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Spray adjustments based on LWA concept in vineyard. Relationship between canopy and coverage for different application settings

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Summary

Crop-adapted dosing of agrochemicals, i.e. dose adjustment has been widely discussed in previous research. In all cases, the main goal has been to adapt the total amount of plant protection products (PPP) to crop characteristics, but the most difficult aspect seems to select the most suitable crop parameter to be used for dose expression. This situation has resulted in a recent proposal by the European agrochemical manufacturing industry to harmonise, across Europe, the efficacy evaluation stage of pesticide registration based on Leaf Wall Area (LWA) concept. However, other than the problem of the "dose expression unit", which expresses the product quantity in relation to the treated area, the achievement of an adequate and optimal volume rate for an intended canopy must be established and determined separately.

This research present the results obtained during the spray process on a vineyard plantation (var. Merlot) using an IRIS multi-row sprayer (Ilemo-Hardi, S.A.U.) Three different adjustments were evaluated from low (250 L 10000 m^{-2}) to high (500 L 10000 m^{-2}) LWA, maintaining in all cases the same nozzle size (Albuz ATR lilac) and forward speed. Average canopy height was 0.8 m. In order to evaluate the effect of canopy characteristics other than crop height, a LIDAR sensor was used for a complete canopy characterization. Research was arranged in order to obtain the relation hip between canopy characteristics and the most adequate amount of liquid for a homogenous canopy wall.

Key words: Dose expression, LWA, Leaf Wall Area, vineyard, spray volume, optimal coverage

Introduction

During the pesticide application process, risk as a function of pesticide dose and harm to sensitive non-target areas are both related to the total amount of plant protection products (PPP) and the spraying efficiency during the distribution process over the entire canopy. However, for orchard and vineyard applications, the different methods commonly used to determine the most suitable amount of PPP and the corresponding application volume rate are difficult to understand in most cases. A direct consequence of this complexity is that different methods have been proposed for the establishment of label dose expression; these different methods make various claims for the improved efficiency of pesticide use (Koch *et al*., 2001; Walklate *et al*., 2003, 2006, 2011; Koch, 2007). In all cases, the proposed alternative for dose expression has been linked to one or several canopy characteristics with great differences in the measurement difficulty.

Attempts to improve the dose expression procedures have included recommendations based upon either two (leaf wall area) or three (tree row volume) dimensional factors related to the canopy structure (Gil *et al*., 2011, 2013; Walklate *et al*., 2011; Escolà *et al*., 2013). However, those efforts have led to a "chaotic" situation in which a comparison of label instructions for PPP authorized in different European countries reveals remarkable differences in dose expression (Koch, 2007). This situation has resulted in a proposal by the European agrochemical manufacturing industry to harmonize, across Europe, the efficacy evaluation stage of pesticide registration (Wohlhauser, 2009). Recently studies (Walklate & Cross, 2013) demonstrated that the harmonised method of LWA dose expression for efficacy may be easily implemented as a regulated model of dose adjustment, without any need for an explicit value of the LWA dose rate on the product label. Furthermore, it has been demonstrated that the LWA dose adjustment model can easily be generalised to make use of additional information where this is available for the special canopy density parameter.

The main objective of this research was to evaluate different LWA values and its effect in the spray distribution quality in a typical Spanish vineyard.

Fig. 1. IRIS multi row sprayer (Ilemo Hardi, S.A.U.) used during the field trials (left); detail of collector's placement on the crop (right).

Materials and Methods

This study was carried out in a vineyard plantation (var. Merlot) located in Castell del Remei (Lleida, NE Spain). In average, vineyard had a height of 80 cm and row spacing was 3.2 m.

Equipment and working parameters

All treatments were performed using an IRIS multi-row sprayer (Ilemo-Hardi, S.A.U.) (Fig. 1). Based on the concept of LWA, three different dose adjustment were evaluated: high dose – 500 L 10000 m^{-2}, 2) medium dose – 350 L 10000 m^{-2} and 3) low dose – 250 L 10000 m^{-2}. Table 1 shows the main working conditions for each treatment.

Table 1. *Working conditions established during the field trials*

	250 L ha^{-1} LWA	350 L ha^{-1} LWA	500 L ha^{-1} LWA
Application rate (L ha^{-1})	125	175	250
Forward speed (Km h^{-1})	4.8	4.8	4.8
Working width	6.4	6.4	6.4
Number of nozzles	16	16	24
Pressure (bar)	7	13	10
Nozzle type	ATR lilac	ATR lilac	ATR lilac

Evaluation of spray quality process

For each treatment application coverage in three heights (top, middle and bottom) and three depths (left, centre and right) was evaluated using water sensitive paper (WSP) in four replicates (vines). After spraying, water sensitive papers were collected and scanned by a scanner with a resolution of 600 dpi non interpolated, with 24-bit. Percentage coverage in each one was evaluated by Image J® software.

Electronic characterization of the canopy

LIDAR was used to characterize the vines where WSP were placed. The LIDAR characterization was made using the same procedure described in the work of Llorens *et al*. (2011*a*). The LIDAR sensor was mounted in a mast attached to one platform and carried by one tractor, the laser sensor scanned completely the row sided on the left when the tractor travels along the field. At the same time, a GPS system was mounted at top of the same mast to know exactly the global position of the system. This system of positioning is based in a precise DGPS (Differential Global Positioning System) with enough accuracy to georeference each point collected by LIDAR sensor, each point was processed following the process described in Llorens *et al*. (2011*b*). Once the LIDAR data is positioned to global position by UTM (Universal Transverse Mercator) coordinates, it is possible to extract crop parameters through the analysis of the cloud of points (Fig. 2). In this work the parameters extracted were: LIDAR impacts, LAI, height of crop and width of crop. Each of these parameters was correlated to the position where the collectors of deposition were placed. It is interesting to remark the variability of LAI and canopy height detected by the Lidar sensor. For the purpose of this research only the average values were taken into account for the calculation parameters. However, this fact should be considered to improve the spray application process using electronic devices.

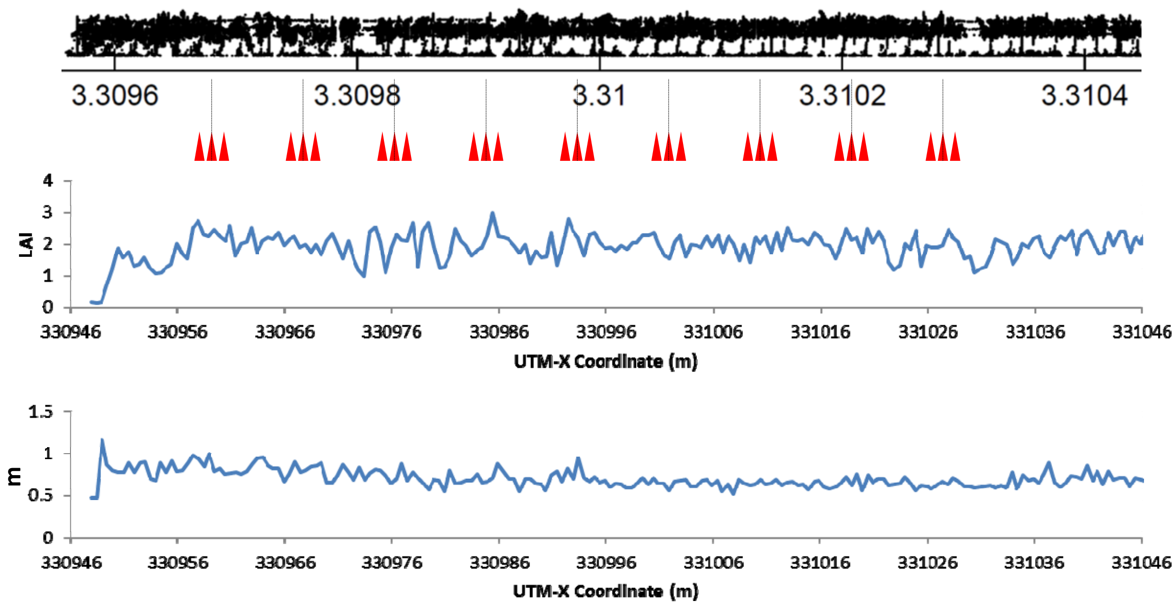

Fig. 2. Georeference placements of sample points (top figure); estimated values of LAI along the row calculated after the data obtained with Lidar sensor (middle figure); variation of canopy height along the row, calculated after the Lidar measurements (bottom figure).

Data analysis

Mean of coverage percentage of dose treatments were compared by one-way ANOVA followed Student–Newman–Keul's test. Data were transformed using a logarithmic transformation (before the statistical analysis in order to homogenize variances. Additionally coverage percentages in vertical and horizontal position were also statistical analysis. All statistical analyses were performed using R software (R Core Team, 2012).

Results

The evaluation process of the spray application is based in the analysis of two main factors: a) deposition on the leaf surface area, represented by the percentage of coverage measured on every single water sensitive paper; and b) the uniformity of deposition in the whole canopy, evaluated through the values of standard deviation among all the samples on every single repetition.

Coverage of leaf surface

Table 2 shows the average value of coverage obtained with the three different theses in terms of volume rate per LWA surface. The statistical analysis indicates no statistically differences between 350 and 500 L ha^{-1} LWA, while 250 L ha^{-1} LWA gave the lower value of coverage, being in this case different to the other two.

Table 2. *Percentage of coverage (%) of the water sensitive papers placed in the vines*

Dose treatment	250 L ha^{-1} LWA				350 L ha^{-1} LWA				500 L ha^{-1} LWA			
Mean ± SEM (%)	34.01	±	4.64	b	41.54	±	4.63	ab	46.52	±	2.88	a

For each dose treatment, mean values with different letters indicate significant differences (Student Newman Keuls, *P*<0.05). SME indicates the standard error of the mean.

Table 3. *Percentage of coverage (%) on every single sample point of the canopy*

	Left				Centre				Right							
250 L ha^{-1} LWA																
Top	11,84	±	8,73		10,79	±	3,88		22,54	±	5,58		**15,06**	±	3,70	**b**
Middle	66,74	±	11,28		46,85	±	10,59		72,27	±	6,99		**61,95**	±	6,09	**a**
Bottom	15,23	±	6,63		41,43	±	17,28		18,37	±	2,75		**25,01**	±	6,65	**b**
	31,27	±	8,94	-	**33,02**	±	7,85	-	**37,73**	±	7,90	-				
350 L ha^{-1} LWA																
Top	10,01	±	3,32		53,22	±	12,15		65,60	±	12,73		**42,94**	±	8,99	**ab**
Middle	59,53	±	13,14		49,40	±	13,28		61,86	±	16,03		**56,93**	±	7,60	**a**
Bottom	25,87	±	8,41		34,14	±	8,09		14,22	±	2,16		**24,74**	±	4,34	**b**
	31,80		7,87	-	**45,58**	±	6,45	-	**47,23**	±	9,39	-				
500 L ha^{-1} LWA																
Top	65,08	±	5,60		33,01	±	8,47		49,31	±	8,16		**49,13**	±	4,90	**-**
Middle	24,85	±	7,38		30,07	±	8,28		81,60	±	2,55		**45,51**	±	6,20	**-**
Bottom	28,67	±	6,81		55,63	±	4,83		50,48	±	3,70		**44,93**	±	3,72	**-**
	39,53	±	5,12	**b**	**39,57**	±	4,67	**b**	**60,46**	±	4,18	**a**				

For each dose treatment, mean values with different letters in rows indicate significant differences depending on the canopy width (Student Newman Keuls, *P*<0.05). Also mean values with different letters in columns indicate significant differences depending on the canopy height (Student Newman Keuls, *P*<0.05). SME indicates the standard error of the mean.

A detailed evaluation of the coverage distribution in the whole canopy and its variation depending on canopy height and/or canopy density can be observed in Table 3 which indicates the single values of % of coverage for all the nine sample points selected in the whole canopy.

The results inTable 3 indicate how position of samples according canopy height influence much more than position in the external or internal part of the canopy, for low or medium volume rates,

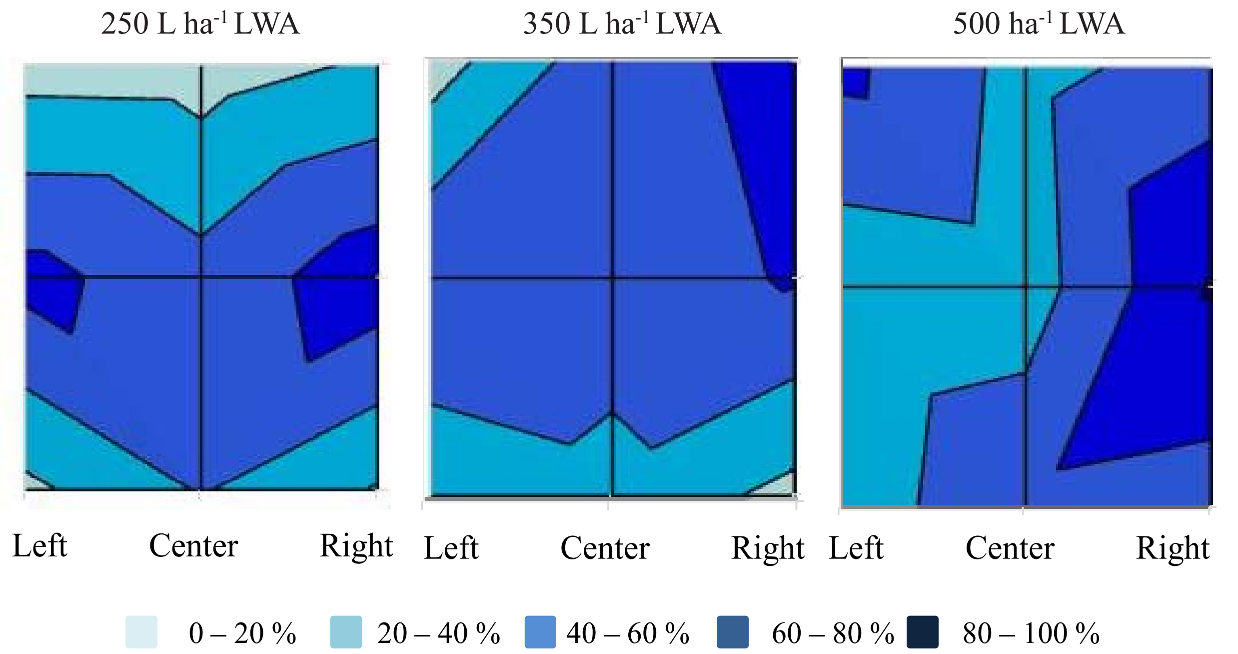

Fig. 3. Iso-coverage maps for the three different volumes rates. Zones within the same colour indicate the same range of coverage.

just the opposite that occurs in the case of the highest volume rate, where horizontal position of the samples (external or internal placement) produced statistically differences on the coverage values.

Graphical representation of those values can be observed in Fig. 3. In this case not only the coverage values, but also the spatial distribution on the canopy, are being an interesting indicator of the spray distribution among the canopy. A global analysis of the figure tends to select the medium value of application rate (350 L ha^{-1} LWA) as optimal value for spray applications in vineyard.

Uniformity of deposition

The second parameter used for spray distribution analysis was the quantification of the uniformity distribution of the spray among the canopy. For this purpose the standard deviation of all the coverage values obtained in the whole sample were calculated for every treatment. Table 4 indicates the values of standard deviation obtained with the different volume rates.

Table 4. *Standard deviation* (σ) *of coverage values obtained in the whole vegetation*

Dose treatment	250 L ha^{-1} LWA		350 L ha^{-1} LWA		500 L ha^{-1} LWA	
Standard deviation (σ)	28.7	A	28.9	a	25.2	a

For each dose treatment, mean values with different letters indicate significant differences (Student Newman Keuls, $P<0.05$).

Results indicate no statistical differences among the treatments in terms of uniformity of deposition, which clearly indicates that there are no benefits when increasing the spray volume rate (Table 4). These results must be evaluated together with Fig. 3 on which, in spite of the values of the standard deviation, a better uniformity can be observed in the case of 350 L ha^{-1} LWA.

Fig. 4 represents the relation between coverage and the distribution uniformity in the whole canopy, measured by the standard deviation of all the samples placed in the vegetation. It is interesting to observe how in all cases the values of coverage were placed in the range from 25–50%, or even more in the case of the highest volume rate, giving an adequate result for most of the particular requirements depending on the pesticide/disease/pest. However, it is difficult to observe any influence of volume rate in the uniformity of distribution in the whole canopy.

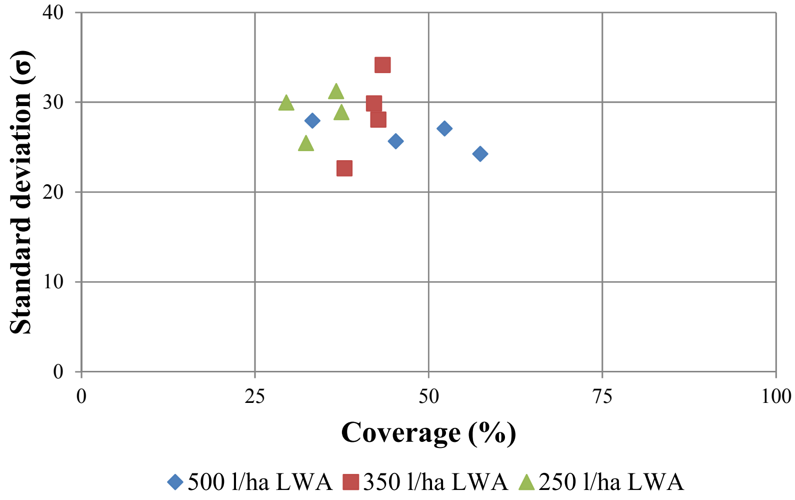

Fig. 4. Relationship between coverage (%) and uniformity of spray distribution (measured by standard deviation) in the whole canopy measured trough the values of the standard deviation.

Electronic characterization of the canopy

Table 5 shows the averaged values of the most important canopy parameters (leaf area index, canopy height and canopy width) according to LIDAR measurements.

Table 5. *Mean of number of measures (points) and values of the main canopy parameters obtained with LIDAR sensor for each dose treatment*

	Points	LAI	Height	Width
250 L ha^{-1}	208	1.88	0.77	0.48
350 L ha^{-1}	228	2.05	0.80	0.47
500 L ha^{-1}	218	1.97	0.79	0.47

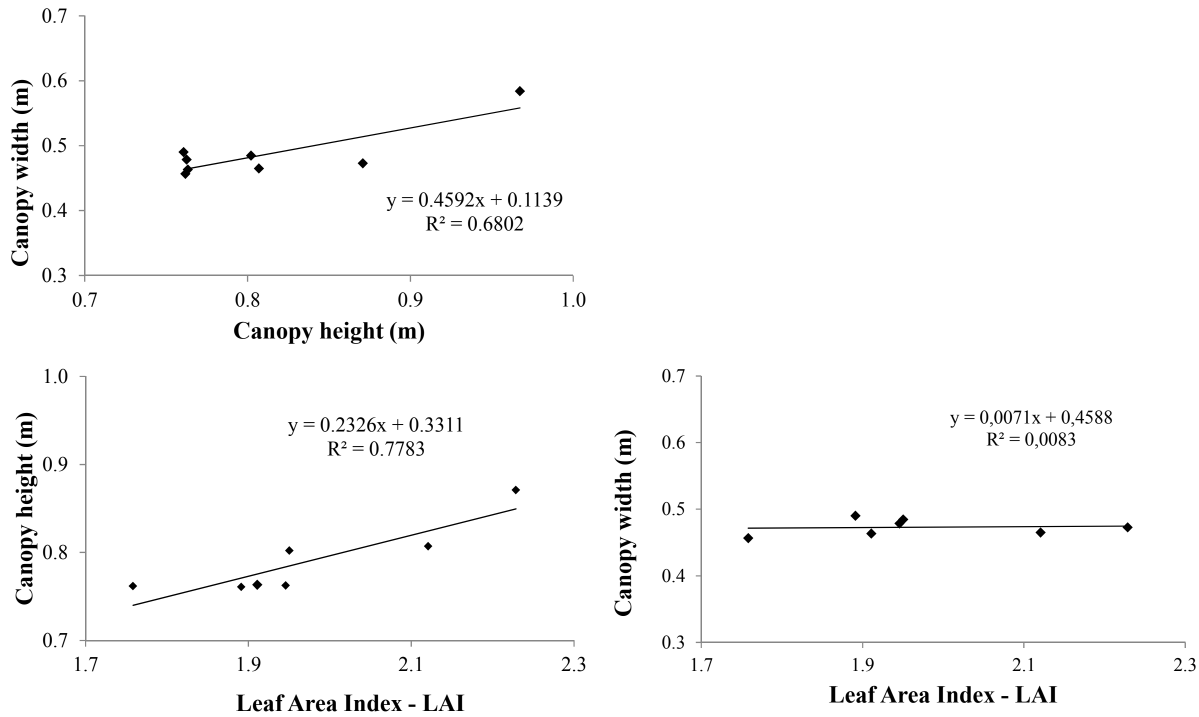

Fig. 5. Relationship between canopy parameters measured with LIDAR sensor.

Canopy variation along the sprayed row was not too important. However, it is interesting to remark that in some cases the differences between values of canopy width can range from 0.39 (lowest case) to 0.79 (the widest zone), and also LAI can vary from 1.52 to 2.23, affecting those variations to the spray distribution.

A further analysis of canopy data obtained with Lidar sensor indicates (Fig. 5) the good relationship between canopy height and canopy width. It is interesting to remark also the good estimation of leaf area index through the canopy height values, following the LWA procedure for the establishment of dose expression.

Conclusions

These preliminary results indicate that a spray volume rate based on LWA concept seems interesting to be adopted for the volume establishment in vineyard crops.

According the canopy measurements obtained with Lidar sensor, canopy height can be used as a good structural parameter to estimate leaf area index, and so, a good, easy measurable and interesting parameter for the establishment of the most appropriate volume rate and dose expression.

Further development of this research should be implemented in different crop stages in order to check the LWA value in the whole vegetative stages in vineyard. Obtained results could be used for pesticide companies for a most suitable dose expression method based on canopy structure.

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