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Vineyard Cover Spraying Evaluation According to Plant Vigour Variations

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The most important goal of pesticide application in agriculture is to get uniform distribution of chemicals throughout the canopy. Under dosage may not give the desired coverage and control needed. Over dosage is expensive as it wastes pesticide and increases the potential for groundwater contamination. New sprayer technologies are needed in order to optimize plant spraying and reduce environmental impact. A conventional low dosage (~85 L ha^{-1}) pneumatic sprayer was used in order to evaluate spraying quality taking in consideration different vineyard vegetation vigour. The data were collected under field operating conditions using water sensitive papers. The papers were positioned at three levels on the crop for each treatment. Each water sensitive paper was analysed using the DepositScan software system. Statistics were reported for Volume Median Diameter (VMD), droplet cover and the ratio between spray volume and leaf volume (L m^{-3}). Results show that droplet cover goes from 0 % to 30 % with a coefficient of variation normally above 80 %; droplet VMD goes from ~100 μm to ~500 μm and the ratio between spray volume and leaf volume goes from 0.02 L m^{-3} to 0.32 L m^{-3}. These huge variations happen because there are no fast and flexible systems reacting to site-specific needs without destroying the quality of spraying. Considering the previous there is a need of smart spraying systems and because of that the CARTS (**C**anopy **A**djusted **R**eal **T**ime **S**praying) project was setup and was initiated in November 2015. The main objective of the CARTS project is to produce a spray equipment with capacity to measure the volume of leaves and adjust, in real time, the spray volume rate to be applied. To achieve this goal, the CARTS project brought together the Hexastep (Business leader: hexastep.pt), the University of Évora (Scientific leader: uevora.pt) and Micron (industrial leader: microngroup.com)

1. Introduction

European directives are promoting the reduction of crop plant protection products by increasing the products application efficiency. This reduction is beneficial for environment and health and reduces the waste of resources.

In the case of vineyards, which have a large vegetative development in a short period of time, systems have been studied to adjust the spray volume rate to vegetation dimensions or area of leaves, in order to avoid situations of over or under-dosage. The vineyard volume canopies can be extremely variable, and volumetric ratios of 1 to 12 can be found within the same plot (CARTS experimental sites). Therefore, plant protection products and volume application rates based on a fixed rate per hectare over-treat early season foliage, but may under-dose late season foliage (Siegfried et al., 2007).

Dose expression and spray volume rate are key questions for spray applications in orchard and vineyard plantations. The spray application process can be evaluated throughout the analysis of the amount of pesticide deposited on the leaves according the intended application rate, and also by the uniformity of the distribution among the canopy (Gil et al., 2012). Establishing the most accurate volume rate for pesticide

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application in vineyards appears to be one of the most difficult aspects of vineyard spraying, with a certain amount of subjectivity being used by most growers (Gil et al., 2011).
The CARTS project main goal is to develop a sprayer prototype, hardware and software, which can adjust in real time the spraying rate volume according to different vegetation canopies. In order to do this, the first steps are concerned on measuring several types of canopies at different growth stages, but also on characterizing spraying operations currently adopted by major farmers.

2. Materials and methods

Field work is being carried out at Vinha do Casito, a vineyard belonging to Fundação Eugénio de Almeida (FEA) near Évora, Portugal (-7° 52‘ 36‘‘ W, 38° 32‘ 59‘‘N). Row spacing is 2.5 m and distance between plants is 1 m. Trials were performed on two varieties (Trincadeira and Aragonês). For each one, plants of high and low vigour were chosen, based upon Normalised Difference Vegetation Index (NDVI), measured on previous year. NDVI presents a significant variation within the same field and variety witch reflects on canopy volume.

2.1 Characterising vegetation

Grapevine growth starts without any leaves and ends with a large canopy and because of that, throughout the growing season, canopies height and width were measured on four locations, combining varieties (Trincadeira and Aragonês) and vigour (high and low) (Figure 1).

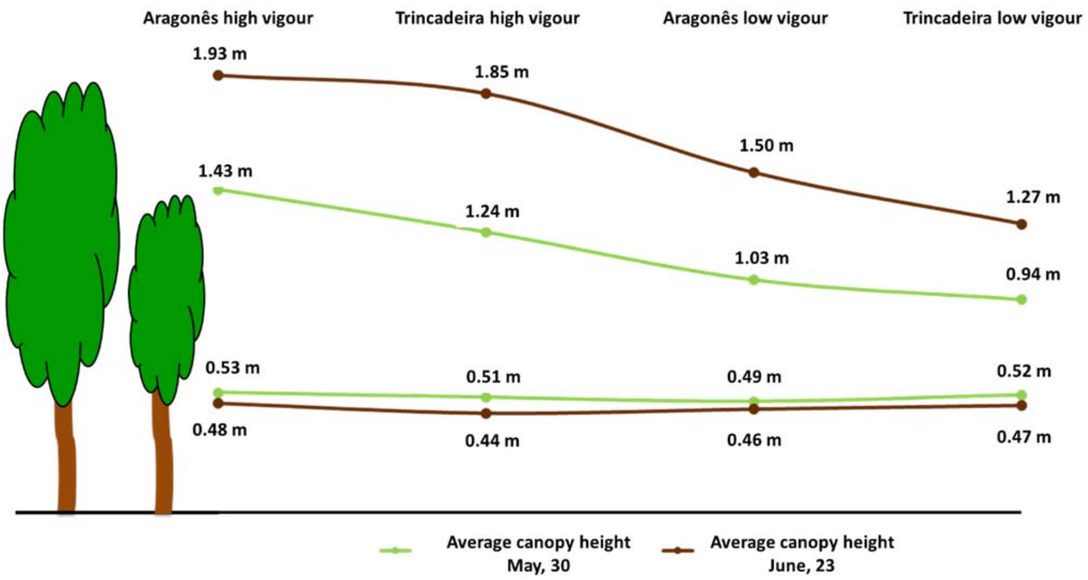


Figure 1: Average canopy height at sample sites on May, 30 and June, 23.

TRV is a simple and objective method used to determine the canopy volume in a hectare of orchard that can be applied to crops with different row spacing, tree sizes, ages and other factors (Scapin et al., 2005). TRV can be calculated by multiplying the following parameters: (1) tree average height in m, (2) tree average width in m, and (3) row length per hectare in m, which is determined by dividing 10,000 m^2 by the distance between rows in m (Sutton and Unrath, 1984, cit. by Scapin et al., 2005).

2.2 Sprayer

Tests were performed using the farmer sprayer, a Berthoud Supair sprayer with yellow Albuz ATR nozzles, working at a forward speed of 8 km h^{-1} with a volume rate of 85 L ha^{-1}. Previously, the sprayer has been calibrated and spray collection volume was measured.

2.3 Water Sensitive Papers

The evaluation process of the spray application was made with Water Sensitive Papers (WSP). Based on previous work (Gil et al., 2012) a sampling scheme was established as shown in Figure 2.
Water Sensitive Papers were 52 x 76 mm in size and at least an area of 75 % was measured. Papers were previously identified, to avoid unnecessary manipulation after spraying.

Water Sensitive Papers were scanned with 600 dpi image resolution using an HP LJ Pro scanner and the images were saved in bmp format. Each paper was analysed with DepositScan (USDA-ARS Application Technology Research Unit, Wooster, Ohio, USA), a software package used by an image processing software (ImageJ). DepositScan measures droplet sizes, total droplet number, droplet density, amount of spray deposits and percentage of spray coverage.

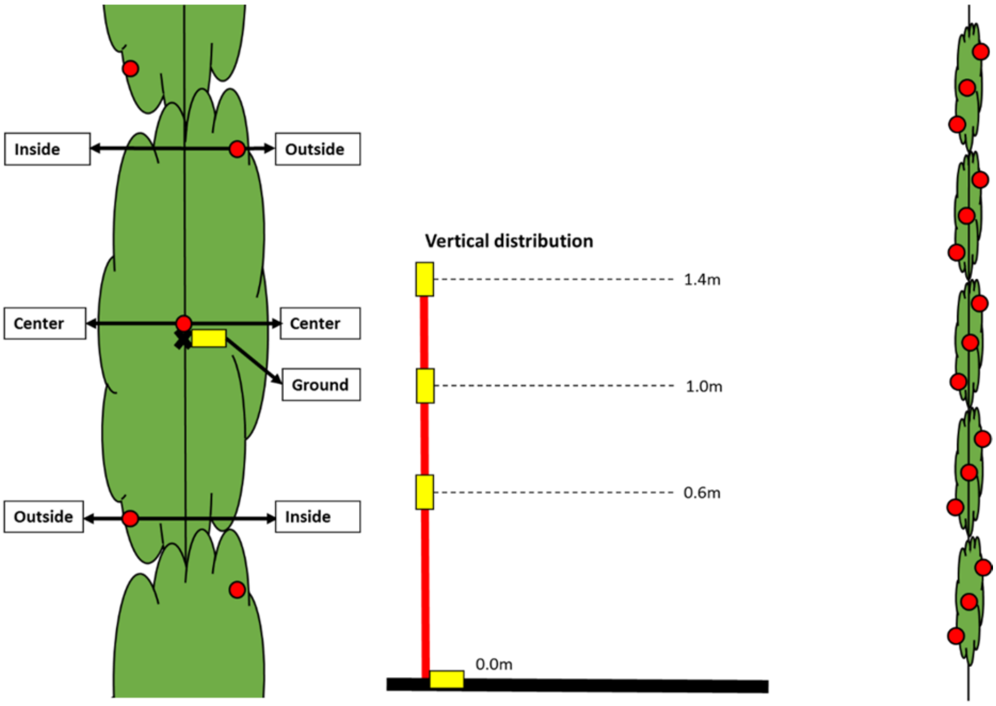


Figure 2: Water Sensitive Papers collectors' placement on plants.

3. Results and discussion

Figures 1 and 3 show the wide range variation that can be found in a vineyard or in a field over space and time. On the same date and between dates we can find vineyard height differences between 0.40 to 0.50 m and 0.50 to 0.60 m respectively. These differences in space and time are not normally considered with current spraying technology producing in this way large environmental and economic inefficiencies.

Figure 4 shows the relationship between the volumes of applied product (Litres) and the canopy volumes measured at each sampling site (m^3) throughout the vegetative cycle. The red line indicates a reference value for this relationship, proposed by Gil et al. (2012) for this type of sprayers. It is possible to verify that the application efficiency hardly met the reference of Gil et al. (2012). As on May 19 the vegetative growth was still low, the "spray volume / canopy volume" ratio was calculated in two situations: (i) considering only the lower nozzles in operation (top nozzles closed); and (ii) considering all nozzles working (top and bottom opened). Nevertheless, in the areas of low vegetative vigour, at that time, the ratio between the spray volume and the leaves volume exceeded the reference value. In the first application, on May 19, only the Aragonês treatment, with high vigour, showed a suitable "spray volume / canopy volume" ratio because all other treatments presented a "spray volume / canopy volume" ratio always higher than the reference. In situations of low vegetative vigour, a value 3 times higher than the reference was found, thus showing a low application efficiency (over application). On June 9, the only treatment that approached the reference was the low-vigour Trincadeira variety, all the remaining treatments presented values lower than the reference (between half and 2/3 of the reference). On June 23 and July 25 all treatments were lower than the reference (close to 2/3 of the reference), showing a lack of application efficiency (under application).

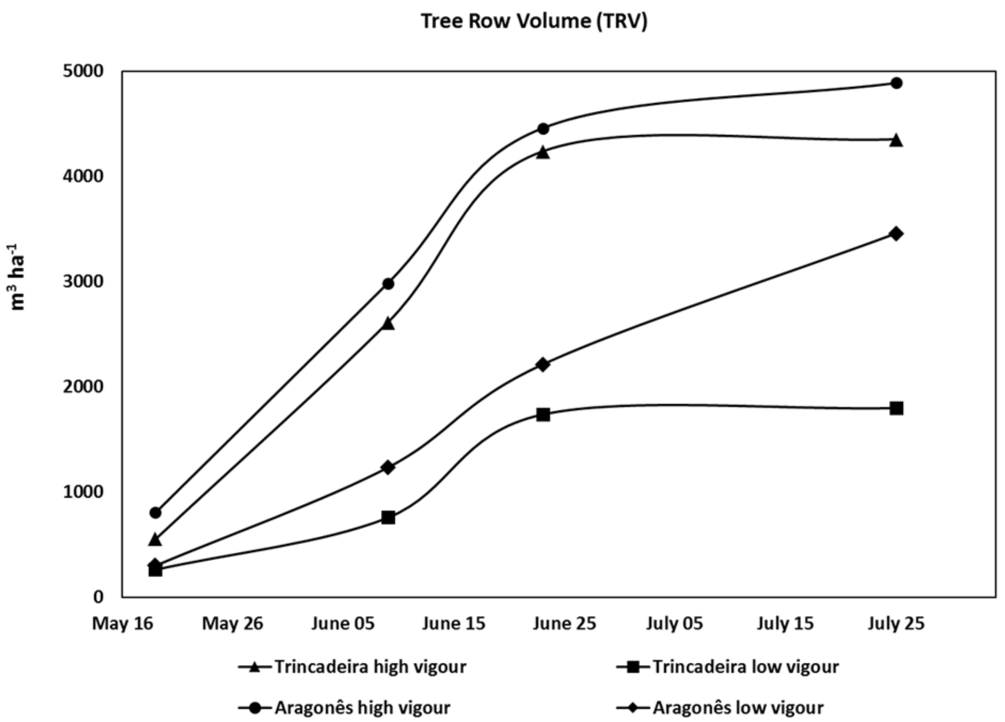


Figure 3: Tree row volume variation in time considering the 4 experimental sites used for the tests.

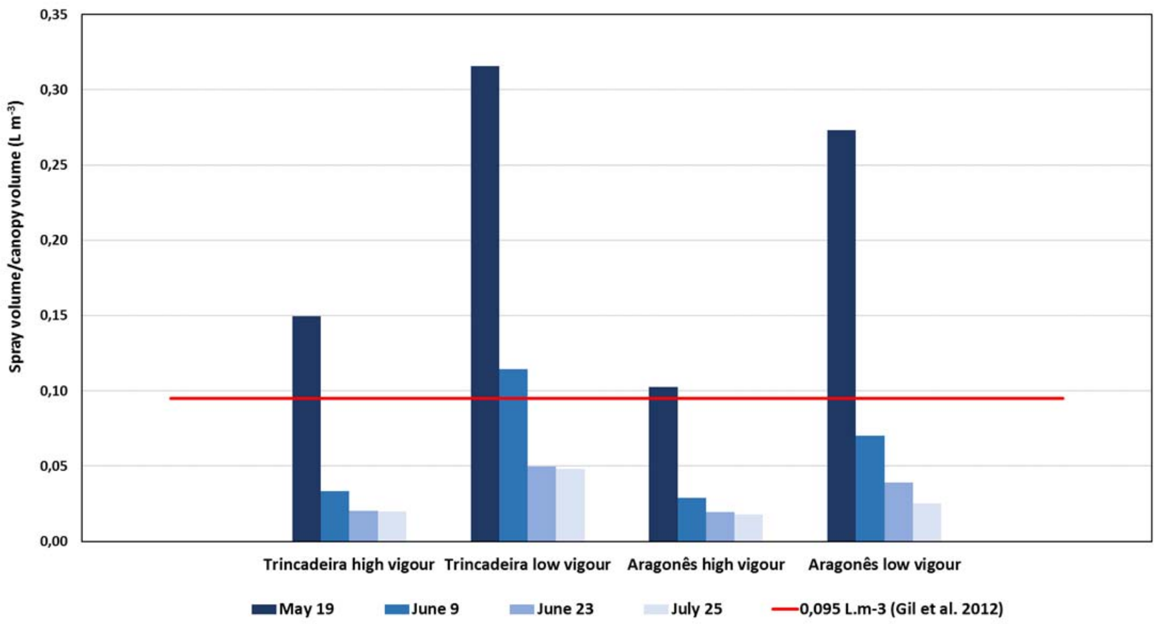
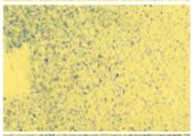
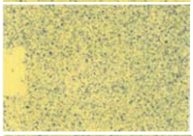
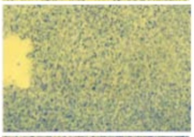
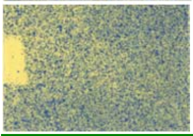


Figure 4: Relationship between volumes of applied product (Litres) and canopy volumes (m^3).

An efficient and effective spraying needs to ensure a correct "spray volume / leaf volume", but at the same time needs to consider that the sprayed leaves have to have the correct coverage of the sprayed product in terms of the quantity (droplet cover and deposition) but also in terms of quality (droplet Volume Median Diameter).

Table 1: Some examples for droplet Volume Median Diameter (VMD), droplet cover and deposition found on field tests.

WSP	% coverage	Deposits/cm^2	VMD (µm)	Deposition (µL/cm^2)
	5 %	130	209	0.199
	10 %	154	291	0.514
	20 %	296	320	1.070
	30 %	314	484	2.164
	40 %*	243*	881*	4.688*

* Above 30% of coverage the DepositScan software does not guarantee quality for the expected values.

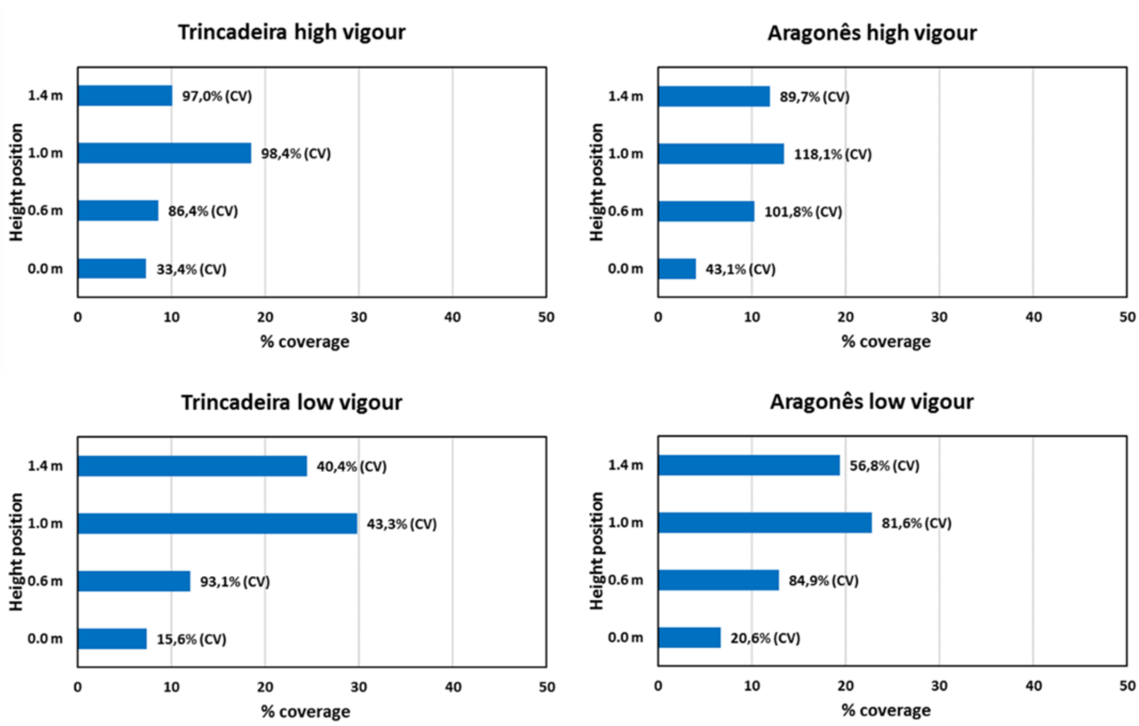


Figure 5: Total average and total coefficient of variation for Water Sensitive Paper coverage on the ground and at three vine height positions.

Considering the coverage tests performed in the field with the water sensitive papers (Figure 2), Table 1 shows some results of the droplet coverage percentage, the number of drops and volume per cm^2 and the droplet Volume Median Diameter of those coverage. As can be seen form Table 1 the process is rather complex because the variability found is usually high.

Regarding the coverage percentage, it can be seen from Figure 5 that it varies not only in height within the vineyard line, but also in the same height considering the coverage variation coefficients presented on Figure 5, normally greater than 80 to 90 %.

General results show that droplet cover goes from 0 % to 30 % for more than 80 % of sampled WPS. About 75 % of droplet Volume Median Diameter (VMD) goes from ~100 μm to ~500 μm.

4. Conclusions

Results show that droplet cover goes from 0 % to 30 % with a coefficient of variation normally above 80 %; droplet Volume Median Diameter (VMD) goes from ~100 μm to ~500 μm and the ratio between spray volume and canopy volume goes from 0.02 L m^{-3} to 0.32 L m^{-3}. These huge variations happen because there are no fast and flexible systems reacting to site-specific needs without destroying the quality of spraying. There is a need of smart spraying systems and because of that the CARTS (Canopy Adjusted Real Time Spraying) project was setup and was initiated in November 2015. The main objective of the CARTS project is to produce a spray equipment with capacity to measure the volume of leaves and adjust, in real time, the spray volume rate to be applied. To achieve this goal, the CARTS project brought together the Hexastep (Business leader: hexastep.pt), the University of Évora (Scientific leader: uevora.pt) and Micron (industrial leader: microngroup.com). With these consortium authors believe that in 2018 there will be available in the market a commercial differential sprayer for vines.

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