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Reduction of the pesticide losses and the improvement of spray deposit through the study of sprayer optimal air velocities in vineyard

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Abstract
A two years study has been carried out in order to assess spray deposits on leaves, as well as ground and drift spray losses, according to the air volumes applied, taking into account different vegetation growth stages. In the first year of experiments, trials were carried out when the vegetation was fully developed (BBCH 77), applying always a volume rate of 230 l/ha, comparing the combinations of three different forward speeds (4, 6 and 8 km/h) and four different air velocities measured on the target (4.7, 7.0, 9.7 and 13.5 m/s). In the second year of the study, the same tests were made in the vineyard at the end of flowering growth stage (BBCH 69). Results pointed out that spray deposits on the leaves increased when low air velocities (5 m/s) and reduced forward speeds (4 or 6 km/h) were adopted. The use of reduced air volumes enabled also to limit drift losses.

Keywords: spray deposit on the leaf, drift losses, ground losses.

Introduction
Several studies have been carried out over the years with the aim to assess the most suitable volume application rates and spraying parameters for application in vineyards (Pergher and Gubiani, 1995; Balsari and Tamagnone, 1996). Nevertheless, only in recent years the adjustment of air flow rates and air velocities generated has become an important point of consideration (Balsari et al., 2001; Pergher, 2006; Cerruto, 2007). It is a fact that the regulation of the air generated by the sprayers' fans usually employed in vineyards is often neglected by farmers. This happens because often there are few options to adjust the air flow rate; typically it is possible only to change the rotation speed of the fan by a gear-box with two velocities (low and high). Moreover, in general terms, farmers do not consider the air adjustment as an instrument enabling to improve significantly the quality of spray distribution on the target. Sometimes they may consider reducing the air flow rate during the early growth stages, when there is only little canopy, mostly to avoid spray drift. Finally, there is a lack of guidelines for the correct air adjustment based on scientific data.

To investigate the effect of the air regulation on the quality of spray distribution in vineyards, a set of tests was carried out combining three different sprayer forward speeds and four different velocities of the air generated by the sprayer fan. Tests were made at two different vine growth stages, to examine the effect of canopy density on the outcome of the study.

Matherials and methods
Tests were carried out in a Barbera espalier trained vineyard, featured by a layout with 1 m distance between plants and 2.8 m distance between rows. In the first year of experiments, the trials were conducted when vegetation was at fully developed growth

stage (BBCH 77), when the canopy wall was on average 1.5 m in height and 0.4 m in width. In the second year, tests were made earlier, at the end of flowering growth stage (BBCH 69), when the canopy wall was on average 1.2 m in height and 0.25 m in width. A lift mounted air-assisted sprayer (Unigreen Turbo Teuton), equipped with a 400 l main tank and a radial fan (500 mm in diameter, nominal air flow rate of 10400 m^3/h at PTO speed of 540 rev/min) was employed. The sprayer is equipped with a system of orientable air spouts (3 per side) connected to the fan by means of flexible air hoses, enabling to obtain an even vertical air profile (Fig. 1). All tests were carried out using hollow cone nozzles (Teejet TXA 01, 015 and 02), mounted on the air spouts. In both growth stages considered, twelve treatments were compared combining three different forward speeds (4, 6 and 8 km/h) and four different air velocities from the air spouts (4.7, 7.0, 9.7 and 13.5 m/s). In order to always apply the same volume rate (230 l/ha) under the same operating pressure (1.0 MPa), different sizes of hollow cone nozzles (Teejet TXA) were used while keeping the droplet sizes produced relatively the same (Tab. 1). The air velocity was measured by means of an anemometer (Allemano Testo 400) positioned at 0.5 m from the outlet of the air spout. This distance corresponds to that existing in practice between the air spout and the vine canopy external leaves. To obtain the different air velocities examined, the PTO rotation speed, the fan gear-box velocity and the position of an air discharge valve in the air conveyor system were opportunely combined (Tab. 2)

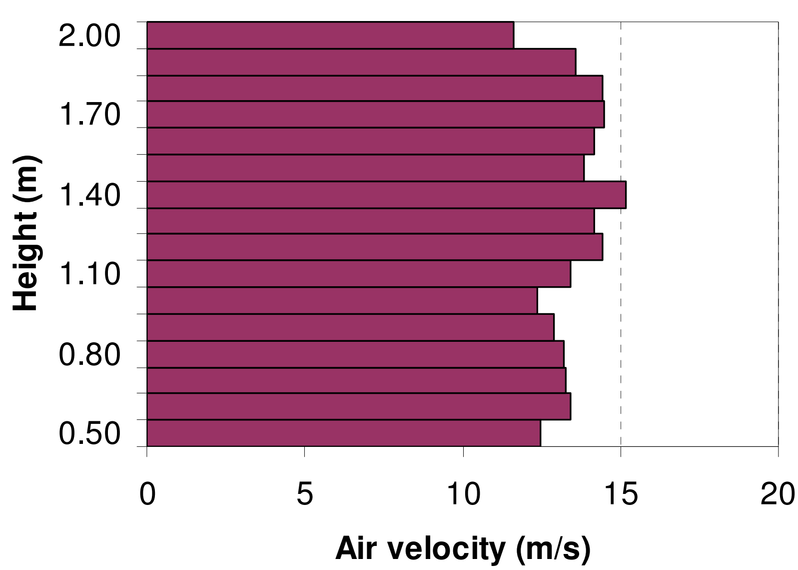

Figure. 1. Air velocities measured at 0.5 m away from the air spouts at different heights with the following operating parameters: PTO speed = 500 rev/min; fan gear velocity = high; air discharged valve = closed; fan rotation speed = 3350 rev/min.

Table 1. List of treatments examined in the experiments and corresponding spraying parameters.

Treatments	Forward speed (km/h)	Nozzle type	VMD (µm)	Air velocity (m/s)
1	4	TXA 8001	113	4.7
2	4	TXA 8001	113	7.0
3	4	TXA 8001	113	9.7
4	4	TXA 8001	113	13.5
5	6	TXA 80015	134	4.7
6	6	TXA 80015	134	7.0
7	6	TXA 80015	134	9.7
8	6	TXA 80015	134	13.5
9	8	TXA 8002	154	4.7
10	8	TXA 8002	154	7.0
11	8	TXA 8002	154	9.7
12	8	TXA 8002	154	13.5

Table 2. Fan parameters adopted to obtain the different air velocities tested in the experiments.

Air velocity (m/s)	PTO speed (rev/min)	Fan gear velocity	Air discharge valve	Fan rotation speed (rev/min)
4.7	250	Low	Open	1500
7.0	350	Low	Closed	2100
9.7	500	Low	Closed	3000
13.5	500	High	Closed	3350

Trials were conducted spraying a water solution of yellow Tartrazine E102 (5%v/v). For each test, the average amount of spray deposit on the leaves, the average amount of ground losses and that of losses in the air beyond the treated row were assessed. Sprayed leaves were sampled from the treated rows using a special frame (Fig. 2A), a 300 mm x 300 mm x 300 mm cube, that was inserted in the canopy. All the leaves included in the volume delimited by the frame were picked up, then washed in laboratory with a known volume of water and washings were analysed by a spectrophotometer (Jenway 6300). Five replications of this sampling were made for each treatment examined, and the average amount of spray deposited on the leaves, expressed in $\mu l/cm^2$ was then calculated. To estimate ground losses three arrays of collectors, 25 x 10 cm sized, made of cellulose material (Camfil CM 360), were placed in the adjacent inter-row area next to the sprayed row at distances of 45, 140 and 235 cm from the treated row, while to assess the spray losses in the air beyond the sprayed row, further collectors (always Camfil CM 360, 25 x 10 cm) were placed on the wires of the next row at three different heights from the ground: 90, 130 and 170 cm (Fig. 2B). Spray deposits on the collectors were then analysed with the same procedure adopted for the leaves. In order to compare the incidence of the ground losses and of the spray losses beyond the treated row between the treatments examined at the same vine growth stage, index values were used. Value 1 was assigned to the treatment with the lowest losses and the other values were calculated as multiples of this reference value.

A B

Figure 2. The iron frame used to define the portion of the row where to sample the sprayed leaves (A) and displacement of collectors on the ground and in correspondence of the second row to assess respectively ground losses and the amount of spray dispersed in the atmosphere beyond the treated row (B).

Results

In the trials carried out with the vegetation fully developed (BBCH 77), a low forward speed (4 km/h) combined with the lowest air velocity tested (4.7 m/s) produced the maximum amount of spray on the leaves (Fig. 3). Independent of the forward speed used, increments in the air velocity from the sprayer fan resulted in a reduction of the spray deposits on the leaves.

Concerning the incidence of ground losses, it was observed that, independently of the forward speed adopted, they generally decreased as the air velocity is increased (Fig. 4). On the other hand, as expected, higher air velocities resulted in higher deposits on the collectors placed beyond the treated row (Fig. 5), generating a higher risk of spray drift.

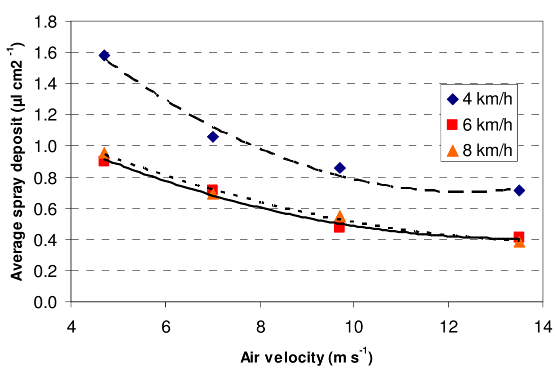

Figure 3. Effect of the air velocity generated by the sprayer fan on the average amount of spray deposit on the leaves, according to the forward speed adopted. Vine growth stage: vegetation fully developed (BBCH 77).

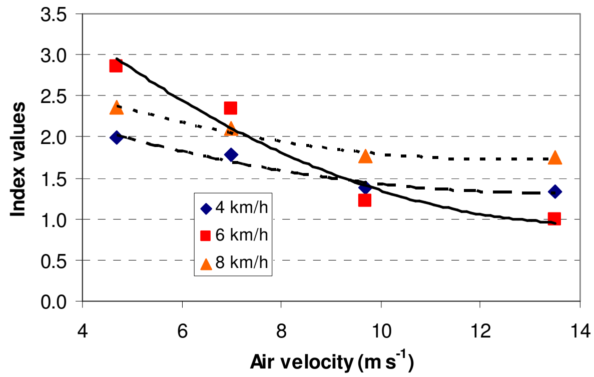

Figure 4. Ground losses registered in function of the air velocity used and according to the forward speed adopted (BBCH 77).

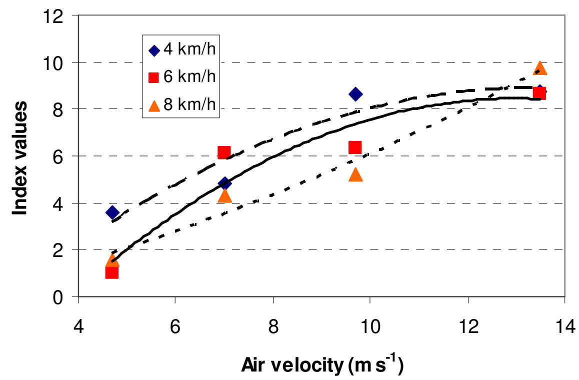

Figure 5. Airborne losses through the treated row registered as a function of the air velocity used and according to the forward speed adopted. Vine growth stage: vegetation fully developed (BBCH 77).

Test results obtained working at the end of flowering growth stage (BBCH 69) confirmed the general trend observed in the previous trials with regard to the effect of the air velocity on spray deposits on leaves (Fig. 6). Nevertheless, in this early growth stage, the best results were obtained adopting a forward speed of 6 km/h , thus applying a lower amount of air per hectare compared to the application at fully developed growth stage.

At the end of flowering growth stage, ground losses under different air velocities showed a similar trend with respect to that registered with the vegetation fully developed (Fig. 7 vs. Fig. 4): increasing the fan air velocity resulted in a decrease almost linearly of deposits on the collectors placed on the ground. Concerning the amount of spray that escaped the treated row and was detected in the second row, a dramatic increment of the values (up to 40 x) appeared as a result of increased air velocity (Fig. 8). This result is related to the fact that, as the vine canopy was still not fully developed, leaves could be easily rotated according to the air flow direction, therefore increasing the dispersion of spray through the treated row.

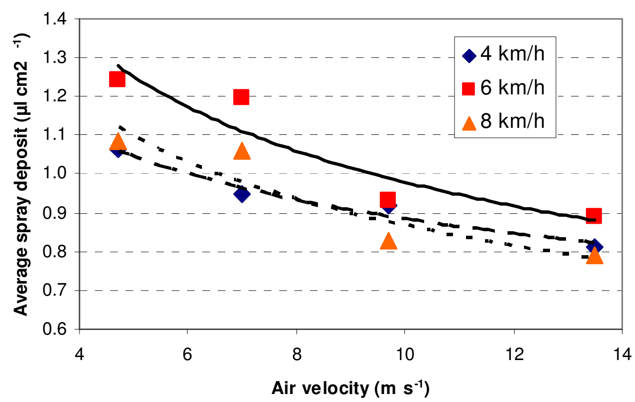

Figure 6. Effect of the air velocity generated by the sprayer fan on the average amount of spray deposit on the leaves, according to the forward speed adopted. Vine growth stage: end of flowering (BBCH 69).

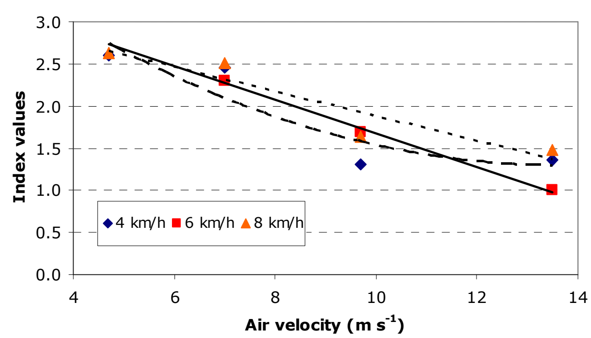

Figure 7. Ground losses registered as a function of the air velocity used and according to the forward speed adopted (BBCH 69).

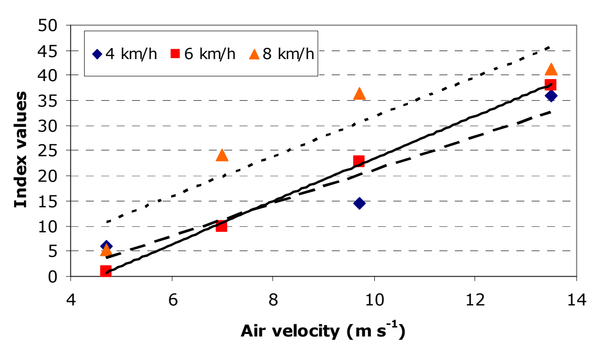

Figure 8. Airborne losses through the treated row registered as a function of the air velocity used and according to the forward speed adopted. Vine growth stage: end of flowering (BBCH 69).

Conclusion

Test results pointed out that, independent of the growth stage, working with high air velocities when spraying in vineyards do not produce higher average spray deposits on the leaves. Best results were obtained adopting an air velocity of around 5 m/s close to the external canopy. Results also showed that spray distribution within the canopy was better at low air velocities, as the coefficient of variation (CV) between the replications was lower than when using higher air velocities (Fig. 9).

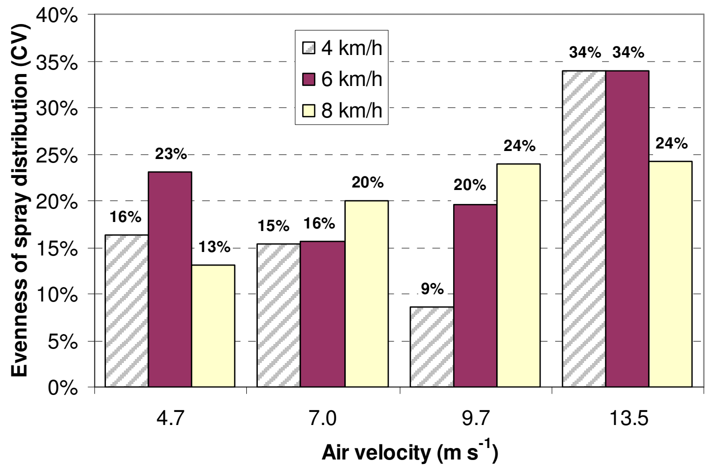

Figure 9. Coefficient of variation between the replications of samples calculated for the different combinations of air velocity and driving speed examined. Vine growth stage: vegetation fully developed (BBCH 77).

The use of high air velocities, moreover, severely increased the incidence of airborne losses, therefore enhancing drift risks.

These results are consistent with previous findings (Balsari et *al*., 2001), but it is to underline that, in order to be able to produce such a low air velocity (5 m/s), a relatively new model of air-assisted sprayer fitted with adjustable air spouts had to be used. The conventional and most commonly used axial fan air-assisted sprayers available on the market, in fact, are equipped with fans which generally produce unnecessarily high air velocities. By observing the current trend in sprayers sold, one can predict that the fan output is likely to continue to get bigger in the future.

It seems therefore necessary to push sprayer manufacturers to reconsider their opinions about air-assistance and to suggest them to provide their machines with finer adjustments of fans and air outputs, considering also the possibility to have different air velocities at different heights. The necessity to reach a good spray penetration into the bunches, for instance, may require higher air velocities only in correspondence of the grapes band. Further studies should be conducted to study the relationships between air velocities and efficient deposition of spray material on grapes.

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