Giuseppe Pellizzi Prize

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DEVELOPMENT OF A FIXED SPRAY DELIVERY SYSTEM FOR GUYOT-TRAINED VINEYARDS

Dissertation presented to the University of Turin, Grugliasco (TO), Italy

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1 Why a fixed spray delivery system?



- **Steep, fragmented and wet vineyards** can make tractor access unsafe or impossible
- Handheld equipment **increases operator exposure and workload**
- **Treatment timing** depends on field accessibility

UNSAFE TRACTOR ACCESS

DIRECT OPERATOR EXPOSURE

DELAYED POST-RAIN APPLICATION

THESIS QUESTION

Can a permanent spray network installed within the crop canopy deliver a uniform dose, be cleaned to current ISO requirements and be functionally inspected throughout its service life?

THESIS AIM

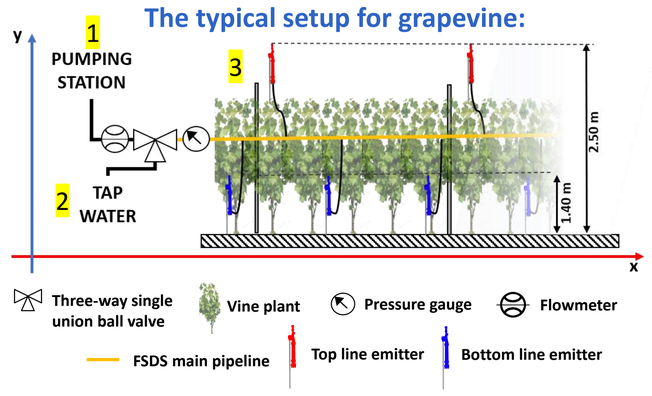
Establish the technical basis for a hydraulic-based fixed spray delivery system (HSD-FSDS) adapted to vineyards

2 How six studies built the HSD-FSDS for vineyards

The HSD-FSDS:

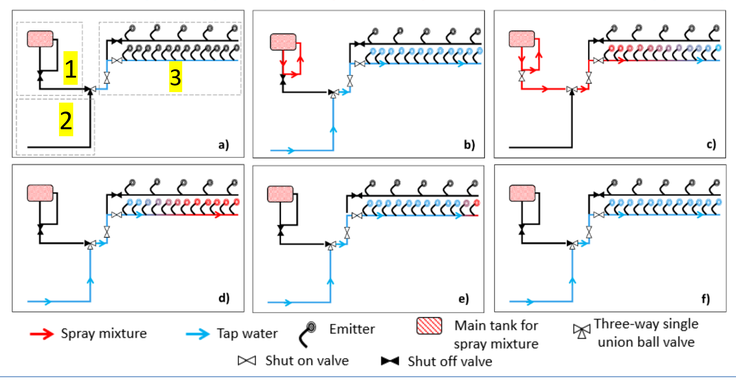
- Consists of *pipelines and pressure-compensating emitters permanently installed* along the rows and *within the canopy*
- A *pumping station*, placed outside the treated area, *injects the spray mixture* into the HSD-FSDS (one injection point)
- *Water is used as a propellant*. It is used to pressurize the system, to deliver the spray mixture and clean the components
- All operating steps are controlled from outside the treated area

The typical setup for grapevine:



Spray application operational steps:

PRESSURIZE (water) > INJECT (mixture) > SPRAY and CLEAN (water)



EVERY RESULT DEFINED THE NEXT EXPERIMENT:

1 **EMITTER SELECTION** (Mozzanini et al., 2023a)
Three commercial pressure-compensating nozzles (emitters) were characterized in laboratory to identify the most suitable for the HSD-FSDS (ISO 5682-1:2017 (ISO, 2017) was applied)

2 **PILOT-SCALE TEST** (Mozzanini et al., 2023b)
A 1-tier HSD-FSDS layout was tested in apple orchard and grapevine. The setup worked for apple orchard but under-covered the grape band in grapevine. For grapevine, a second spray line was demonstrated to be necessary to achieve higher spray coverage. A 2-tier HSD-FSDS layout was studied

3 **FULL-SCALE HSD-FSDS PROTOTYPE** (Mozzanini et al., 2024a)
Because the HSD-FSDS has a single spray-mixture injection point, a full-scale field prototype was tested for uniform delivery along the row, including at the farthest locations.
The same setup was tested for its internal cleaning performance after the spray applications (ISO 22368-1:2004 (ISO,2004) was applied)

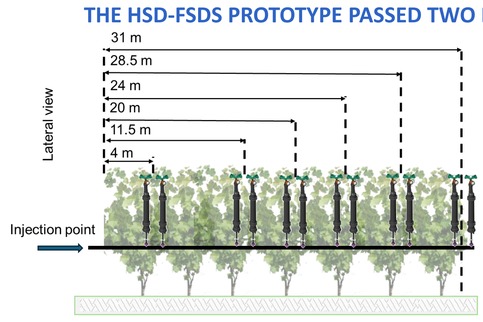
4 **PSD-FSDS BENCHMARK** (Mozzanini et al., 2024b)
A pneumatic-based fixed spray delivery system (PSD-FSDS), a variant of the FSDS in which air, instead of water, is used as propellant, was tested for its internal cleaning performance after the spray applications. As a result, air alone was insufficient and a series of water rinses were required to meet the cleaning criterion (ISO 22368-1:2004 (ISO,2004) was applied)

5 **FUNCTIONAL INSPECTION** (Mozzanini et al., 2023c)
A first pre-inspection, testing and reporting method for the HSD-FSDS was presented. The documents were adapted from EN ISO 16122-1:2015 (ISO, 2015a) and EN ISO 16122-4:2015 (ISO, 2015b)

6 **FIELD HSD-FSDS LAYOUT COMPARISON** (Mozzanini et al., 2024c)
Four 2-tier layouts, derived from the emitter characterization conducted in Study 1, were compared for spray deposition and ground losses

3 Uniform spray mixture delivery and the internal cleaning

THE HSD-FSDS PROTOTYPE PASSED TWO ENGINEERING GATES





Sampled at six distances for mixture delivery and at three distances for internal cleaning

DELIVERY UNIFORMITY
coefficient of variation = 6.91%
Mean spray mixture variability across sampled emitters

REMOVE RESIDUES:
99.95%
HSD-FSDS copper oxychloride reduction

ISO THRESHOLD:
>99.67%
ISO 16119-4:2014 internal cleaning (ISO, 2014)

The HSD-FSDS prototype delivered a similar mixture amount along the row and could be internally cleaned with water



The PSD-FSDS tested achieved a value equal **to 99.82%** after three successive water rinses

The internal cleaning for PSD-FSDS can be achieved but water is need to comply with the ISO internal cleaning threshold reported by ISO 16119-4:2014 (ISO, 2014)

4 More emitters = lower spray deposit and higher losses

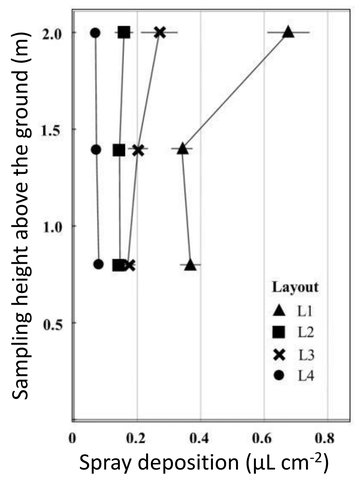
LOWER-FLOW HSD-FSDS LAYOUTS

- **L1** emitters: StripNet + VibroNet
- **L3** emitters: StripNet + MistNet
- Total flow rate (each): 19.8 L min^{-1}
- 12,774 emitters ha^{-1} each layout

HIGHER-FLOW HSD-FSDS LAYOUTS

- **L2** emitters: VibroNet only
- **L4** emitters: MistNet only
- Total flow rate (each): 31.2 L min^{-1}
- 20,128 emitters ha^{-1} each layout

SYSTEM FLOW higher- vs lower-flow: +58%
TOTAL APPLICATION RATE higher- vs lower-flow : +84%



In figure: mean spray deposition (µL cm^{-2}) of each layout according to the sampling height above the ground (0.8, 1.4, and 2.0 m)

The ratio between the SPRAY DEPOSITION and GROUND LOSSES: L1 9%, L2 4%, L3 7%, L4 1%
Layout using emitters with a spray pattern that matches the canopy characteristics has to be preferred to maximize the spray deposition on the canopy

Greater emitter density and application rate increased spray mixture wash-off instead of improving spray deposition

DESIGN RULE
Match spray pattern to canopy zone, then minimize flow rate and emitter density

LIMITATION
All HSD-FSDS layouts showed excessive wash-off. Field optimization remains necessary

5 From proof of concept to TRL 6

TRL 3 > TRL 6

From experimental proof of concept to *full-scale prototype field validation*

THE THESIS DELIVERED a 2-tier system with target-specific emitters, uniform delivery, ISO-compliant internal cleaning and the first FSDS functional-inspection framework. It also identified the field limitation that must be solved before commercialization.

NEXT DESIGN

Retain the 2-tier architecture. Reduce flow rate, emitter installation density, and water volume used, then develop and test a grapevine-specific emitter. Results reported in: (Mozzanini et al., 2026)

RECOGNITION: **2025 Guarnieri-Montel Award for best PhD thesis in Agricultural Mechanics | 2025 ASABE Superior Paper Award**

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