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Abstract

National policies in Europe aim to reduce use of pesticides. Grapevine receives yearly many sprayings. There is a great variety of sprayers available for vineyards. We can sum up questions addressed to research bodies by the following issues. Is it possible to sort out sprayers and practices according to crop protection and environmental performances? How much is it possible to save on amounts of chemicals sprayed when one uses an efficient sprayer?

The present contribution to this research is based on a 4 rows, 10 meters length, physical full scale model of a vineyard. The Evasprayviti model of a vineyard row was designed to reproduce different foliage volume and densities and to simulate the interaction of the canopy with the flow of plant protection product and air emitted by a mobile sprayer. It comprises a collecting device, and a complementary structure on each side of it. The collecting device enables accurate and repeatable sampling of the spray deposits. It is composed of plastic sheets that simulate leaves, attached to vertical aluminium posts. The complementary structure prevents perturbative effects on the spray flow on the edges of the collecting device. Evasprayviti can be configured to simulate different growth stages (Codis&al, 2013). The test spray is a mix of a tracer, Tartrazine, and water.

A standard pneumatic sprayer, an airblast sprayer and an air-assisted face to face sprayer were tested. The pneumatic sprayer was tested in 3 configurations, for spraying respectively 2, 3 and 4 rows at a time. The face to face sprayer and the airblast sprayer were configured to be used to spray 3 rows and 2 rows, respectively.

The amount of product deposited in the canopy and its distribution according to depth and height of leaves was studied for early, intermediate and full growth stage, with respective Leaf Area Index (LAI) values of 0.24, 0.88 and 1.68 ha/ha. The sampling of a cross-section of the collecting device was divided in compartments (3 depths x 3 heights at full growth stage). Deposits on rows close to sprayer and on rows next to sprayer were compared when relevant. The mass of deposits per unit of leaf surface, normalised by amount sprayed per hectare of ground, was measured for each compartment. For precision assessment, this normalised deposit was divided by the reference potential deposit on the target, which is calculated for each growth stage according to the hypothesis that all the spray is homogeneously deposited in the compartments.

Results showed different deposition profiles, which are discussed. The face to face sprayer exhibited the best efficiency and homogeneity in full and intermediate growth stage, and best efficiency on early stage as well, with homogeneity comparable to the pneumatic sprayer's on this stage. The airblast sprayer used on two rows had a good overall efficiency for early and intermediate stages but a bad homogeneity at all stages.

Keywords: crop protection, spraying precision, grapevine

1 Introduction

European directives and national policies in Europe aim to promote a reduced and sustainable use of pesticides (Barzman et Dachbrodt-Saaydeh, 2011). Many phytopharmaceutical sprayings are applied on grapevine crops every year and there is a growing concern about applying appropriate chemical quantities, achieving good spraying quality and minimizing losses in the air and on the ground. It can also be observed that there is a great variety of sprayers in use in vineyards and this diversity is not narrowing in the spraying equipment market today. Several questions are addressed to research bodies on the following issues. Is it possible to sort out sprayers and practices according to criteria of crop protection quality and environmental performances? How much is it possible to reduce dosage of chemicals sprayed when an efficient sprayer is used?

The present contribution to this research is based on a physical full scale model of a vineyard, which allows to collect the spray deposited on several rows and also to evaluate losses to the ground. Each row models the interaction of foliage with the combined air and fluid flow generated by a sprayer. Foliage volume and density can be parametrized. The simulated vine row enables accurate and repeatable sampling of the spray deposits. Profiles of deposited quantities according to depth and height can be determined.

The purpose of this paper is to evaluate the capability of the physical model, which is called Evasprayviti, to sort out different spraying technologies and configurations, according to resulting quality of deposition in the foliage.

2 Materials and methods

2.1 The EvaSprayViti model of a vineyard row

The test bench used in this study comprises 4 rows of artificial vine. Some data and schematics about this bench were published in (Codis et al., 2013). Each row is 10 meters length. It comprises a collecting device, and a complementary structure on each side of it. The collecting device is composed of plastic sheets that simulate leaves, attached to vertical aluminium posts. Posts are grouped in 10 posts lines according to the depth axis, from a depth of 2 lines (early growth stage) to a depth of 6 lines (full growth stage). Consecutive lines are arranged so that posts positions are in quincunx setting (see top view on figure 1). The number of artificial leaves on each post depends on the simulated growth stage, from 6 leaves (early growth stage) to 14 (full growth stage). In the medium growth stage, the collecting device was set with 4 lines and 11 leaves per post. Leaves are arranged alternatively on one side of the post that faces the sprayer and on the opposite side of the post. The complementary structure prevents perturbative effects on the spray flow on the edges of the collecting device. Its depth and height may vary and are set during experiments to match those of the collecting device

For the present study, three growth stages were simulated: early growth stage, medium growth stage and full growth stage. The density of the simulated canopy is such that the respective following Leaf Area Indexes (LAI) are simulated for a 2.5m inter-row spacing: 0.24, 0.88 and 1.68 hectare of leaf surface per hectare of ground surface.

2.2 Spraying configurations tested

Three sprayers of different technological types were tested: a standard pneumatic sprayer, an airblast sprayer and an air-assisted face to face sprayer. The pneumatic sprayer was tested in 3 configurations, for spraying respectively 2, 3 and 4 rows at a time (configuration codes respectively: V2, V3, V4) . The face to face sprayer (code AAFF) and the airblast sprayer (code AB) were configured to be used to spray 3 rows (AAFF3) and 2 rows (AB2), respectively. Overall, 5 configurations were tested and compared. The air flow was set as recommended by the manufacturers of tested equipment. The range of applied volume were 50 l/ha, 100 l/ha and 130-170 l/ha for early, medium and full growth stage, respectively.

2.3 Sampling

The spray mix was a water solution of Tartrazine, which is a food dye tracer (E 102). When dry, the collectors were collected and rinsed with a given volume of water. The concentration of Tartrazine is determined by using absorbance spectrometry (L = 423 nm) and converted to a mass of tartrazine per leaf surface area. This is a standard procedure for evaluation of spraying quality on artificial or real crops (ISO 14253 part 1 and Part 2).
Not all the leaves of the collecting device were sampled, and those sampled were collected and analyzed by groups. Sampling the whole collecting device leaf by leaf is a time consuming task: there are 840 leaves for the full growth stage. Extensive sampling is performed only when high resolution is required. For this experiment, the leaf sampling groups were as follows. 3 cross-sections, with section width of 1 post per line, were sampled separately in order to check the repeatability of the results.
For each cross-section, groups were defined according to depth and height. For full growth stage, 9 groups were distinguished for each cross-section: 3 groups along depth axis (D_i, $i \in [1..3]$) and 3 groups (H_j, $j \in [1..3]$) according to vertical axis. The layout of sampling is given in figure 1.
For medium growth stage, the layout is similar, with the difference that there are only 2 groups along depth axis and 3 groups according to vertical axis.
For early growth stage, the distribution according to vertical axis was not studied, because the foliage height is small. In this early growth stage, all 3 cross-sections were merged so as to get enough leaves in a group. It should be noted that, in this case, the leaves that are in front of a post and those that are at the rear of a post were sampled separately to check for masking effects. Yet, we merge this data here and distinguish only 2 groups that account for 2 depth levels. A photograph in figure 2 illustrates the setting for both early and medium growth stages.
The number of leaves per sampling group is given in table 1.
For configurations with the pneumatic sprayer where more than 2 rows at sprayed simultaneously, the deposits were measured on 2 row types: one row immediately close to the sprayer (C row) and one distant row (F row). For the other cases, one single representative row was sampled.

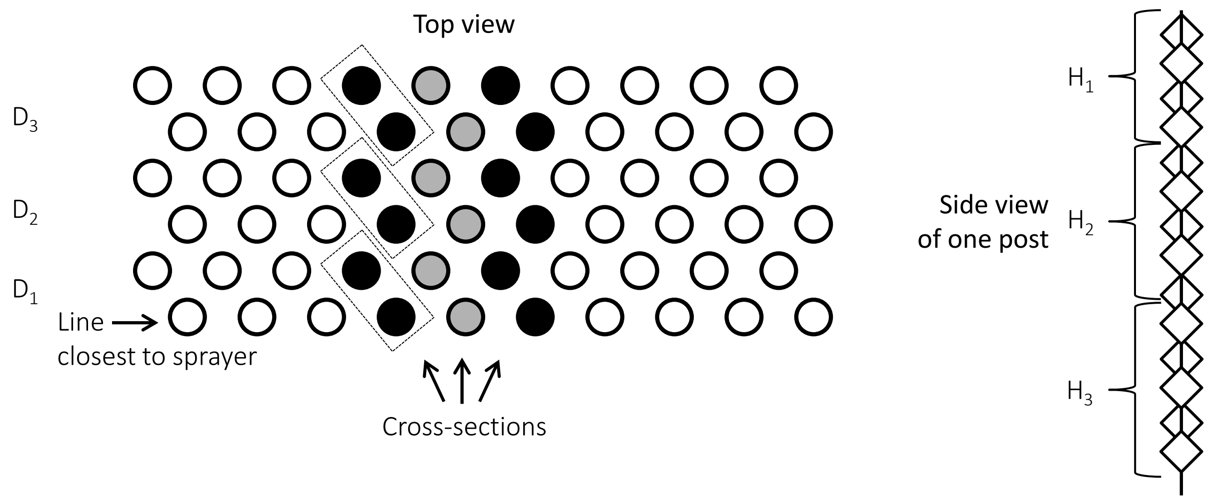

Figure 1: Schematics for the sampling of the collecting device, full growth stage

Table 1: Sampled leaf groups

Growth stage	**Leaf groups**	**Cross-sections**	**Number of leaves per group & cross-section**
Early g.stg	D_1, D_2	1	18
Medium g.stg	D_1H_1, D_2H_1	3	6
	D_1H_2, D_2H_2, D_1H_3, D_2H_3	3	8
Full g.stg	D_1H_1, D_2H_1, D_3H_1	3	8
	D_1H_2, D_2H_2, D_3H_2, D_1H_3, D_2H_3, D_3H_3	3	10

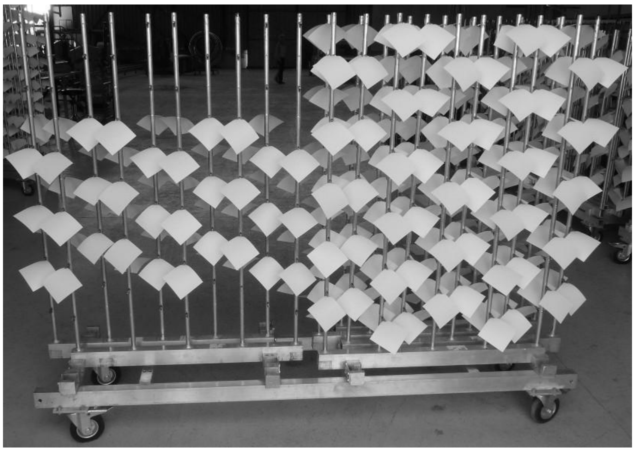

Figure 2: Photo of the collecting device:

Posts and leaves setting for early growth stage(left) and medium growth stage (right)

2.4 Analysis of efficiency and homogeneity of deposits

Samples are analyzed in order to determine the mass of tracer deposited on the total surface of a group of leaves, with reference to the given mass emitted by the sprayer which is calculated per surface of ground. Thus, a ratio r_{mes} can be obtained by dividing the tracer mass per surface of leaves (considering both upper and lower leaf sides) with the emitted tracer mass per surface of ground area. This ratio is called normalized deposit in (Gil et al, 2011). We used the following unit for r_{mes}: g.ha_leaves^{-1}/ g.ha_ground_area^{-1}.

If we consider a constant dose rate per surface of ground area all along the season, as it is the case for registered crop protection chemicals in France, the r_{mes} ratio changes as a direct consequence of the increase in the surface of leaves (dilution phenomenon).

We thus calculate a ratio r_{ref}, which is calculated by making the theoretical hypothesis that all product is sprayed uniformly on all leaves of the canopy without any losses on the ground and in the air. r_{ref} can be calculated from the Leaf Area Index (LAI) as follows:

$$r_{ref} = 1\ g.ha\_leaves^{-1} / g.ha\_ground^{-1} / (2 * LAI)$$

Then, for each group of sampled leaves, a unit-less and dilution independent interception coefficient η was calculated as follows:

$$\eta = r_{mes} / r_{ref}$$

In the hypothetical case where the spray would be uniform in all groups of leaves, without any loss, η should have value 1. If the spray is non-uniform and some losses are observed, η would be typically below 1 and may be upper 1 when one group in a cross-section receives more product than another.

3 Results and discussion

When η is calculated for the whole cross-section of a canopy row, its value expresses the portion of spray that is intercepted by the canopy. It may be called "gross efficiency" and 1-η may be called "gross loss coefficient". The latter is well recognized as an issue when it comes to environmental concerns.
We give in table 2 the results obtained for the three simulated growth stage

Table 2: Interception coefficient for whole cross-section of a canopy row

For medium and full growth stages, the results are a mean of three sampled cross-sections

	Early G-S			Medium G-S			Full G-S		
	η C row	η F row	mean η	η C row	η F row	mean η	η C row	η F row	mean η
V2	25%		25%	44%		44%	66%		66%
V3	24%	26%	25%	42%	37%	40%	59%	52%	57%
V4	27%	29%	28%	53%	43%	48%	70%	49%	59%
AB2	36%		36%	57%		57%	62%		62%
AAFF3	41%		41%	67%		67%	74%		74%

The values obtained at early growth stage suggest that there is room for technological improvement related to sustainable use of pesticides. Yet, it should be noted that a grower may find that the quantity of products deposited on the few leaves is sufficient for the protection of the crop, as the dilution factor is low in the early stage.
The air-assisted face to face sprayer performed better than other tested configurations. Yet, the airblast sprayer, when used on 2 rows, exhibits a gross efficiency that is reasonable when compared to the standard pneumatic sprayer.

The study of deposition profiles according to depth and to height in the canopy brings forward homogeneity issues which are also of much importance for sustainable use of pesticides. Let us examine first the issue of spray penetration in the depth of the canopy.

Table 3: Interception coefficient according to depth in the canopy row – full growth stage

The results are a mean of the three sampled cross-sections

	C row			F row			Std-dev
	D1	D2	D3	D1	D2	D3	
V2	80%	59%	61%				12%
V3	72%	39%	66%	49%	50%	56%	12%
V4	128%	57%	25%	77%	47%	22%	39%
AB2	115%	50%	20%				49%
AAFF3	69%	65%	89%				13%

Table 4: Interception coefficient according to depth in the canopy row – medium growth stage

The results are a mean of the three sampled cross-sections

	C row		F row		Std-dev
	D1	D2	D1	D2	
V2	44%	44%			0%
V3	43%	39%	38%	37%	3%
V4	75%	31%	36%	49%	20%
AB2	78%	37%			29%
AAFF3	71%	64%			5%

According to tables 3 and 4, the airblast sprayer, configured for 2 rows spraying, and the standard pneumatic sprayer, configured for 4 rows spraying, are the two configurations that exhibit significant lower depth homogeneity (expressed in the column “std dev” for standard deviation) when compared to other configurations.

Let us now examine the homogeneity issue according to height in the canopy.

Table 5: Interception coefficient according to height in the canopy row – full growth stage

The results are a mean of the three sampled cross-sections

	C row			F row			Std-dev
	H1	H2	H3	H1	H2	H3	
V2	53%	100%	43%				31%
V3	41%	99%	34%	4,07%	61,38%	79,54%	34%
V4	70%	86%	54%	22,56%	76,71%	42,06%	24%
AB2	73%	58%	57%				9%
AAFF3	47%	91%	80%				23%

Table 6: Interception coefficient according to height in the canopy row – medium growth stage

The results are a mean of the three sampled cross-sections

	C row			F row			Std-dev
	H1	H2	H3	H1	H2	H3	
V2	30.23%	52.25%	46.41%				11%
V3	20.37%	58.17%	41.17%	40.39%	42.09%	40.25%	12%
V4	36.19%	69.82%	49.98%	33.49%	56.34%	50.41%	13%
AB2	62.64%	54.26%	56.12%				4%
AAFF3	45.37%	82.30%	69.09%				19%

A rather obvious observation that can be made from table 6 is that the compartments (leaf groups) that have medium height intercept more spraying than others. This is in accordance with expectations.
It also appears that it is difficult to achieve a good covering of the top zone for the distant row when using a standard “arch shaped” pneumatic sprayer.

The homonogeneity according to depth axis and vertical axis are not the same for a given configuration. It would be necessary here to introduce epidemiological knowledge for various grapevine diseases in order to assess the possible impacts of the unhomogeneity of spraying on risks of disease outbreak and propagation. In their work about dose adjustment for orchards, Walklate and Cross (2013) introduce a disease specific target zone within the canopy, which is associated to a partial-width of tree row.

4 Conclusions

We gave a quick presentation of the EvaSprayViti model of a vineyard row and presented how this device can be used to compare the performances of different spraying configurations. We used a unit-less and dilution independent interception coefficient to characterize the situations. When applied to a whole cross-section of a vine row, this coefficient characterizes the efficiency of spraying. When applied to a set of compartments within the canopy, the variation of this coefficient are an indication of the homogeneity of spraying.
Using a few equipments of technologies that are of frequent use, we shown that the EvaSprayViti device makes it possible compare spraying performances.

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