm conditions before its recommendation to use in spray systems.

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## ACKNOWLEDGEMENTS

Authors would like to express their gratitude to Adam Clark, Barry Nudd, and Andy Doklovic for their technical assistance throughout the laboratory tests.

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