Influence of nozzle type, nozzle arrangement and side wind speed on spray drift as measured in a wind tunnel

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Ref: 0385

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Abstract

Spray drift is a great concern because of environmental consequences of agricultural practices. Many studies were conducted in wind tunnel (Miller, 2011; Nuyttens, 2007; Herbst, 2003) mainly focusing on the definition of quantitative deposition on collectors at different distances or heights according to (ISO 22856, 2008). In most cases, only one nozzle positioned frontally (wind direction perpendicular to the main axis of a Flat Fan spray) is tested. This study was carried out in IRSTEA wind tunnel that includes a 9 m distribution test bench. A short boom of 4 nozzles (50 cm spacing, 60 cm height) was oriented in either lateral or frontal position. The effect of wind speed (2, 4 and 7.5 $m.s^{-1}$), nozzle type (including mix types) were studied. Nozzle types were FF110 02 (Albuz AXI), air injection FF (Albuz CVI) 110 02, and air injection twin jets (Albuz CVI Twin) 110 02 and were used at 2.5 bar. Different nozzle arrangements represented 18 tests in lateral position and 21 in frontal position. Deposition values every 5cm are processed with an inverse cumulative calculation. Results are expressed in terms of (i) the cumulated amount of drift (ii) drift values at 5m (minimum buffer zone width in France).

Results logically showed that an increase of wind speed leads to an increase in lateral spray drift values for all modalities. Results confirmed that drift reduction classification of nozzles based on lateral or frontal measurements are not comparable (Douzals, 2012).

In frontal position, the number of nozzles induced a cumulative effect on spray deposition without protective effect between collateral sprays.

In lateral position, CVI and CVI Twin nozzles involved less drift amount compared to AXI nozzles. Drift values were reduced when replacing the first or the two first AXI nozzles -that are most exposed to the wind- by a CVI or CVI Twin. However, drift mitigation ratio was better for the CVI Twin compared to CVI nozzle.

These results will contribute to a wider study on interactions between sprays types & position and their potential contribution to drift or drift mitigation.

Keywords: Nozzle type, Wind speed, spray drift.

Introduction

Generally pesticides are applied through sprays with the intent of maximizing deposition on target sites. However spraying operation often generates losses -as spray drift- to the environment. Spray drift is a great concern because of environmental consequences of agricultural practices in terms of sustainable use of pesticides. Spray drift is defined as the quantity of spray liquid that is carried out of the sprayed (treated) area by the action of air currents during the application process [ISO 22866]. Driftability of sprays are dependent on physical factors (droplet size, droplet velocity, droplet evaporation, physiochemical prosperities of spray liquid); meteorological factors (wind speed, air temperature, relative humidity, stability); and technological factors (nozzle height, nozzle angle, nozzle pressure, nozzle type). As in-field measurements of drift are susceptible to weather conditions and practical constraints of field orientation, many studies were conducted in wind tunnels with methodologies described by ISO 22856 [Taylor et al., 2004; Nuyttens et al., 2007; Nuyttens et al. 2009; Miller et al.

2011; Douzals, 2012]. Measurements of spray drift by using wind tunnels experiments have been used by a number of researchers to determine the risk of pesticide drift contamination of nozzles (Herbst, 2001; Taylor et al., 2004; Nuyttens et al., 2007; Miller et al., 2011; Douzals, 2012). In addition, the advantage of wind tunnel experiments consider an efficient way for supporting, complementing the data derived and can be evaluable alternative from field experiments to evaluate spray drift potential (Nuyttens et al., 2011).

Existing research works mainly focus on the definition of quantitative deposition on collectors (mainly PE wires of 2 mm ϕ) at different distances or heights according to ISO 22856 by using a dye tracer. In most cases only one nozzle positioned frontally (wind direction perpendicular to the main axis of a Flat Fan spray) was tested. Such protocol is widely used to test and authorize low drift nozzles in UK and Germany.

Nozzle type and working conditions (nozzle height and operating pressure) may influence droplet size with negative or positive effect on drift. [Nuyttens et al., 2007]. Additionally the influence of nozzle type and nozzle size was also found to be statistically significant [Nuyttens et al., 2009]. Apart from nozzle settings, wind speed and wind direction have a significant effect on drift values as shown by [Hewitt et al 2002 ; Nuyttens et al, 2007b]. However the position of the nozzle -frontally or laterally- may lead to a different classification in terms of drift reduction ratio [Douzals, 2012].

The main objectives of this study were to measure spray drift by using different nozzle types and nozzle mix (combination) and its arrangement on boom spraying in a wind tunnel at various wind speed to calculate their drift ratio and to compare the results of these drift with the reference spraying nozzle to calculate drift reduction ratio.

1. Materials and Methods

1.1 Wind tunnel settings

IRSTEA Montpellier wind tunnel was used in this study. The wind tunnel is a closed-circuit system with a working section of 3m*2m*9m (width, height and length respectively). A distribution test bench (180 grooves of 5cm width) is placed along the wind tunnel in order to measure ground deposition in windy conditions. A mobile device includes 60 measuring tubes (500mL capacity) placed over load cells. Spray deposition is then quantified under the boom (direct spray) and up to 9.0 m downwind.

A short boom of 4 nozzles (50cm spacing) is placed in the wind tunnel. The position can be easily switched from frontal to lateral position. Boom height was 60cm in any cases. Wind speed is adjustable from 0 to 12 $m.s^{-1}$. 3 reference wind speeds were used corresponding to 2, 4, and 7.5$m.s^{-1}$).

1.2. NozzleType

Nozzles selected for this study are listed in the following Table 1. Droplet sizes were measured by using IRSTEA PDPA device at 25 cm from the nozzle outlet (stepwise process). Output flowrates were measured by using IRSTEA flowmeter device with 20°C water ad 3 repetitions. Reference nozzle for France is Albuz® AXI (Flat Fan - 110 02) and accredited low drift nozzles are Albuz® CVI (Air Injection - Flat Fan - 110 02) and Albuz® CVI Twin (Twin Jets - Air Injection - Flat Fan - 110 02). Nozzles were operated @ 2.5 bar.

Table 1: Nozzles Characteristics

Nozzle type	Nozzle size	Top angle (°)	Output Flowrate ($L.min^{-1}$)	VMD (µm)	%volume <100 µm
AXI	02	110	0.78	226	8.9
CVI	02	110	0.73	322	0.15
CVI Twin	02	110	0.74	430	0.8

1.3. Nozzles arrangement

Different nozzle arrangements were tested as introduced in Table 2. Nozzle order on the boom refers to the position more or less exposed to the wind. The 1st nozzle is the most exposed.

Table 2: Schemes of nozzle arrangements and testing conditions

Modality	Boom orientation	Position on the boom				Wind Speeds ($m.s^{-1}$)
		1	2	3	4	
A	Lateral (i.e. boom parallel to wind direction)	AXI	AXI	AXI	AXI	2 - 4 - 7.5
B		CVI	CVI	CVI	CVI	2 - 4 - 7.5
C		CVI Twin	CVI Twin	CVI Twin	CVI Twin	2 - 4 - 7.5
D		CVI	AXI	AXI	AXI	2 - 4 - 7.5
E		CVI Twin	AXI	AXI	AXI	2 - 4 - 7.5
F		CVI	CVI	AXI	AXI	2 - 4 - 7.5
G		CVI Twin	CVI Twin	AXI	AXI	2 - 4 - 7.5

1.4. Air and wind conditions

Air speed, temperature and relative humidity are respectively measured by using a 2D sonic anemometer, a Pt100 and air hygrometer placed at 1m height from ground surface and positioned upwind compared to the spray boom. Atmospheric conditions are recorded every 30s. Average recorded meteorological circumstances during the measurements are summarized in Table 3

Table 3: Average air conditions during wind tunnel experiments

Number of modalities	Air speed ($m.s^{-1}$)	Temperature (°C)	Relative Humidity (%)	CV temperature	CV Relative humidity	CV wind speed
7	2	19.88	92.31	1.0%	3.0 %	4.0%
7	4	19.91	90.75	1.0%	3.0 %	17.0%
7	7.5	19.98	90.48	1.0%	2.0 %	9.0%

1.5. Statistics analysis

Statistics analysis were performed with GRAPHPAD IN STAT 3 software. Differences among samples group were considered significant when the Kruskal-Wallis non-parametric-test gave a P-value of 5%.

3. Results and discussion

Results presented in this paper mainly concern lateral position measurements. An exhaustive presentation of frontal drift measurements are presented in [Douzals et al, 2014].

3.1. Effect of nozzle type, nozzle arrangements on sedimentation flowrate for different wind speeds

The effect of nozzle type on sedimentation flowrate with different wind speeds is shown in Fig.1 (same type). The distance (0) is defined as the distance corresponding to the half of nozzle spacing after the last nozzle.

Increasing wind speed induced a clear decrease in the peak value of sedimentation flowrate and involved a shift in the peak values distance for all types of nozzles as well as for mix-type configurations.

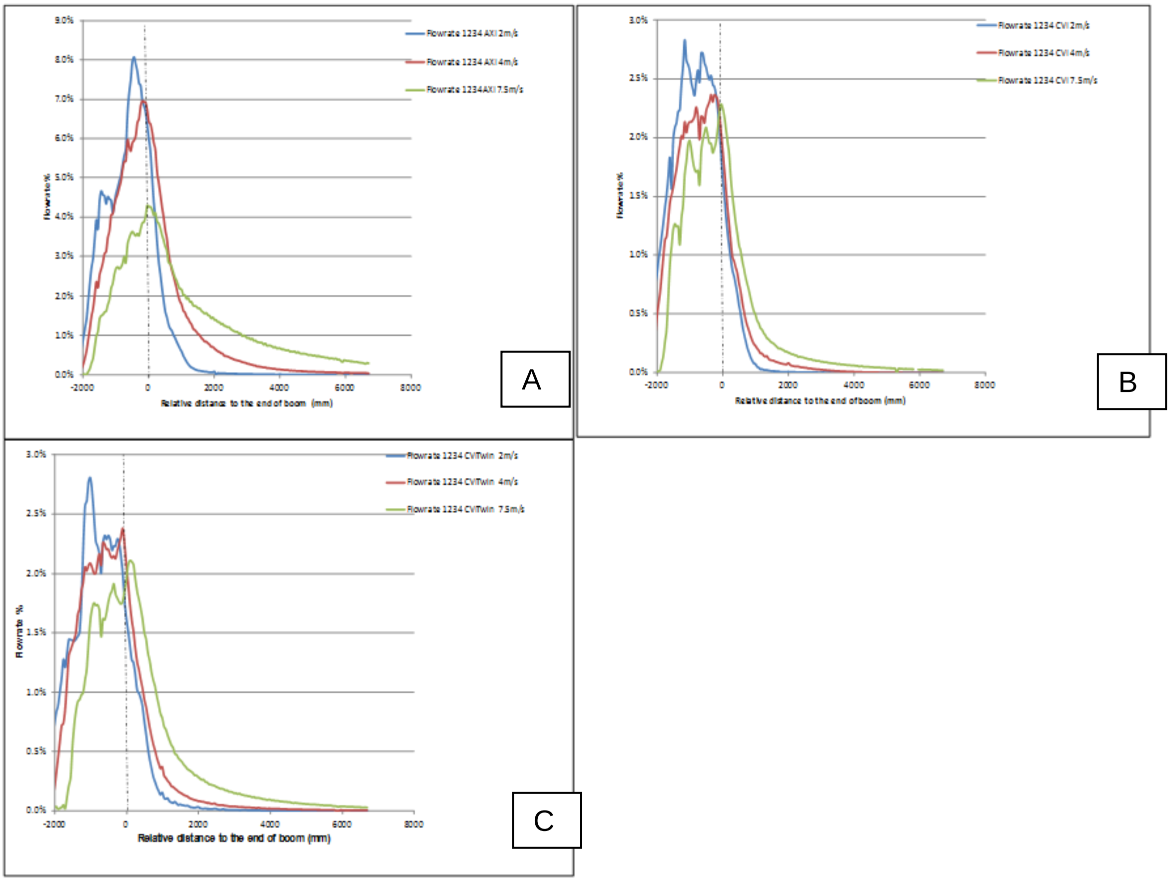

Figure 1. Effect of nozzle type and wind speed on sedimentation flowrate.

When only nozzle # 1 or nozzles #1 and #2 are changed into Air Injection (single or twin jets), results are introduced on Fig.2

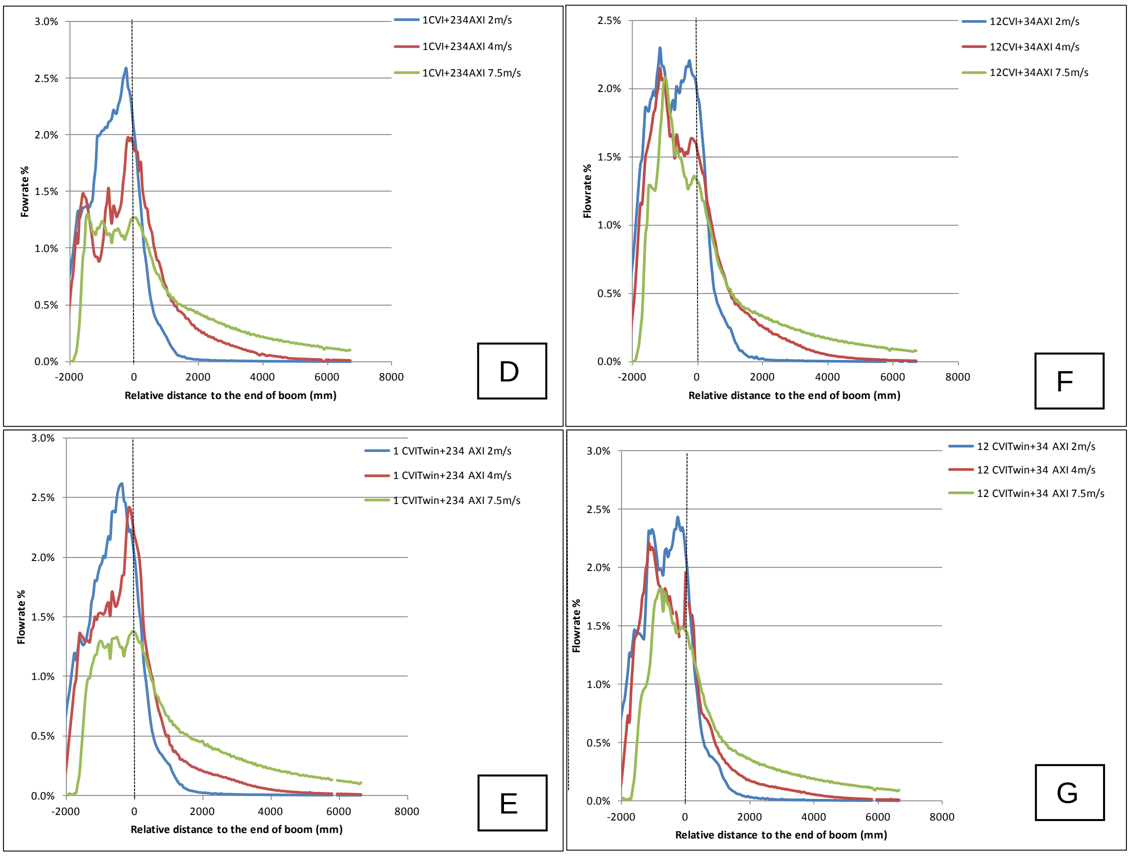

Figure 2: Effect of nozzle type, nozzle position and wind speed on sedimentation flowrate. (D) CVI + 3 AXI; (E) CVI Twin + 3 AXI; (F) 2CVI+ 2AXI and (G) 2 CVI Twin + 2 AXI

3.1. Effect of nozzle type and wind speed on drift ratio

Deposition values are cumulated along the distance and the opposite is calculated. As a result a drift ratio is calculated starting from 100 % under the boom and progressively decreasing along the distance. At a given distance the drift ratio corresponds to the remaining drift volume beyond as given by the following equation 1:

$$Dr = 1 - \sum_i v \qquad \text{(Eq 1)}$$

Dr is the drift value in %, v the collected volume at the position i.

As the distribution test bench is not infinite, the recovery on the test bench is not 100%. The last value of drift ratio corresponds to the uncollected fraction.

Fig.3 gives spray drift ratio as a function of distance along the collecting bench.

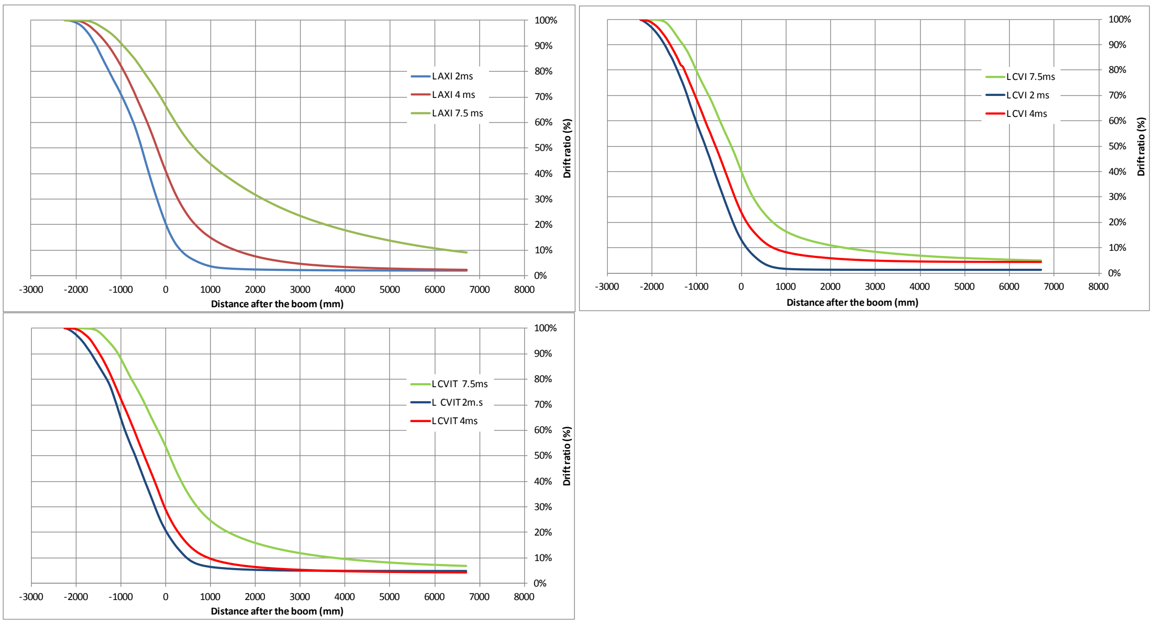

Figure 3 : Effect of wind speed and nozzle type on drift ratio (up-left AXI – up-right CVI – down left CVI Twin nozzles)

The impact of nozzle type on drift ratio was found significant. In addition the influence of nozzle type shown on Fig. 3 appears obvious which is dependent on wind speed.

3.2. Effect of nozzle arrangement and wind speed on drift ratio

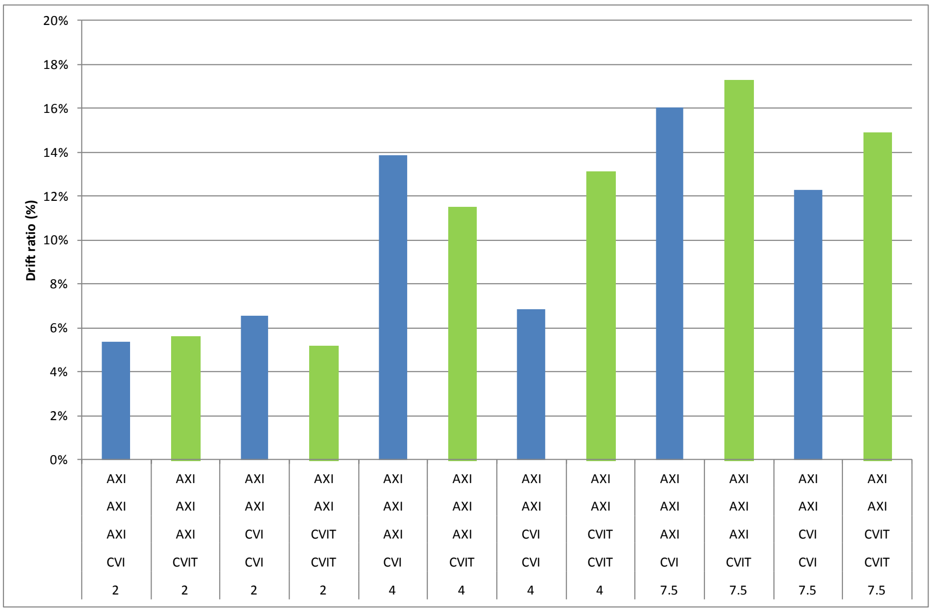

Figure 4 : Effect of substitution of AXI nozzles by CV I or CVI Twin @ the nozzle position 1 or 1 and 2 on drift ratio at 5m downwind.

Fig.4 demonstrates the correlation between spray drift ratio at a relative distance of 5m for different nozzle configurations and different wind speeds. Spray drift ratio increases for all nozzle configurations with the increasing wind speed.

Conclusion

Results of this study indicate that the spray drift ratio is function of wind speed, nozzle type and nozzle arrangements. In lateral position, the type of nozzle and nozzle-mixes on boom and the respective position of nozzles have a great impact on deposition values. A protective effect is observed when the 1st nozzle or the 2 first nozzles are substituted by Air Injection type. However the effect of air injection nozzles is mainly visible with the highest wind speed. These results will contribute to a wider study on interactions between spray types, position and their potential contribution to drift control or drift mitigation.

Acknowledgement
Authors are grateful to the French Ministry of Agriculture and Coorstek Cie.

References

Douzals J.P., 2012. Frontal/lateral drift reduction ratio of different types of accredited nozzles. Proceedings of AgENg 2012 Valencia Spain.

Douzals J.P.; Al Heidary, M., 2014. How spray characteristics and orientation may influence spray drift in a wind tunnel. *Aspects of Applied Biology*, 122, 271-278.

Herbst, A., 2003. Pesticide formulation and drift potential. The BCPC conference, pp. 255 - 260.

ISO 22856, 2008. Equipment for crop protection-Methods for the laboratory measurement of spray drift- Wind tunnels.

ISO 2005, 2005. Equipments for crop protection- In–field measurement of drift, XXp.
Miller, P.C.H.; Nuyttens, D., Baetens, K., De Schampheleire, M., & Sonck, B. 2007. Effect of nozzle type, size and pressure on spray droplet characteristics. Biosystems Engineering, 97(3), 333–345.

Nuyttens, D., Taylor, W. A., De Schampheleire, M., Verboven, P., Dekeyser, D., 2009. Influence of nozzle type and size on drift potential by means of different wind tunnel evaluation methods. *Biosys Eng*, 103(3), 271–280.

Nuyttens D, De Schampheleire M, Baetens K, Brusselman E, Dekeyser D, Verboven P. 2011. Drift from Field Crop Sprayers using an Integrated Approach: Results of a 5 Year Study. *Trans ASABE*, 54(2): 403-408.