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[F] PhD Extended Abstract Form

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

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Extended Abstract

Introduction

In viticulture, achieving effective crop protection through pesticide application is particularly challenging in steep-sloped and fragmented terrains, which are common across many European vineyard regions. These landscapes often render the use of traditional ground-based sprayers challenging, forcing growers to rely on labor-intensive, less efficient, and high-risk solutions such as knapsack mist blowers or handheld spray lances. These approaches, indeed, not only limit treatment precision and repeatability but also expose operators to direct chemical contact, creating serious health and safety concerns. Beyond operational drawbacks, poor spray uniformity can lead to suboptimal pest control, residues in non-target areas, and increased pest resistance. Recent societal, political, and environmental pressures listed by the EU's Farm to Fork Strategy, demand technologies that reduce the risk and use of chemical pesticides while preserving efficacy. In this context, Fixed Spray Delivery Systems (FSDSs), and more specifically hydraulic-based FSDSs (HSD-FSDS), have emerged as viable alternatives. These systems represent a modification and adaptation of an irrigation system to deliver agrochemicals. Briefly, an HSD-FSDS consists of a network of polyethylene pipelines with pre-positioned emitters installed into the canopy to deliver the spray mixture within the crop with high temporal precision and minimal operator involvement. All the operations (priming, mixture injection, spray delivery and cleaning) are fully carried out outside of the sprayed area by means of a dedicated pumping station. Since the system is fixed, it allows applications under otherwise prohibitive or difficult operative conditions (e.g., wet soil, steeply sloped terrain, post-rain events), enhancing treatment timeliness, operator safety, and potentially improving pest control outcomes. Despite promising results in apple orchards and to a lesser extent in vineyards, there has been little structured research on adapting HSD-FSDS to Guyot-trained vineyards. This doctoral work belongs to "*Agricultural Machines and Mechanization*" through the development, testing, and standard-oriented evaluation of a new spray delivery technology. Briefly, the work aimed to bridge the knowledge gap by characterizing, testing, and optimizing HSD-FSDS components and layouts, assessing their compliance with international standards, and proposing a foundation for future regulatory frameworks to support large-scale adoption in viticulture.

Objectives

The primary objective of this research was to establish a scientific and technical basis for the implementation of the HSD-FSDS in Guyot-trained vineyards. To this end, the study was structured around the following specific objectives:

- Identify and characterize emitters suitable for low-pressure, fixed-position spray delivery under vineyard conditions.
- Evaluate spray coverage, droplet size, and ground losses both in laboratory and pilot-scale field environments.
- Develop and test full-scale HSD-FSDS prototypes to assess spray distribution uniformity and internal cleaning performance, while quantifying the effect of emitter installation density and layout design on deposition uniformity and environmental loss across multiple configurations.
- Validate cleaning efficacy against EN ISO standards commonly used for conventional sprayers (ISO, 2004; 2014).
- Propose an initial inspection methodology adapted from EN ISO 16122-1 and -4 (ISO, 2015a; 2015b) to enable regulatory oversight of FSDS technology post-installation.

Thesis chapters

The research was organized into six chapters, each addressing a specific research question.

1. Characterization of irrigator emitter to be used as Solid Set Canopy Delivery System: which is best for which role in the vineyard?

Chapter 1 (Mozzanini et al., 2023a) presented laboratory tests on three emitters: single-sided flat fan, double-sided flat fan, and circular spray pattern. Each was assessed for flow rate uniformity, horizontal spray pattern, and droplet size spectrum following ISO 5682-1 protocols (ISO, 2017). The results showed that emitter suitability depended on canopy target: double-sided flat fan emitters were more suitable for the canopy top, whereas circular emitters were more suitable for the middle and lower canopy zones. Overall, a combined double-sided flat fan plus circular-emitter layout emerged as the most promising solution for homogeneous canopy coverage with reduced ground losses.

2. Preliminary evaluation of irrigator emitters for pesticides application through solid set canopy delivering system in apple orchard and vineyard

Chapter 2 (Mozzanini et al., 2023b) tested the double-sided flat fan emitter under pilot-scale field conditions in apple orchards and vineyards. The performance of the pilot-scale HSD-FSDS was compared to that of conventional airblast sprayers equipped with drift-reducing technologies. Canopy spray coverage was quantified by positioning water sensitive papers in predefined canopy sampling areas. Water was used as testing liquid, and coverage data were obtained through image analysis of the scanned water sensitive papers using ImageJ software. The emitter performed reliably in apple orchards, but its vertical spray distribution in vineyards was less uniform. In particular, in the grape band area the coverage dropped, underscoring the importance of emitter placement to cover that area as well. These results showed that emitter placement and density had to be specifically adapted to Guyot-trained vineyards, and they directly informed the layout configurations later tested in the full-scale HSD-FSDS studies.

3. Hydraulic-based fixed spray delivery system: homogeneity distribution among emitters and internal cleaning performances evaluation

In Chapter 3 (Mozzanini et al., 2024a), a full-scale HSD-FSDS prototype for vineyards was designed and assembled based on the findings presented in Chapters 1 and 2. Spray mixture delivery uniformity and internal cleaning performance were evaluated using water solutions of tartrazine and copper oxychloride as tracers, respectively. Sampling across emitters and time intervals allowed the assessment of distribution uniformity. Cleaning efficiency was evaluated in accordance with ISO 22368-1 (ISO, 2004) and ISO 16119-4 (ISO, 2014). The full-scale HSD-FSDS prototype achieved high spray uniformity across emitters when precise spacing and alignment were adopted, while water rinsing alone exceeded the ISO 16119-4 (ISO, 2014) compliance threshold of 99.67% by 0.28%. The derived relationships between flow rate, rinse volume, and cleaning time provide practical design and management criteria for future FSDS adoption.

4. Cleaning performance evaluation of pneumatic spray delivery based solid set canopy delivery system

Chapter 4 (Mozzanini et al., 2024b) assessed the cleaning performance of a pneumatic-based FSDS (PSD-FSDS) developed in the US for Guyot-trained vineyards. Five cleaning methods, including compressed air and water rinses, were tested. First, the cleaning methodologies were tested at pilot-scale laboratory conditions using a water solution of Pyranine tracer. Second, the most promising cleaning technique was field tested at a full-scale PSD-FSDS using a water solution of copper oxychloride. Cleaning efficiency was evaluated in accordance with ISO 22368-1 (ISO, 2004) and ISO 16119-4 (ISO, 2014). The results showed that water rinsing was more effective than compressed air alone, achieving a cleaning efficiency 0.15% above the ISO 16119-4 (ISO, 2014) compliance threshold. This study, which received the ASABE Superior Paper Award in 2025 (at the ASABE Annual International Meeting held in Toronto, Canada, between 13th-16th July), extended the thesis scope by showing that effective and standard-oriented cleaning approaches can also be defined for pneumatic FSDS variants.

5. Proposal of a methodology for the functional inspection of a fixed spray delivery system

Chapter 5 (Mozzanini et al., 2023c) addressed the lack of specific FSDS inspection standards, a relevant barrier to the wider adoption of this technology. A first methodology for the functional inspection of FSDS was proposed by adapting EN ISO 16122-1 (ISO, 2015a) and EN ISO 16122-4 (ISO, 2015b), identifying the components to be inspected, the corresponding performance thresholds, and the methods to verify their functionality. This chapter laid the basis for a future regulatory framework for mandatory post-installation inspection of FSDS.

6. Quantifying canopy deposition and ground losses of fixed spray delivery system layouts for trellised vineyards

Finally, Chapter 6 (Mozzanini et al., 2024c) presented the first field study conducted in a Guyot-trained vineyard with a HSD-FSDS. Four layouts, derived from the results of Chapter 1, were compared using a tartrazine water solution as tracer, and canopy deposition and ground losses were quantified through spectrophotometric analysis of sampled leaves and Petri dishes. The comparison showed that increasing emitter density did not result in a linear improvement in canopy deposition and, in some cases, promoted spray wash-off and inefficient distribution. The results demonstrated that emitter layout and density are key determinants of HSD-FSDS performance and identified intermediate-density configurations as the most promising for Guyot-trained vineyards.

Final remarks concerning benchmarks and strength points of the Pellizzi Prize 2026

This PhD thesis clearly falls within Agricultural Machines and Mechanization, as it develops and validates an innovative fixed spray delivery system (FSDS) for pesticide application in Guyot-trained vineyards. Its originality lies in moving FSDS from concept to field-oriented engineering through emitter selection, layout optimization, spray quality assessment, internal cleaning evaluation, and a first methodology for functional inspection. The work also includes the first field study conducted in a Guyot-trained vineyard with a hydraulic FSDS, providing evidence on canopy deposition and ground losses under real operating conditions. Beyond technical novelty, the thesis offers a field-validated and transferable framework for safer, more timely, and more sustainable crop protection in viticulture. Its quality is confirmed by the 2025 Guarnieri-Montel Award for the best PhD thesis in Agricultural Mechanics (promoted by the University of Bologna and the University of Foggia and sponsored by FederUnacoma and AIIA), while the ASABE Superior Paper Award further supports its international relevance. By offering a detailed, field-tested roadmap for FSDS adoption, this research supports viticulturists in transitioning toward safer and more sustainable crop protection strategies.

References

- ISO, (2004) 22368-1. Crop protection equipment – Test methods for the evaluation of cleaning systems – Part 1: Internal cleaning of complete sprayers. ISO (International Organization for Standardization). Retrieved from https://www.iso.org/standard/34976.html
- ISO, (2014) 16119-4. Agricultural and forestry machinery – Environmental requirements for sprayers – Part 4: Fixed and semi-mobile sprayers. ISO (International Organization for Standardization). Retrieved from https://www.iso.org/standard/57414.html
- ISO, (2015a) 16122-1. Agricultural and forestry machinery Inspection of sprayers in use Part 1: General, ISO International Organization for Standardization. https://www.iso.org/standard/56721.html
- ISO, (2015b) 16122-4. Agricultural and forestry machines Inspection of sprayers in use Part 4: Fixed and semi-mobile sprayers, ISO International Organization for Standardization. https://www.iso.org/standard/57415.html
- ISO, (2017) 5682-1. Equipment for crop protection - Spraying equipment - Part 1: Test methods for sprayer nozzles, ISO International Organization for Standardization. https://www.iso.org/standard/60053.html
- Mozzanini E., Grella M., Marucco P., Balsari P., Gioelli F. (2023a) Characterization of irrigator emitter to be used as solid set canopy delivery system: which is best for which role in the vineyard? Pest Management Science, 79(2):584–597. https://doi.org/10.1002/ps.7228
- Mozzanini E., Grella M., Bondesan D., Marucco P., Rizzi C., Ioriatti C., Balsari P., Gioelli F. (2023b) Preliminary Evaluation of Irrigator Emitters for Pesticides Application through Solid Set Canopy Delivering System in Apple Orchard and Vineyard. Acta Horticulturae, 13778:227–236. https://doi.org/10.17660/ActaHortic.2023.1378.30

- Mozzanini E., Balsari P., Grella M., Marucco P., Gioelli F. (2023c) Proposal of a methodology for the functional inspection of a fixed spray delivery system. Standardised Procedure for the Inspection of Sprayers in Europe (SPISE). 2-4 May 2023, Naaldwijk, NL. https://spise.julius-ku-ehn.de/index.php?menuid=xxmenuidxx&downloadid=289&reporeid=xxreporeidxx
- Mozzanini E., Grella M., Marucco P., Hoheisel G.-A., Biglia A., Balsari P., Gioelli F. (2024a) Hydraulic-based fixed spray delivery system: Homogeneity distribution among emitters and internal cleaning performances evaluation. Crop Protection, 175:106440. https://doi.org/10.1016/j.cropro.2023.106440
- Mozzanini E., Bhalekar D.G. Grella M., Hoheisel G.-A., Samy S., Balsari P., Gioelli F., Khot L.R. (2024b) Cleaning Performance Evaluation of Pneumatic Spray Delivery Based Solid Set Canopy Delivery System. Journal of the ASABE, 67(4):1049–63. https://doi.org/10.13031/ja.15944
- Mozzanini E., Grella M., Marucco P., Balsari P., Gioelli F. (2024c) Quantifying canopy deposition and ground losses of fixed spray delivery system layouts for trellised vineyards. International Advances in Pesticide Application (AAB-IAPA). 23-25 January 2024, Brighton, UK. https://web.cvent.com/event/4f6543ca-334e-43d6-8a62-dcfa7a55d055/summary