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Technological innovations in vineyard spraying: assessment of PWM technology and future prospects

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The Institut Français de la Vigne et du Vin and INRAE have worked with the companies OPTIMA Concept and Berthoud to develop a high-precision digitally controlled sprayer that automatically adjusts the volume of spray delivered by each nozzle according to geo-referenced guidance maps. This paper describes the technical characteristics and performance of the solutions studied, and outlines the prospects for deploying these technologies in viticulture.

Presentation of the technologies used on the prototype

The precision sprayer designed jointly by OPTIMA Concept and Berthoud was developed based on a WinAir side-by-side trailed sprayer[1]. The machine is equipped with 4 vertical booms, allowing 2 rows to be sprayed side by side. Each vertical boom has 4 nozzle heights (Figure 1). In terms of spray quality, the Berthoud WinAir 2-row side-by-side model has been assessed using the PerformancePulvé® system www.performancepulve.fr. It achieved Performance class 2, which ranks it among the best sprayers on the market in terms of the quantity deposited on the canopy. The detailed sprayer data sheet, used for analysis of its performance over an entire crop cycle (early, mid and full canopy stages), can be accessed via the following link: https://www.performancepulve.fr/downloads/open/fiche/148.

The sprayer is equipped with the Smart Regulation Pressure (SRP) nozzle control system developed by OPTIMA Concept. This system is based on Pulse Width Modulation (PWM) technology[2].

PWM technology is based on the principle of adjustable nozzle opening times to vary the spray flow rate. A special solenoid-operated nozzle holder replaces the conventional nozzle holder on each diffuser. The nozzle itself is of the standard type. The operating frequency (here 15 Hz) determines the number of nozzle opening and closing cycles per second. For each cycle, a configurable DutyCycle value (DC, in %) is used to modify the spray flow rate. The DC value represents the percentage of time the nozzle is open. The DC is automatically increased or decreased depending on the required flow rate.

The SRP system from OPTIMA Concept incorporates electronic control of flow rate in proportion to tractor speed (DPAE for "débit proportionnel à l'avancement électronique") on each of the 16 nozzles fitted. This maintains a set volume/ha at each nozzle at different tractor speeds. The spray flow rate from each nozzle is controlled independently by its PWM nozzle holder, by changing the DC value. The spraying circuit has been adapted so that changes to flow rates on the boom take place at constant pressure, whatever the number of nozzle heights or vertical booms open, and for a wide range of nozzle gauges and models. Various nozzle categories and gauges were tested: XR80°, Teejet; IDK90°, Lechler; AD90°, Lechler. When using nozzles up to ISO 04 gauge (red color), pressure variation in the circuit is limited to 0.2 bar over the entire DC range, ensuring uniform spraying.

Calibration curves are required to regulate the volume/ha at the PWM nozzle holders[3]. At a given circuit pressure, these calibration curves link the spray flow rate from the nozzle (in ml/min) to the DC value (%). A specific calibration curve must be defined for each model of nozzle (Figure 2). Calibrations are carried out over DC values ranging from 15 % to 90 %. Above 90 % DC, the flow rate is constant. Below 15 %, the droplet spectrum is not always formed correctly, depending on the nozzle model, and differences in flow rate between nozzles are likely to occur. As an example, over the DC range of 20 % to 90 % adopted as the operating range for the SRP system, flow rate from AD90°03 nozzles at 4 bar varies between 0.32 l/min (DC = 20 %) and 1.37 l/min (DC = 90 %), i.e. a 1:4 variation in spray flow rate.



FIGURE 1. Prototype sprayer based on PWM nozzle control technology (the SRP system). Photo credit: IFV.

The translation of this article into English was offered to you by Moët Hennessy.

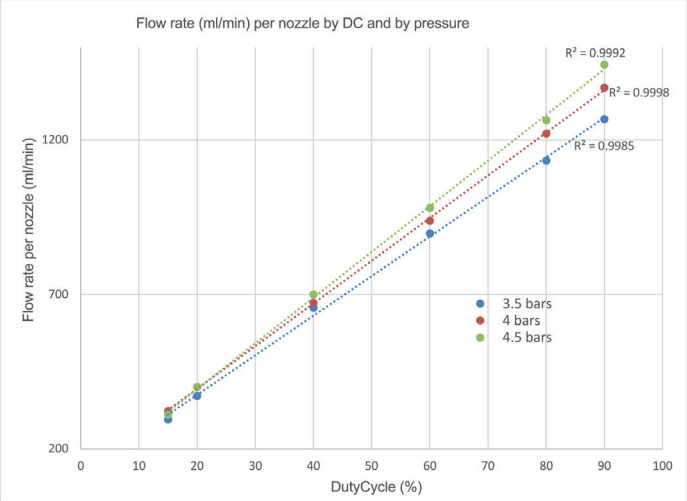


FIGURE 2. Calibration curves of the AD90° 03 nozzle at 3 pressures (3.5, 4.0 and 4.5 bar).

Up to ISO 04 gauge nozzles, the spray flow rate varies linearly with DC. The calibration curve is independent of the number of open nozzle heights and the vertical boom.

The sprayer is equipped with a console (Xenius model, OPTIMA Concept) for reading geo-referenced guidance maps in shapefile format. It is equipped with an RTK GNSS receiver for centimeter-precision geo-positioning and a 4G modem for receiving corrections (www.reseau-teria.com). Application parameters are monitored and recorded in real time using a pressure sensor and four electromagnetic flow meters (IFM brand) on each drop leg. Geo-referenced recording of instantaneous flow rates and pressure at a frequency of 10 Hz provides a check on the accuracy in applying the set volume/ha.

Analysis of application accuracy

To test the prototype's ability to accurately apply the recommended doses, several guidance maps were trialed on the sprayer control system. These maps were made up of 7 polygons, with a set volume/hectare defined for each of the 16 nozzles. The guidance maps were designed to cover a very wide range of DC values in DPAE mode. During application, the spraying parameters (flow rate, pressure, tractor speed) were recorded and geo-referenced.

Figure 3 shows an example application, with a comparison between the instantaneous volume/ha applied and the set volume/ha (in l/ha) for one of the 4 drop legs on the 7 polygons. The guidance map was drawn up with a 1:3 variation in the set volume/ha for the 7 polygons (from 50 l/ha to 150 l/ha for one drop leg, i.e. 100 to 300 l/ha for the entire row sprayed).

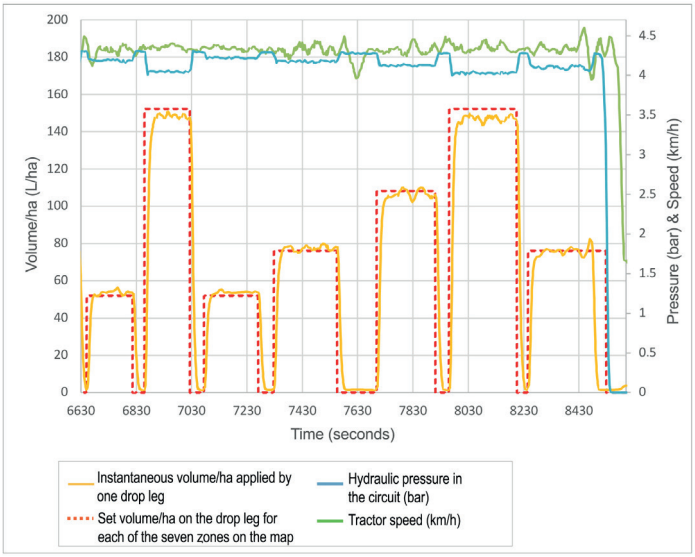


FIGURE 3. Comparison between the instantaneous volume/ha applied by one drop leg (yellow line) and the set volume/ha (red line) for the 7 zones.

Analysis of the instantaneous flow rate recordings shows very good accuracy in applying the set volume/ha. In all the configurations tested – corresponding to 42 points of comparison – the error in the volume/ha applied across the row sprayed showed a maximum error below 5.4%, with mean absolute error values close to 2.5%.

Additional tests were carried out to assess other machine performance parameters. With regard to the response time of the prototype, the time needed to start or stop spraying or change the volume/ha applied is close to 100 ms. With regard to the accuracy of the geographical positioning of application based on previously geo-referenced instructions on guidance maps, trials carried out at 7.4 km/h showed inaccuracy of less than 26 cm in all cases (mean 23 cm over 12 trials) and less than 19 cm at 4.0 km/h (mean 14 cm over 12 trials).

The technological solutions developed by OPTIMA Concept and deployed with Berthoud on the prototype appear promising and should be developed for perennial crops, given their potential in terms of accuracy, modularity (robustness of application quality despite variations in speed and volume/ha applied) and response time.

The technological solutions deployed represent a real step forward in the development of precision spraying which, once the adjustment rules have been defined, will enable the dose to be adapted according to the canopy to be sprayed. OPTIMA Concept has just developed a new Automatic Foliage Spraying (AFS) system that combines PWM technology with ultrasonic sensors to automatically cut off the spray in the presence of gaps in the canopy. This solution, recognized with an award at SITEVI 2023, is currently being evaluated by the joint research unit UMT ECOTEC composed by IFV, CTIFL and INRAE in Montpellier. Initial trials have shown that this solution could be an alternative to recovery panels for reducing input losses, without the disadvantages of the large size of the panels and the need to clean them. ■

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