Experimental study using wind tunnel for measuring Variability of spray drift sedimentation

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Abstract. Spray drift is defined as physical movement of pesticides by air action as a particle droplet and is not deposited on the intended target. Evaluation of the parameters affecting on spray drift is difficult. The accurate studies are expensive, as well as, the variability is high under field conditions due to instability in wind speed and turbulence. Wind tunnel experiments are adequate to simulate the results of field measurements for spray drift. A laboratory experiments were carried out to study the variability in the wind tunnel for measuring sedimentation of spray drift under stable weather conditions, and boom height. Different models are conducted in this study using three type of nozzles of Flat fan nozzle, Flat fan air injection(single jet) and flat fan air injection (twin jet). All these nozzles at the same angle and size 110 02, three wind speeds of 2, 4, and 7.5 ms^{-1}, and the boom height was of 60 cm. Distribution test bench used for measuring sedimentation of spray drift . Air temperature and relative humidity were 20° and upon 95% respectively. Main results showed low variability in the measuring of sedimentation of spray drift in a wind tunnel experiments compared to the previous studies. Higher variability observed with flat fan air induction nozzle twin jet compared to other nozzles tested in this study.

Keywords: sedimentation of spray drift, variability, wind tunnel

Introduction

Spray drift is defined as the movement of pesticides as spray particle or vapour to off-intended target site at soon or after spray application by the action of air speed and wind direction (ASAE, 2009). Several factors as nozzle type, operating pressure, boom height, and wind speed, can effect on spray drift sedimentation during the spraying process (Nuyttens et al., 2007; Miller et al., 2011; Douzals and Alheidary, 2014). One of the main problems in spraying process occurring in field or laboratory tests is the variability in droplet deposition especially when is that differences in droplet spectrum. During agriculture spraying, spray drift varied in the rate of deposition from site to another in the site testing due to the variability. Many factors have influenced on the variability of spray drift in amount and size of the droplet as boom height, wind speed, operating pressure, equipment design, nozzle size, nozzle type. Best distribution patters for nozzle spray related to spray drift is achieve when the variability in a low level which guaranty best spray uniformity and deposition on the target with a limit of spray drift as possible. The most commonly indicators used to measure the variability in spray droplet are the coefficient of variance and standard deviation. Several studies are conducted on Spray drift measurements in field according to ISO 28866, 2005 with high variability in data due to the variable in atmospheric conditions (Rautmann et al., 2001; Nuyttens et al., 2005; Balsari et al., 2007). Furthermore, this procedure is considering an expensive method and it isn't repeatable. Due to the big differences in the fine droplet size at the time of spraying, the variability in high-level in the field when the weather conditions are unstable at spraying process. So, one of the alternative methods to measure spray drift with an acceptable average in dispersion at laboratory experiments is wind tunnel according to ISO 28856, 2008. This method used to limit the variability in spray drift measurement and can be repeatable the tests with the same conditions as possible. Several researchers conducted their studies in wind tunnel experiments for measuring spray drift using these parameters separately.

The more parameters that influence on droplet variability during spraying application are nozzle height, operating pressure, and wind speed. Information about variability of spray drift is relatively scarce. The purpose of this study is to measure the variability of spray drift sedimentation using wind tunnel.

Methods and materials

Laboratory experiments were conducted in IRSTEA-Montpellier wind tunnel as shown in Figure 1.

Figure 1: View of wind tunnel

Different models were carried out in this study using wind tunnel with an internal section 2m width, 3m height, and 9m distribution test bench (180 grooves). All tests applied with the same of operating pressure of 2bar.

Spray drift sedimentation within each experiment of test bench was calculated at different distances from the nozzle location until 9m. There is a mobile device of 3m width (60 tubes) to collect spray deposit from each channel. At the time of measuring, when the volume collected arrive to 500 ml, the measuring will stop then weighted the volume collected in tube after that save data and pass automatically to the next distance from nozzle location until 7 position (9m).

Nozzle characteristics

Three nozzle types are used in this study as shown in Table 1.

Table 1: Specifications of Nozzles

Nozzle type	Nozzle angle/size	Nozzle color	Nozzle flowrate $L.min^{-1}$	VMD* µm
Flat Fan standard (AXI)	110 02	Yellow	0.64	164.9
Flat Fan air induction (single jet) (CVI)	110 02	Yellow	0.73	434.6
Flat Fan air induction (Twin jet)(CVITwin)	110 02	Yellow	0.73	380.0

*VMD is Volume Median Diameter

Boom nozzle setup

IRSTEA-Montpellier wind tunnel consist short boom with 4 nozzles (50 cm distancing). Boom height was tested in this study in 60 cm. The position of boom was in frontal position (perpendicular towards wind speed direction). All measurements conducted at a constant operating pressure of 2.5 bar.

Meteorological conditions

During laboratory test in wind tunnel, three wind speeds were selected of 2, 4, and 7.5m.s^{-1}. Air temperature and relative humidity were 20^{o}C and upon 90% respectively.

Spray drift measurements

Measuring spray drift in wind tunnel carried out using distribution test bench with a long duration exposure. After setting these parameters, the volume collected. Then, the volume is converted into flowrate after corrected to the real flowrate at a constant operating pressure. Then calculated flowrate cumulate. Finally, spray drift ratio is obtained by oppositions of the volume collected using following formula

D_{ri}= 1-∑qi …….. (1) (Douzals and Alheidary, 2014)

Where D_{ri} is drift ratio at position i; qi is the flowrate at the position i

All tests in this study were repeated three times then the average was calculated.

Measuring Spray drift sedimentation is considered to be variable and the difference between replicate measurements in a wind tunnel by calculating the CV and standard deviation of each trial of spray distribution.

Spray Variability

In this study, four different measures of spray variability were considered as average, average+, average-, standard deviation, and coefficient of variance. Of these four, the coefficient variance is by far the most important.

The coefficient of variation (CV) of the data is calculated as

$$CV = \frac{\sigma}{\bar{X}} * 100$$

Where σ is standard deviation, and $\bar{X}$ is the mean of values. The higher value of CV, means the more dispersion in data collected.

Data analysis

For all experimental conditions, spray drift sedimentation data were expressed as a percentage values. The coefficient of variation (CV) of spray drift sedimentation was calculated to measure the variability.

Results

Spray drift variability

Table 2 showed a big variability in spray drift as measured in a wind tunnel under the conditions of these studies due to the differences in droplet size measured. The reason of variability may be due to unstable wind speed at the time of measurements.

Table 2: previous studies on the variability of spray drift

Reference	Context	Protocol	CV range
Nuyttens et al., 2009	Wind tunnel 18 rep	Vertical array of nylon string 2m/s	180%
Nuyttens et al., 2009	Wind tunnel 18 rep	Horizontal distribution of nylon string 2m/s	128%
De Schampheleiere et al., 2009	Wind tunnel XX rep	Filter papers 0.25*0.25m2- 4mls	74%

Number of nozzle mounted on boom and variability using Flat Fan nozzle (AXI)

The effect of the number of nozzles mounted on the boom is introduced in Fig.2. Increasing the number of nozzles mounted on the boom revealed increasing in the variability of spray drift then it decrease with four nozzles mounted on the boom. These increasing in the variability was slight in CV compared to previous studied that mentioned in table2.

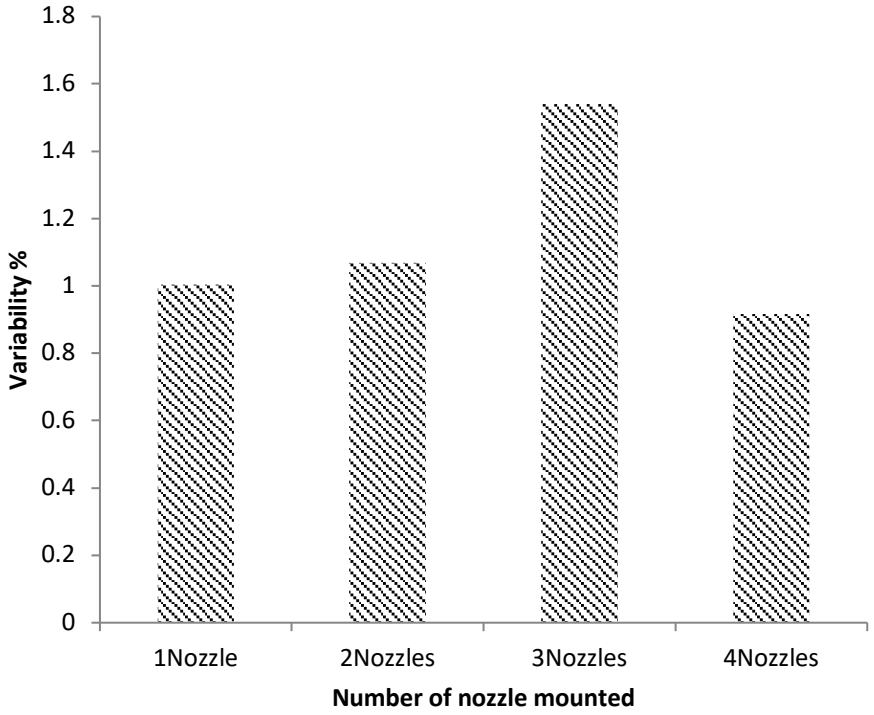

Figure 2: Variability in spray drift sedimentation at different nozzles number

Effect of nozzle type on the variability in spray drift

The results as shown in Fig.3 demonstrated a big variability in the repeatability of droplet size data at the time of measurements in wind tunnel. Flat fan air induction nozzle with twin jet spray showed a greater variability in their patterns in spray drift compared to Flat Fan standard nozzle and Flat Fan air induction single jet spray.

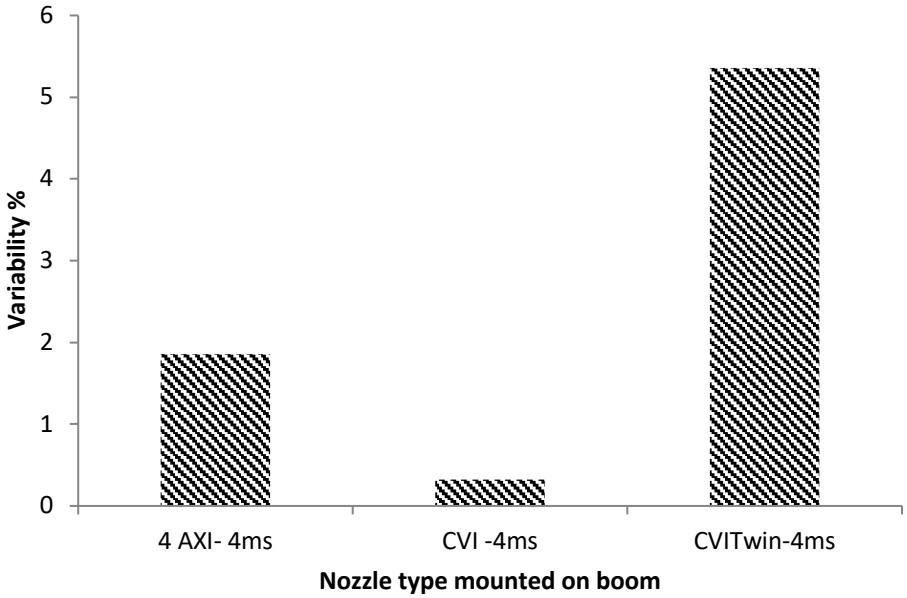

Figure 3: Effect of nozzle type on drift variability

Effect of wind speed

Drift variability for one nozzle mounted on the boom is introduced in Fig.4 at different wind speeds. Increasing wind speed showed an increasing in drift variability. Also, the results revealed low differences in drift variability when increasing the number of nozzles mounted on the boom.

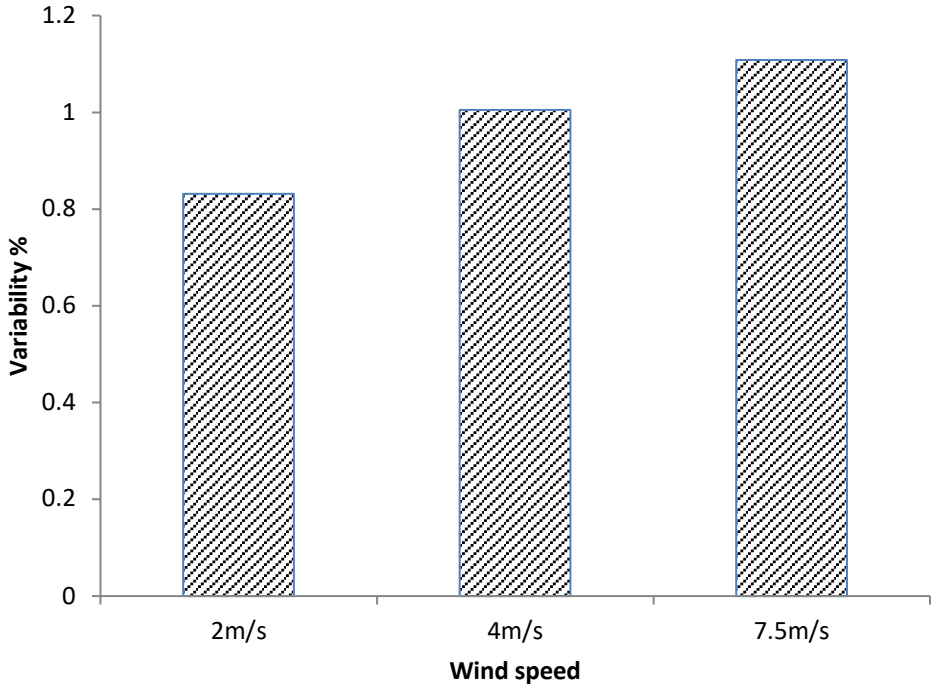

Figure 4: Effect of wind speed on drift variability

Conclusions

An experimental study was performed in wind tunnel to quantify variability for measuring spray drift sedimentation occurring at the time of experimental using different nozzle types as Flat fan nozzle, flat fan air induction single jet , and flat fan air induction twin jet (110 02) at 2bar operating pressure. The initial results showed the variability in spray drift measured in wind tunnel can be higher when spraying with flat fan air induction nozzle with twin jet compared to other nozzles tested. When to compare the results of this study with the previous studied, higher variability in spray drift when spraying with a short duration exposure than long duration protocols.

The results of this study will further help in selection of the most uniform nozzle to limit variability in spray drift sedimentation and determine a suitable way in spray exposure.

References

ASAE S572.1, 2009. Spray Nozzle Classification by Droplet Spectra. Am. Soc. Agric. Eng., St. Joseph, MI, p. 4.

Balsari P., Doruchowski G., Marucco P., Tamagnone M., Van de Zande J.C., Wenneker M. 2007. The development of a Crop Identification System (CIS) able to adjust the spray application to the target characteristics. Proc. SuProFruit 2007 – 9thWorkshop on Spray Application Techniques in Fruit Growing. Alnarp, Sweden, 12-14 September 2007, pp. 17-18.

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.

ISO 28866 , 2005. Equipment for crop protection - Methods for field measurement of spray drift.

ISO 22856, 2008. Equipment for crop protection-Laboratory measurement of spray drift-part 1: wind tunnel.

Miller, P.C.H., Ellis, M.C.B., Lane, A.G., Tuck, C.R., 2011. Methods for minimizing drift and off-target exposure from boom sprayer applications. Aspects of.Appled Biology 106, 281-288.

Nuyttens, D., Baetens, K., De Schampheleire, M., Sonck, B., 2007a. Effect of nozzle type, size and pressure on spray droplet characteristics. Biosyst. Eng. 97 (3), 333-345.

Nuyttens, D., Sonck, B., De Schampheleire, M., Brusselman, E., Steurbaut, W., Baetens, K, Verboven, P., Nicolaï, B, Ramon, H., 2005. Het belang van drift en haar reducerende maatregelen ter bescherming van het milieu in Vlaanderen. Eindverslag onderzoeksovereenkomst IWT/20424, pp: 218.

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

Rautmann, D., Streloke, M., Winkler, R. 2001.New basic drift values in the authorisation procedure for plant protection products. In: Forster R, Streloke M, editors. Workshop on risk assessment and risk mitigation measures in the context of the authorisation of plant protection products (WORMM), vol. 383. Berlin-Dahlem, Heft, Germany: Mitt. Biol. Bundesanst. Land-Forstwirtsch.