# Study and development of a test methodology to assess potential drift generated by air-assisted sprayers

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## Summary

DiSAFA – University of Torino and DEAB – Polytechnic University of Catalonia started a set of experiments aimed at defining a new methodology for the assessment of potential drift generated by fruit crop sprayers using ad hoc test benches, operated in absence of wind and without any target in front of the machine. A set of tests using two different air-assisted sprayer models, one for vineyard and one for orchard, was made in order to compare the results obtained combining conventional and air induction nozzles with high and low air flow rates. Results pointed out that thanks to the use of the test benches is possible to discriminate the potential drift of the different sprayer configurations tested and that trends of the ranked sprayer configurations resulted the same for both sprayers. Further studies are needed to verify the consistency of the results obtained with those achieved applying ISO 22866 test method for drift assessment in the field.

**Key words**: spray drift, test bench, air-assisted sprayer, air induction nozzle.

## Introduction

Spray drift may cause diffuse contamination of the environment with agrochemicals; therefore in recent years several measures have been adopted to prevent it and to mitigate its pollution risks. In some European countries buffer zones are already prescribed with specific widths that are defined according to the spraying equipment employed and its conditions of use (Gilbert, 2000; Herbst and Ganzelmeier, 2000; Nilsson and Svensson, 2004; Van de Zande et al., 2000). These criteria will soon be extended to all EU countries to comply with the requirements of EU Directive 128/2009 on sustainable use of pesticides. It will be therefore necessary to foresee a classification of all sprayer types and configurations according to drift risk.

The only available methodology to assess spray drift using air-assisted orchard sprayers is actually the one described in ISO 22866 standard, which is difficult to apply for drift classification purposes due to the influence that wind conditions has on the results obtained. As there is a huge number of types and configurations of air-assisted sprayers for arboreal crops, their classification applying ISO 22866 test methodology would be long and expensive. Moreover, it should be repeated in each country/region taking into account the most common characteristics of the vineyards/orchards (layout, training system, plant size, etc.) that have an important effect on drift. The aim of the present study was therefore to develop a simpler methodology for assessing the potential drift generated by air-assisted sprayers for arboreal crops in absence of wind and without any target in front of the machine. DiSAFA – University of Torino and DEAB – Polytechnic University of Catalonia started a set of experiments aimed at defining a new methodology for the assessment of potential drift generated by fruit crop sprayers using ad hoc test benches (Balsari et al., 2007; Gil et al., 2013) – developed by University of Torino and Salvarani-AAMS company – enabling to assess potential drift generated by air-assisted sprayers in open field and in absence of wind. Tests were made employing two different air-assisted sprayers models (a Dragone $k_2$500 for vineyards and a Fede Qi 90 Futur 2000 for orchards), comparing the use of conventional and air induction nozzles combined with different air settings.

## Materials and Methods

Tests were carried out using two different air-assisted sprayers. At DiSAFA – University of Torino a mounted vineyard sprayer Dragone $k_2$500 fitted with a 400 l polyethylene tank, a tower shaped air conveyor and equipped with 6 nozzles for each side of the sprayer was used. The 500 mm diameter axial fan was provided with a two speed gearbox that enabled to vary the air flow rate from 11000 $m^3$ $h^{-1}$ to 16000 $m^3$ $h^{-1}$. Tests were made operating at 6 km $h^{-1}$ forward speed combining two different nozzle types (conventional hollow cone Albuz ATR orange – nominal flow rate 1.39 l min-$^{1}$ @ 1.0 MPa – and air induction hollow cone Albuz TVI 8002 – nominal flow rate 1.45 l min-$^{1}$ @ 1.0 MPa – , both operated at 1.0 MPa pressure) and two different air settings (11000 $m^3$ $h^{-1}$ and 16000 $m^3$ $h^{-1}$ air flow rates, Table 1), resulting in an application volume rate of about 670 l $ha^{-1}$, assuming to operate in a vineyard featured by a 2.5 m distance between rows. For each thesis five test replicates were made. At DEAB – Polytechnic University of Catalonia, a trailed orchard sprayer Fede Qi 90 Futur 2000 equipped with a 2000 l polyethylene tank, an axial fan 900 mm diameter and 8 nozzles for each sprayer side was employed. The sprayer was fitted with a fan two speed gearbox plus a mechanical system enabling to tune the air flow rate through the modification of the air outlet size; tests were made operating at 6 km $h^{-1}$ forward speed combining two different nozzle types (conventional hollow cone Albuz ATR red – nominal flow rate 1.97 l $min^{-1}$ @ 1.0 MPa – and air induction hollow cone Albuz TVI 80025 – nominal flow rate 1.82 l $min^{-1}$ @ 1.0 MPa –, both operated at 1.5 MPa pressure) and two different air settings (29000 $m^3$ $h^{-1}$ and 46000 $m^3$ $h^{-1}$ air flow rates, Table 2), resulting in an average volume application rate of about 800 l $ha^{-1}$, assuming to operate in an orchard featured by a 4.5 m distance between rows. Also in this case, for each theses five test replicates were made and coefficient of variation (CV) was determined. For all the nozzles used the main droplets characteristics (VMD, $D_{10}$ and $D_{90}$) were determined at the operating pressure through a laser diffraction instrument (Malvern Spraytec).

Table 1. *Parameters of the theses examined using the Dragone k2 500 vineyard sprayer*

| Thesis ID | Nozzle type | Operating pressure (MPa) | $D_{10}$ (µm) | VMD (µm) | $D_{90}$ (µm) | Air flow rate ($m^3$ $h^{-1}$) |
|---|---|---|---|---|---|---|
| 1 | ATR orange | 1.0 | 39 | 80 | 148 | 11000 |
| 2 | ATR orange | 1.0 | 39 | 80 | 148 | 16000 |
| 3 | TVI 8002 | 1.0 | 136 | 432 | 862 | 11000 |
| 4 | TVI 8002 | 1.0 | 136 | 432 | 862 | 16000 |

Table 2. *Parameters of the theses examined using the Fede Qi 90 orchard sprayer*

| Thesis ID | Nozzle type | Operating pressure (MPa) | $D_{10}$ (µm) | VMD (µm) | $D_{90}$ (µm) | Air flow rate ($m^3 h^{-1}$) |
|---|---|---|---|---|---|---|
| 5 | ATR red | 1.5 | 33 | 83 | 188 | 29000 |
| 6 | ATR red | 1.5 | 33 | 83 | 188 | 46000 |
| 7 | TVI 80025 | 1.5 | 131 | 430 | 845 | 29000 |
| 8 | TVI 80025 | 1.5 | 131 | 430 | 845 | 46000 |

In both laboratories, all tests were carried out in absence of wind (average wind velocity <0.5 m/s), operating the sprayer along a track made of concrete 50 m long and 3 m wide, in order to minimise the effects of eventual jerks on spray distribution. A solution of water and tracer (yellow Tartrazine E102) at 5-6 g $l^{-1}$ concentration was applied. On the left side of the track, perpendicular to the sprayer forward direction, two test benches 20 m long were placed on a turf surface at 1 m spacing (Fig. 1) and the first collector of each bench was positioned at 1 m distance from the outer nozzle of the sprayer.

Fig. 1. Disposal of test benches with respect to the sprayer.

Each test bench consists in an aluminium frame 50 cm wide holding plastic slots 50 x 20 cm sized that are positioned every 50 cm along the bench; in these slots collectors (Petri dishes 150 mm diameter) are placed; a system of sliding covers enables to cover/uncover the slots and is activated automatically by the sprayer pass through a pneumatic system. In practice, a tractor mounted appendix hits a vertical pole that is linked to the mechanism of the sliding covers (Fig. 2).

Fig. 2. Detail of the mechanism which allows to automatically open the test bench by means of the sprayer pass.

In all the tests one test bench was left with its slots permanently uncovered, in order to assess the spray range profile, intended as the fallout of the sprayer output detected at ground level through the use of the Petri dish collectors, in absence of any crop (obstacle) in front of the machine. The second test bench was kept covered during the sprayer pass in front of it and collectors were revealed four seconds after the nozzles passed in front of the bench. Definition of this 4 s time for uncovering the test bench was made on the basis of preliminary experiences (Balsari *et al.*, 2012). According the principle of functioning of the drift test bench, deposits measured in the collectors of this second test bench therefore enabled to calculate the fraction of droplets that remained suspended in the air after the sprayer pass and then fell down to the ground, representing the part of droplets more prone to drift as they could be blown out of the treated area by environmental wind.

The tracer concentration at the artificial collectors was quantified at DEAB using a spectrophotometer (Thermo Scientific Genesys 20). The DISAFA analyses were carried out using a specially designed robot system. It consists of a multi-purpose robotic arm (Kawasaki FS03N), a balance (Sartorius GP 3202, with a measuring range 0.01÷3200 g), a spectrophotometer (Biochrom Lybra S11) set at a wavelength of 434 nm and fed by a peristaltic pump (Watson-Marlow 101F/R), and a PC for recording the weights and absorbance values.

On the basis of the spray deposits measured on the permanently uncovered collectors, the recovery rate (RR) with respect to the sprayer output was calculated as follows:

$$RR = \left[ \sum_{i=1}^{n} D_i * 50 / SSO \right] * 100$$

Where
$D_i$ is the spray deposit on the single deposit collector, expressed in µl/cm$^2$;
*SSO* is the amount of liquid (µl) sprayed along 1 cm of advancing;
50 is the distance in cm between two adjacent collectors.

The deposits detected on the Petri dishes placed in the second test bench, that was uncovered four seconds after the sprayer pass, were used to calculate the spray potential drift (PD) according to the following formula:

$$PD = \sum_{i=1}^{n} D_i * d_i * 50$$

Where
*PD* is the total potential drift assessed on the test bench, expressed in µl;
$D_i$ is the spray deposit on the single deposit collector, expressed in µl/cm$^2$;
$d_i$ is the distance (cm) of the single deposit collector from the sprayer outer nozzle(s);
50 is the distance in cm between two adjacent collectors on the test bench.

Recovery rate and potential drift were then considered for the calculation of a Drift Potential Value (DPV) to assign to each theses tested. The formula adopted was the following:

$$DPV = PD * (100 - RR)$$

Where
*DPV* is the Drift Potential Value
*PD* is the total potential drift
*RR* is the recovery rate from sprayer output

## Results

Tests carried out at DiSAFA – University of Torino pointed out that the average DPV values obtained for the four theses examined were influenced by the spray quality and by the air flow rate as it was expected (Table 3). In details, the highest DPV value was reached when the conventional hollow cone nozzles combined with the high air flow rate (16000 $m^3$ $h^{-1}$) were employed and the lowest DPV value was obtained combining the air induction nozzles with the low air flow rate (11000 $m^3$ $h^{-1}$).

Table 3. *DPV values obtained using the Dragone k2 500 vineyard sprayer*

| Thesis ID | Average DPV | CV between five replicates | Average recovery rate (RR) |
|---|---|---|---|
| 1 | 284 | 23% | 65% |
| 2 | 558 | 53% | 55% |
| 3 | 80 | 20% | 50% |
| 4 | 85 | 51% | 71% |

The influence of the air flow rate on Drift Potential Value was more evident when conventional hollow cone nozzles (fine droplets) were used while it was slighter when the coarse droplets were sprayed employing the air induction nozzles. In theses 1 and 3 the reproducibility of results was fairly good with coefficient of variations – calculated between the DPV values obtained in the five test replicates – around 20%. More variability of results (CV around 50%) was found for theses 2 and 4, where the high air flow rate was adopted. Recovery rate on the permanently exposed collectors ranged from 50% to 71% of the sprayer output.

Looking at the spray deposit profiles obtained for each theses examined on the two test benches, it was noticed that the use of air induction nozzles reduced the length of the spray range in comparison with the conventional hollow cone ones. On the permanently exposed samplers it was observed a higher peak of spray deposits at about 4 meters from nozzle positions using the air induction nozzles and in this case deposits after the peak decreased dramatically while employing the conventional nozzles spray deposits decreased more gently along the test bench. In the collectors placed on the test bench uncovered four seconds after the sprayer pass higher deposits were found when fine droplets were sprayed, while the use of air induction nozzles reduced the amount of spray deposits detected on this second test bench (Fig. 3)

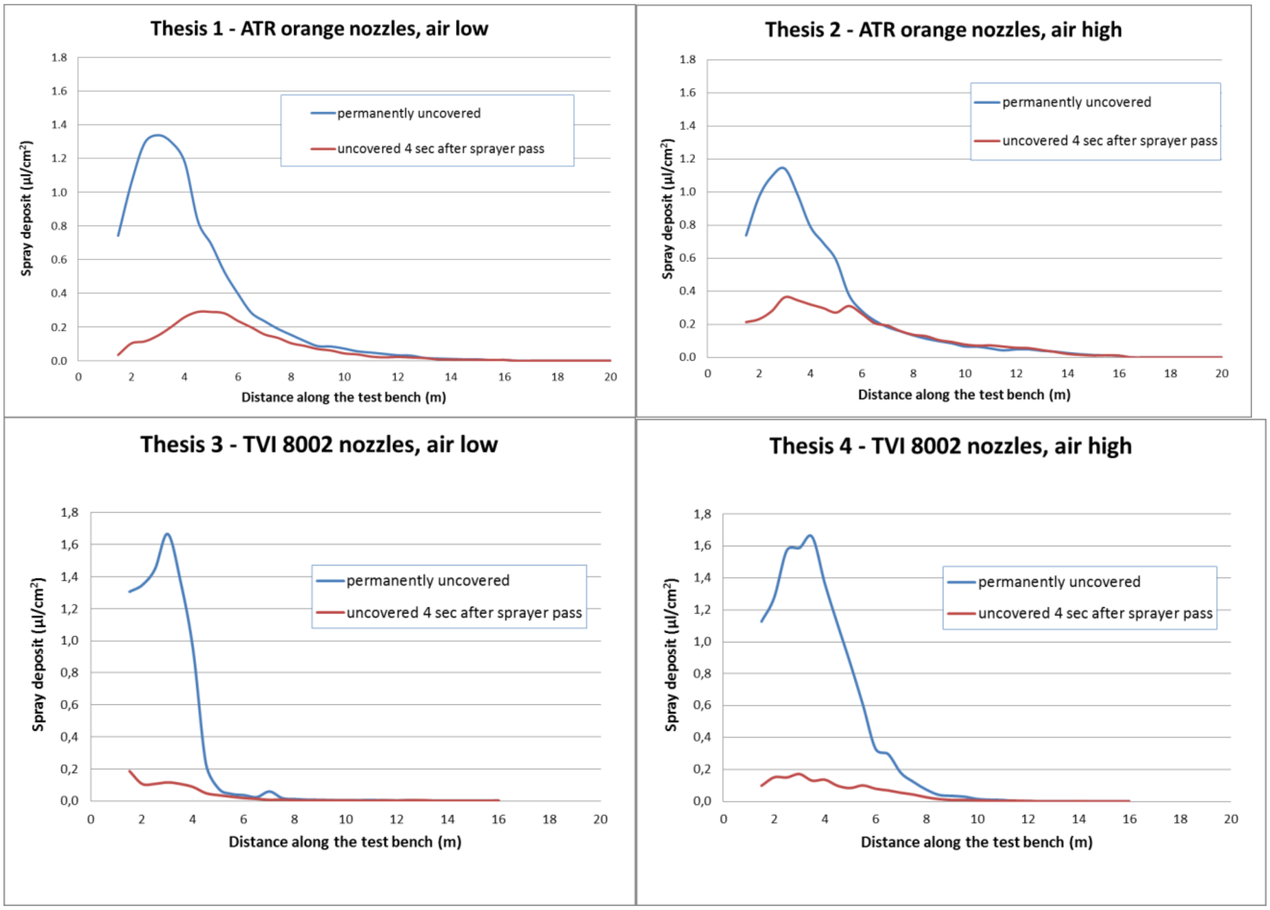


Fig. 3. Spray deposit profiles obtained on the two test benches for the four theses examined employing the Dragone k2 500 vineyard sprayer.

Also in the tests carried out at DEAB – Polytechnic University of Catalonia, where the Fede orchard sprayer was employed, it was observed that DPV values were higher using conventional hollow cone nozzles combined with the high air flow rate (46000 $m^3$ $h^{-1}$) and were lower when air induction nozzles were combined with a reduced air flow rate (29000 $m^3$ $h^{-1}$, Table 4). Coefficient of variations between the five test replicates of each thesis ranged between 19% and 43% but, in this set of tests, the highest variability of results was observed for thesis 7 when air induction nozzles and low air flow rate were combined (see Table 2). The average recovery rate resulted higher when the conventional nozzles were used while it was poor (only between 34% and 37% of the sprayer output) when air induction nozzles were used.

Table 4. *DPV values obtained using the Fede Qi 90 orchard sprayer*

| Thesis ID | Average DPV | CV between five replicates | Average recovery rate (RR) |
|---|---|---|---|
| 5 | 553 | 19% | 54% |
| 6 | 958 | 25% | 56% |
| 7 | 69 | 43% | 37% |
| 8 | 269 | 29% | 34% |

Spray deposits profiles obtained on the test benches pointed out that the use of conventional hollow cone nozzles provided a more irregular shape of the spray ranges, which resulted always longer (up to 18 m from the nozzles position) with respect to the ones achieved using the air induction nozzles (which reached 12 m maximum). As it was already observed for the vineyard sprayer, also in this case in the collectors placed on the test bench uncovered four seconds after the sprayer pass higher deposits were found when fine droplets were sprayed (Fig. 4)

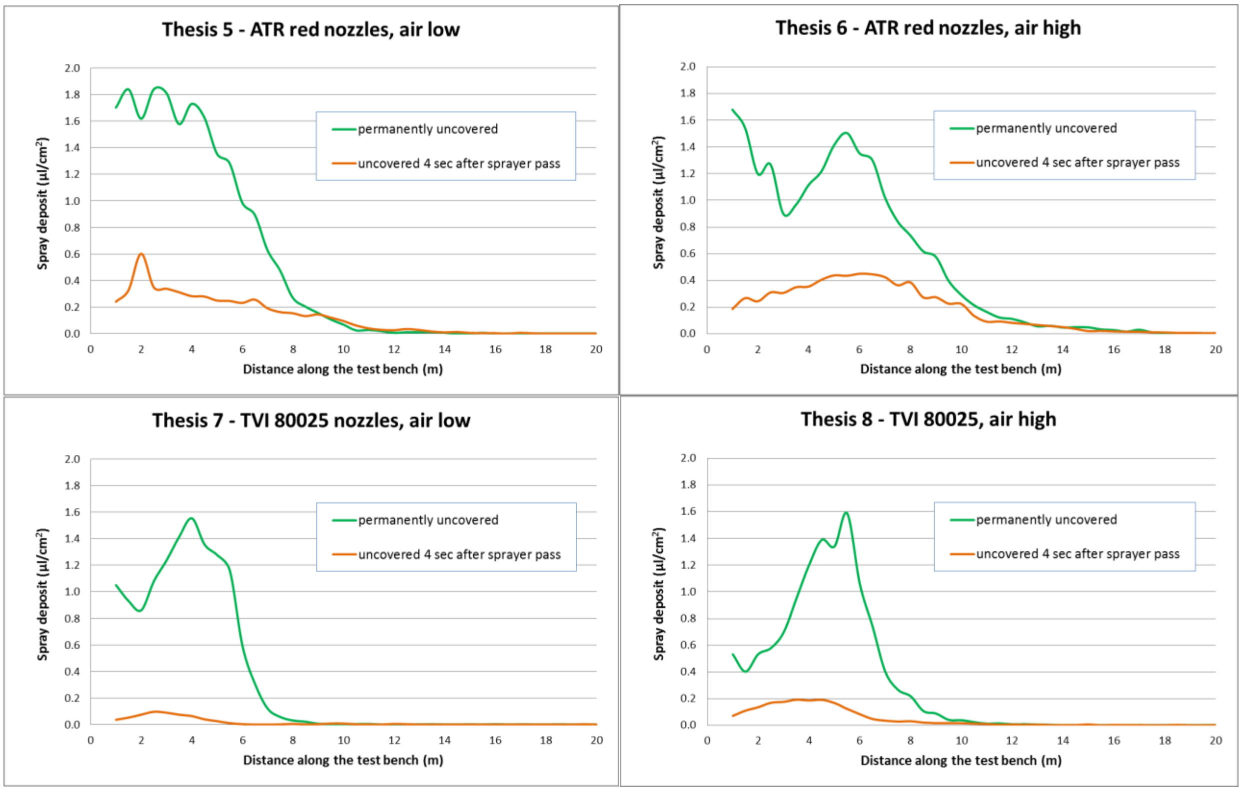

Fig. 4. Spray deposit profiles obtained on the two test benches for the four theses examined employing the Fede Qi 90 orchard sprayer.

## Discussion

On the basis of the data acquired in these first sets of tests it was possible, for each sprayer model, to rank the different configurations examined according to DPV values (Table 5 and Table 6). In both cases the configuration featured by the combination of conventional nozzles and high flow rate was taken as reference.

Table 5. *Ranking of Dragone k2 500 vineyard sprayer configurations according to DPV values.*

| Thesis ID | Sprayer configuration | DPV | Drift reduction vs. reference |
|---|---|---|---|
| 2 | Conventional nozzles + high air flow rate | 558 | Reference |
| 1 | Conventional nozzles + low air flow rate | 284 | 49% |
| 4 | Air induction nozzles + high air flow rate | 85 | 85% |
| 3 | Air induction nozzles + low air flow rate | 80 | 86% |

Table 6. *Ranking of Fede Qi 90 orchard sprayer configurations according to DPV values.*

| Thesis ID | Sprayer configuration | DPV | Drift reduction vs. reference |
|---|---|---|---|
| 6 | Conventional nozzles + high air flow rate | 958 | Reference |
| 5 | Conventional nozzles + low air flow rate | 553 | 42% |
| 8 | Air induction nozzles + high air flow rate | 269 | 72% |
| 3 | Air induction nozzles + low air flow rate | 69 | 93% |

Trend of the ranked sprayer configurations resulted the same for both sprayers even if the percentages of drift reduction for the different configurations examined with respect to the reference one were different in the two cases. For instance, concerning the vineyard sprayer, the use of air induction nozzles reduced DPV of about 85% with respect to the reference configuration independent of the air setting. On the other hand, for the orchard sprayer the use of air induction nozzles combined with the high air flow rate enabled to reduce DPV only by 72% with respect to the reference configuration, while air induction nozzles combined with low air flow rate allowed to further reduce DPV by 93%. On the orchard sprayer the influence of air assistance resulted therefore more evident, independent of the nozzle type used.

## Conclusions

The proposed methodology and the use of the test bench have allowed to assess potential drift from air-assisted sprayers and to rank different sprayer configurations according to drift risk. Nevertheless further studies are needed in order to consolidate this methodology mainly in terms of its repeatability and comparison of the obtained drift ranking value with those coming following the present ISO standard methodology (ISO 22866). Following these requirements additional tests are going on at Disafa and DEAB.

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