Evaluation of potential spray drift generated by different types of airblast sprayers using an “ad hoc” test bench device

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Evaluation of potential spray drift generated by different types of airblast sprayers using an "*ad hoc*" test bench device.

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Abstract: Drift is one of the most important issues to be consider for realise a sustainable pesticide application. This study proposes an alternative methodology for quantify the Drift Potential (DP) for vineyard crop sprayers, trying to avoid the difficulties faced in conducting field trials according to the reference standard protocol (ISO22866:2005). Thanks to a specific test bench device, it is possible to collect and quantify the spray fraction that remains suspended over the test bench immediately after passage of the sprayer and that can potentially be carried out of the target zone by environmental air currents, defined as "potential drift fraction". The proposed methodology requires to made the test in absence of target and in calm of wind. Contextually, a variation of original test method (absent a target) was used to investigate both the possible effect of the target on the final results and the suitability of the test bench device to measure potential spray drift generated by multiple-row sprayers. The methodologies have been tested using two types of vineyards sprayers, namely conventional axial fan tower shaped and pneumatic single or multiple rows, in different configurations. By the comparison with the results obtained from a reference sprayer the resulting drift reduction potential (DRP), obtained from the two indirect methodologies investigated (presence or not of the target), were compared. The test bench trials confirmed the ability of the proposed methodology to discriminate the DP generated by different vineyard sprayers and their configurations tested. Furthermore, the results obtained from the two methodologies, indicate that, although the vineyard target influence the total amount of liquid collected by test bench, the absence of target is negligible and irrelevant in terms of final drift reduction sprayers classification.

Keywords: test bench method, spray drift potential, classification, vineyard sprayers

1 Introduction

In 2009 the Council of the European Union adopted Directive 2009/128/EC on Sustainable Use of Pesticides (SUD) that highlighted pesticide drift risks generated during spray applications (European Commission, 2009). Among the pollutants from PPP use, agro-

chemical spray drift continues to be a major challenge because pesticides can be deposited in undesirable areas and pose risks to both the environment and bystander. Spray drift is a more constant threat in bush/tree crops than in arable field crops. Different methods to measure spray drift, both direct as spray drift field measurements and indirect as drift potential laboratory measurements, have been developed in the recent years. Direct drift measurements from field experiments utilize the complex and time-consuming standardized protocol ISO 22866 (Gil et al., 2018). It provides results that are highly affected by external factors like environmental conditions during testing (Grella et al., 2017a). In contrast, indirect methods allow drift measurements to be conducted under comparable and repeatable conditions in an easy and quick way (Nuyttens et al., 2017). Recently, to both simplify the test procedure and reduce trial costs, authors began to develop and test an alternative methodology for quantifying the potential spray drift generated by a bush/tree crop sprayer capable of reproducing objective results independent of cultivar and canopy structure variations (Grella et al., 2017b). Simultaneously, they aimed to minimize result variability due to meteorological conditions. This new methodology implied the use of an *ad hoc* designed test bench device, trial layout and test protocol. The trials would be performed in absence of a crop and nearly absent of wind. The layout was specifically designed to avoid result variability due to canopy parameters that affect spray drift amounts, and to minimize the strong influence of wind velocity and direction on sprayed airborne droplets.
The aim of this study was to verify the suitability of the test bench and its methodology for two purposes: comparative assessment of potential spray drift generated by different types of vineyard crop sprayers, and classification of different sprayer configurations according to their relative Drift Reduction Potential (DRP). In addition, to validate the test bench method, the effect of the presence of the target crop on spray drift potential and consequence on DRP sprayers classification was assessed by comparing Drift Potential Values (DPV) obtained from test bench trials conducted in absence of the crop with that obtained in presence of target.

2 Materials and Methods

2.1 Technical characteristics of spray drift test bench device and potential spray drift measurements.

A 20.0 m long test bench was placed transverse to the sprayer forward direction in order to catch the spray output from one side sprayer nozzles. Petri dishes aligned in an array transverse to the sprayer forward direction were placed along the test bench slots with 0.5 m distance within each other. All collectors were initially covered. The actuator of the pneumatic system for opening the collectors was activated by the sprayer pass and it was placed at a relative distance from the test bench line, so that 4 s after the sprayer passed the perpendicular line of the bench the collectors were revealed. All tests were conducted with an average wind speed < 0.5 m s^{-1}. Test bench estimates the spray drift risk during pesticide application through the evaluation, in calm of wind conditions, of the free floating fraction of spray cloud falling time after its discharge. The procedure is based on the assumption that longer free floating droplets lingering times might lead to a larger risk of spray drift generation in case of windy conditions. The sprayer started the application 20 m before and stopped it 20 m after the position of the collector array. The actuator of the pneumatic system for opening the collectors was activated by the sprayer pass revealing simultaneously all the collectors initially covered by the test bench sliding cover system.

2.2 Experimental design to validate the methodology through the study of canopy effect.

To validate the methodology for the measurements of DPV from the airblast sprayer for single row spray application, as originally proposed by Grella et al., (2017b), the effect of canopy (absence or presence) on final DPV and DRP results during test bench trials was evaluated. So, two parallel trial methodologies were arranged and compared. The first trial consisted of applying the original methodology, positioning the test bench transversely to the concrete flat lane used as the tractor track without the crop target between the sprayer and the tests bench. The second methodology introduces the crop (vineyard espalier- trained at full growth stage) between the sprayer and the test bench device; it was maintained transverse to the forward direction of the sprayer but behind the vineyard crop row (Fig. 1) (Grella et al., 2019).

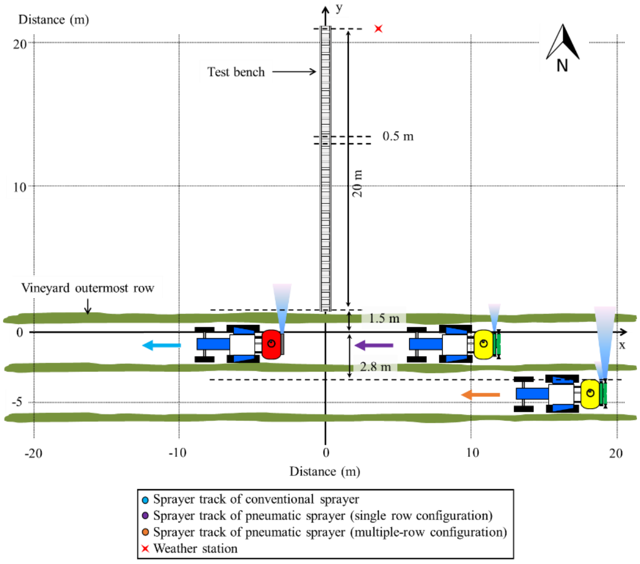

Fig. 1 Drift test bench to assess potential spray drift from vineyard sprayers and layout of field test to assess the influence of vineyard canopy using conventional airblast sprayer and multiple-row pneumatic sprayer.

Furthermore, both methodologies tested (in absence and in presence of canopy) were adapted to evaluate the potential spray drift generated by the multiple-row sprayer. For this purpose 4.3 m distance between spray output and test bench was used (1.5 m + 2.8 m –inter-row distance); the original methodology foresee a fixed distance equal to 1.5 m between the spray output and the first collectors placed on the test bench.

2.3 Characteristics of air blast sprayer and configurations tested.

Two types of vineyard sprayers characterized by different liquid atomization and passes management between rows were tested. A mounted conventional airblast sprayer Dragone k2 500 (Dragone S.n.c., Castagnole Asti, AT, Italy) with a tower shaped air conveyor and an axial fan (600 mm) and a semi-mounted multiple-row pneumatic sprayer Cima 50 Plus 400L (Cima S.p.a., Pavia, Italy) equipped with spray head TC.2M2C and a radial fan (500 mm) were used (Fig. 2).

(a)

(b)

Fig. 2 Conventional mounted airblast sprayer Dragone k2 500 (a) and multiple-row pneumatic sprayer Cima 50 Plus 400L equipped with spray head TC.2M2C (b) during field pesticide application.

The Dragone k2 500 sprayer was equipped with a 200 L polyethylene tank and six nozzles on each side (Fig. 2a). Two-speed gearbox enabled the airflow rate to vary from 11,000 to 20,000m^3 h^{-1}. Table 1 summarizes the configurations tested using Dragone sprayer based on combinations of two different air fan settings (airflow rate 11 000 and 20 000m^3 h^{-1}) and two nozzle types, conventional hollow cone ATR 80 orange and air injection hollow cone TVI 8002 (Albuz® CoorsTek, Evreux, France), used at a working pressure of 1.0 MPa and with a nominal nozzle flow rates of 1.39 and 1.46 L min^{-1}, respectively.
The pneumatic sprayer was equipped with 400L polyethylene tank and the spray head was featured by two hand-type spouts and two cannon-type spouts placed at the bottom and at the top respectively. The hand-type nozzle is characterized by individual air spout

disposed as fingers of the main spout, whose mission is to spray the row next to the sprayer pass, and the cannon-type nozzle, with main wide spout that aims at spraying the further row (Fig. 2b). Despite the spray head TC.2M2C was specifically designed for multiple-row spray purposes the possibility to disable the spouts individually give the possibility to apply a single row for each sprayer pass. So, the configurations tested using the pneumatic sprayer were based on different management of passes between the rows: 2 rows sprayed each pass activating all spouts (2 hands plus 2 cannons) and single row sprayed each pass activating only hand spouts at the bottom of spray head (Table 1). Using pneumatic sprayer, all the tests were performed with a working pressure of 0.1 MPa and with a single spout flow rate of 2.70 L min^{-1} (disc with perimeter calibrated holes used in position 7). Based on previous research work (Grella et al., 2017a), all trials were conducted at 1.67 m s^{-1} (6 Km h^{-1}) as it is the best forward speed to measure potential spray drift of bush/tree crop sprayers using the test bench.

Table 1 Parameters of sprayers' configurations examined in trials conducted in absence and presence of canopy vineyard target: reference and candidates.

Test	**Config. ID**	**Sprayer**	**Nozzles/spouts**					**Fan air flow rate (m^3 h^{-1})**
			Type	**Spray pressure (Mpa)**	**Active nozzles (n°)**	**Tot. Flow rate (L min^{-1})**	**Applied volume (L ha^{-1}) †**	
Reference	ATR6H	Dragone k2 500	ATR80 orange	1.0	6	16.32	583	20000
Candidate	ATR6L	Dragone k2 500	ATR80 orange	1.0	6	16.32	583	11000
Candidate	TVI6H	Dragone k2 500	TVI8002	1.0	6	17.52	626	20000
Candidate	TVI6L	Dragone k2 500	TVI8002	1.0	6	17.52	626	11000
Candidate	MC6S	Cima 50 Plus	TC.2M2C ††	0.1	4 †††	10.8	193	7750
Candidate	M6S	Cima 50 Plus	TC.2M2C ††	0.1	2 ††††	5.4	193	7750

† 2.8m inter-row distance considered; †† multiple-row pneumatic spray head equipped with two hand-spouts type at the bottom and two cannon-spout type at the top of spray head; ††† cannon and hand spouts activated (2 rows sprayed for each sprayer pass); ††† hand spouts activated (single row sprayed for each sprayer pass).

2.4 Sprayed liquid and deposition assessment

In all trials E-102 Tartrazine yellow dye tracer − 85% (w/w) – (Novema S.r.l., Torino, Italy) was added to the sprayer tank at a concentration of about 10 g L^{-1}.
60 s after the automatic opening of test bench system (complete exposure of collectors), the samples were collected and then the spray amount was determined quantifying the tracer recovered, by means of a spectrophotometer UV-1600PC (VWR, Radnor, PA, USA). The deposit on each artificial collector was then calculated to obtain the spray drift profile according each tested configuration. Five replicates were conducted for each sprayer configuration.

2.5 Drift Potential Value –DPV- and Drift Reduction Potential –DRP- calculation procedure for classification purposes.

From the spray drift profiles, the related Drift Potential Values (DPVs) were calculated according the formula proposed by Grella et al., (2017b; 2019). Then, the spray drift reduction value was calculated based on the DPVs according to ISO 22369-1 formula (ISO, 2006), for each sprayer configuration. The configuration chosen as reference was the ATR6H tested with Dragone sprayer. Classification was determined from comparison of the spray drift reductions achieved using the reference spray equipment and the candidate sprayer configuration. The ISO22369-1 defines reduction classes A to F as follows: A≥99%, B 95≤99%, C 90≤95%, D 75≤90%, E 50≤75%, and F 25≤50%.

2.7 Statistical analysis

The statistical analysis were performed using IBM SPSS Statistics for Windows (V.25). The statistical differences among DPVs obtained were evaluated using two-way ANOVA considering the test bench methodology (absence or presence of target) and configurations as source of variation.

3 Results and discussion

Irrespective of canopy target absence (Fig. 3a) or presence (Fig. 3b), the results achieved using the proposed test bench drift measurement methodology pointed out that testing the conventional airblast sprayer Dragone k2 500 both the reduction of airflow rate and the use of air injection nozzles as Spray Drift Reducing Techniques (SDRT) enable to reduce the DPV (Fig. 3), determining statistical differences among tested configurations (Tab. 2); this founding further confirm the previous results (Grella et al., 2017b; 2019), pointing out the repeatability of DPV measurements. Also considering the pneumatic sprayer Cima 50 Plus, the drift low-prone spray application technique tested (M6S), that foresee the application of single row for each sprayer pass using only the hand spouts placed at the bottom of spray head, allow to effectively reduce the spray drift (Fig. 3).

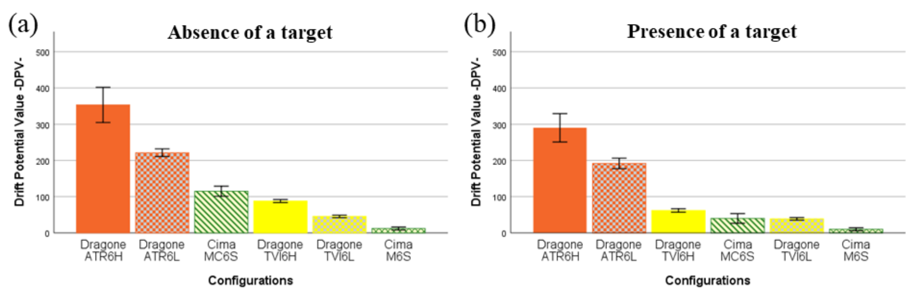

Fig. 3 DPVs obtained and bars ± SE of the mean obtained from trials conducted in absence (a) and presence (b) of canopy vineyard target testing the conventional and pneumatic sprayer configurations.

Table 2 Significance obtained in a two-way ANOVA for Drift Potential Values –DPV- as affected by test bench methodology applied (absence and presence of a target) and configurations tested.

Source	*p* (>F)	Statistical significance[a]
Test bench methodology	0.005	**
Configuration	9.640E-21	***
Configuration x test bench methodology	0.390	NS

[a] Statistical significance level: NS $p > 0.05$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Even if the presence of canopy determines statistical differences between DPVs obtained from trials conducted in presence and in absence of target (Tab. 2), the comparison of DRP values obtained from drift classification process results in an identical final classification of the tested sprayers/configurations (Tab. 3). Only the configuration Cima MC6S results in different final DRP according to the trials type –absence and presence of target- (Tab. 3); the difference could be attributable to the management of passes between the rows (one passage every two rows) that generates different spray drift profile deposition on the test bench because a double canopy wall in front of the test bench was present during vineyard trials. The identical final classification of spray application techniques tested using the two different types of sprayer, namely conventional and pneumatic, suggest that the target absence has negligible effect when test bench is used for comparative measurements aimed at determining the DRP of a given vineyard sprayer/configuration intended for single row spray application. Nevertheless, further investigations aimed to improve the test bench methodology for DPV measurements of multiple rows sprayers are needed.

Table 3 Drift Reduction Potential -DRP- (%) of configuration tested applying both indirect methodologies, namely absence ad presence of target. Classification of the different configurations tested according to their drift risk is also provided.

Test	Config. ID	Absence of target		Presence of target	
		Drift Reduction Potential -DRP- (%)	Drift class achieved*	Drift Reduction Potential -DRP- (%)	Drift class achieved*
Reference	ATR6H	-	-	-	-
Candidate	ATR6L	37	F	34	F
Candidate	TVI6H	75	D	79	D
Candidate	TVI6L	87	D	87	D
Candidate	MC6S	67	E	86	D
Candidate	M6S	97	B	97	B

*ISO22369-1:2006

4 Conclusion

The test bench method makes it possible to discriminate between potential drift generated by different vineyard sprayer types and their configurations. Furthermore, the comparison of the indirect test methods indicated that the absence or presence of a canopy affected DPVs obtained from the various configuration tested, yet calculated DRPs resulted in identical final classifications regardless of the indirect methodology tested. Therefore, the test bench methodology as originally proposed in the absence of a target was validated proving that the target absence had negligible effect when test bench is used for comparative measurements aimed to determine DRP of a given vineyard sprayer configuration when used for a single row spray application passage.

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