XIIIth International Terroir Congress
17–18 November 2020
Virtual Congress | Adelaide, Australia

TAKING ADVANTAGE OF DIFFICULTIES. VARIABLE RATE APPLICATION BASED ON CANOPY MAPS TO ACHIEVE A SUSTAINABLE CROP PROTECTION PROCESS

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Abstract

Aim: The aim of this work was to evaluate the use of Variable Rate Application technologies based on prescription maps in commercial vineyards with large intra-parcel variability to achieve a more sustainable distribution of Plant Protection Products (PPP).

Methods and Results: Eight vineyard plots on three Spanish wineries (Jean Leon, Viñas del Vero and Martín Códax) were selected. In all of these plots, a Variable Rate Application (VRA) system was implemented during the whole season. A UAV flew over plots at three different crop stages (BBCH 60, 75 and 81) in order to generate the corresponding canopy maps. For this process, a multispectral camera with five spectral bands (Red, Green, Blue, NIR and RedEdge) was embedded on the UAV. In order to obtain a vigor map, the NDVI vegetative index was calculated and aggregated at three different levels (low, medium and high vigor). The three different vigor zones were validated by manual measurements of canopy height and canopy width in the three defined zones. Generated canopy maps were transformed into application prescription maps using the DSS DOSAVIÑA®. Prescription maps were uploaded into the VRA sprayer that works as follows: 1) determining its GPS position on the plot, 2) getting the objective volume rate from the prescription map considering the GPS position, 3) reading the actual spraying pressure, 4) readjusting the spraying pressure to the objective volume rate 5) recording, every second, actual data about forward speed, pressure, volume rate and prescribing a volume rate and 6) generating an actual application map with the recorded data. The actual application maps obtained allows comparison with the VRA technology versus the conventional spray application. Preliminary data demonstrated a 20% savings both, on pesticide amount and on water volume, resulting also in a more profitable time consumption. Biological efficacy evaluation demonstrated no differences in control, only an increase in the efficiency of pesticide application and a reduction in environmental contamination risk.

Conclusions: This work demonstrates in the success of PPP application using VRA technologies. The system was able to maintain or even increase the spray distribution quality in the whole canopy structure, reducing losses to the ground and cutting down drift by adjusting the optimal amount of liquid according the canopy characteristics. As in all cases PPP concentration was maintained following the pesticide label recommendations, the VRA system reduced the total amount of PPP per hectare. All together effective pest/disease control was maintained.

Significance and Impact of the Study: The PPP application requires accuracy, as imprecise or excessive use can lead to serious problems such as environmental pollution, traces of pesticides in food, and health issues in humans. The high degree of intra-parcel variability in the vineyard crop makes it difficult to determine a suitable solution for all areas of the plot. A more sustainable use of PPP will reduce the total amount of pesticides used, reduce the environmental contamination risk and increase food quality.

Keywords: Variable rate application, vineyard, prescription map, unmanned aerial vehicle, DOSAVIÑA

Introduction

The PPP application based on canopy structure has been widely studied (e.g., Gil *et al.,* 2014; Garcerá *et al.,* 2017). These studies have established the necessity to adjust the total amount of PPP to suit the canopy characteristics. The high degree of intra-parcel variability makes it difficult to determine a suitable solution for all areas of the plot. When a uniform canopy structure is assumed for the whole vineyard, differences in the total amount of pesticide arriving at the canopy can occur, which reduces the effectiveness of spray application. In that sense, the variable rate application is capable of reducing the effect of intra-parcel variability, adjusting the volume rate to the canopy characteristics in all areas of the plot. Two types of variable rate application technology are currently known:

1. Using onboard sensors to perform the variable rate application in real time. This technology does not require previous knowledge of the crop, as it modifies the working parameters according to the information obtained by the sensors at the time of application (Gil *et al.,* 2007; Bennur and Taylor, 2010).
2. Using prescription maps to carry out the variable rate application. In this case, a previous study of the crop is needed, either through data collected manually in the field, or through sensors in the crop, or through remote sensing (Michaud *et al.,* 2008; Campos *et al.,* 2019, 2020). It should be noted that the variable rate application technology of PPP based on prescription maps is widely used in field crops but not in specialty crops, where the technology is incipient.

The aim of this work is to evaluate a variable rate application system based on prescription maps obtained from spectral images taken with UAV in three representatives Spanish wine regions.

Material and Methods

Experimental Site

The trials were conducted on eight vineyards of three Spanish wineries (Jean Leon, Viñas del Vero and Martín Códax) located in three different Spanish regions. The main characteristics of the selected vineyards are shown in Table 1.

Table 1: Main characteristics of the selected vineyards.

Winery	Nº Plot	Plot	Variety	Row spacing (m)	Vine spacing (m)	Area (ha)
Jean Leon	1	Sant Pere 2	Chardonnay	2.2	1.2	2.21
	2	Vinya Vella	Merlot	2.2	1.2	2.80
	3	Cal Xim	C. Sauvignon	2.2	1.2	1.38
	4	Xim 2	C. Sauvignon	2.2	1.2	2.80
	5	Fransola	Chardonnay	2.2	1.2	6.58
Viñas Vero	6	Arnal	Chardonnay	3.0	1.2	5.73
	7	Herminio	C. Sauvignon	3.0	1.2	4.28
Martín Códax	8	Viladervós	Godello	3.0	1.2	3.90

Canopy Vigor Maps Generation

Plots were flown with an unmanned aerial vehicle (UAV) at three different crop stages, BBCH 60, 75 and 81 (Meier, 1997). The UAV was loaded with a multispectral camera (RedEDGE, Micasense, Seattle, USA) equipped with five bands (R, G, B, RedEdge and NIR). Flights were conducted at 95 m above ground level (AGL) and were adjusted an 80% of forward overlap and a 60% of side overlap. In order to obtain a vigor map, NDVI vegetative index (Rouse *et al.,* 1973) was calculated and aggregated at three different levels (low, medium and high vigor).

Prescription Maps Generation

Once the vigor maps were generated, the canopy were characterized in all of the identified vigor zones following EPPO standard (OEPP/EPPO, 2008). In order to determine the optimal volume rate considering the canopy characteristics, the decision support system (DSS) DOSAVIÑA® (Gil *et al.,* 2019) was used. Finally, the obtained volume rates were loaded in the classified vigor maps in order to obtain the prescription maps.

Adapted Sprayer for Variable Rate Application

In the Jean Leon winery, two sprayers were equipped with: a) One pressure sensor GEMS 1200 series (Gems Sensors & Controls, Plainville, USA) to allow the adjustment of required pressure according to the prescription map, b) Electronic controller (Estel S.L., Barcelona, Spain), including GNSS receiver with a frequency of 1 Hz, a touchscreen and an automatic section controller. In order to follow the prescription maps.

In the Viñas del Vero and Martín Códax wineries a sprayer was equipped with the H3O system (Pulverizadores Fede S.L., Valencia, Spain). This system equips the sprayer with a sensor pressure, an electronic flowmeter, electro valves, a GNNS receiver, an on-board computer and a touch screen in the tractor.

The function of both systems was: 1) to determine the position of the sprayer in the field detected by the GNSS receiver, 2) to determine the desired volume rate based on the previously uploaded prescription map, and 3) to modify the working pressure in order to obtain the adjusted nozzle flow rate.

Evaluation of the Biological Efficacy

In order to evaluate the biological efficacy of the variable rate applications (VRA), another eight different plots were selected and treated with conventional application (CONV). These plots were selected with the same main characteristics shown in Table 1. The evaluation involved determining the presence of powdery mildew (*Uncinula necator*) in the studied plots (VRA and CONV plots). To achieve this comparison, a systematic sampling of 20 points ha^{-1} was implemented. The percentage of infection was determined following the EPPO guideline (OEPP/EPPO, 2002).

Results and Discussion

During the spraying season, a total of 37 variable rate applications were performed. Depending on the disease pressure in each parcel, the number of spray applications varied between plots. In each of these cases, the vegetation in each area of vigor was measured in order to determine the optimum volume rate using DOSAVIÑA and thus create the prescription map.

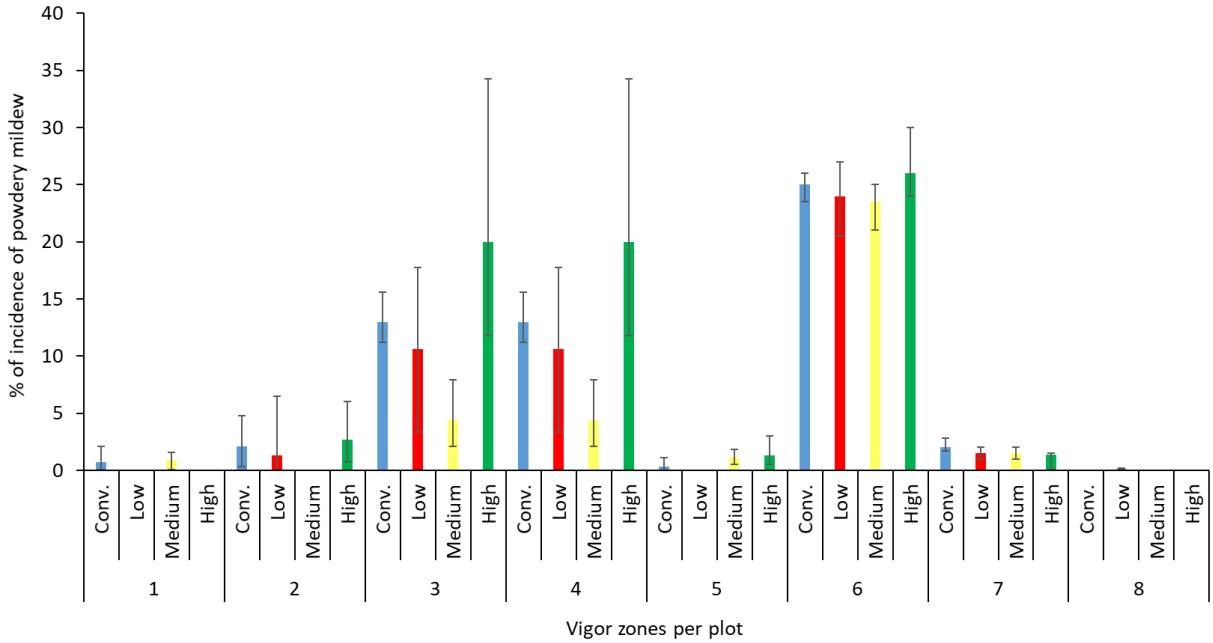

Figure 1: Percentage of incidence of powdery mildew for each studied plot and differentiate per vigor zones.

Figure 1 presents the results obtained for powdery mildew incidence in the vineyards leaves. Generally, the incidence of powdery mildew was higher in the plots applied with the variable rate application system. However, no significant differences were found between the plots applied with the conventional system and the plots applied with the variable rate application system.

In general, applied volume rates ranged from 180 to 600 L ha^{-1} for conventional application, based on farmer's experience, while the range was reduced to 150 to 400 L ha^{-1} calculated with DOSAVIÑA® (Gil *et al.,* 2019). In the

case of variable rate application, the volume rate was always related to the canopy characteristics. In contrast, to conventional applications, the volume rate was largely invariable for all spray applications.

The results show a positive effect of the use of the variable rate application. The amount of liquid consumed and the amount of active ingredient were reduced by 17% using the variable rate application based on prescription maps. Similar results were found in Campos *et al.* (2019, 2020), where the difference of liquid consumed between conventional plots and variable rate application plots was around 20% and 40% respectively.

Conclusions

In this research, two different variable rate application systems were tested along an entire vineyard growth season. The results shown above reveal some important facts: 1) both systems are able to read the prescription maps and modify the working pressure depending on the position of the sprayer in field. 2) The variable rate application process can obtain equivalent results regarding biological efficacy as a conventional pest application process. 3) The combination of vigour maps with Dosaviña® (DSS) to determine the optimal volume rate can reduce by around 20% the amount of water wasted in a spray application process and the amount of pesticide, as long as the concentration of the product is maintained.

Acknowledgments

This research was funded by the project Gophytovid: *Optimización del uso de fitosanitarios en viticultura en base a mapas de vigor* (Rural development 2014-2020 for Operational Groups).

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