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Determination of drift potential of different flat fan nozzles on a boom sprayer using a test bench

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This study's objective was to evaluate the functionality of an *ad hoc* test bench for spray drift measurement with boom sprayers, using it for evaluating different nozzles according to drift risk. The repeatability of results was evaluated by conducting similar tests at two different laboratories. Drift potential values (DPV) obtained showed an interesting effect of Venturi flat fan nozzles on drift reduction, in comparison with conventional flat fan nozzles (reference nozzle was XR 11003). Newly designed flat fan nozzles reduced the risk of drift. Reasonably relations between 10th-percentile, D[v,0.1], 50th-percentile or Volume Median Diameter, D[v,0.5], 90th-percentile, D[v,0.9], V_{100} and DPV were observed in all cases, with R^2 values of 0.58, 0.65, 0.66 and 0.72, respectively. The lowest drift values were achieved with TTI and TD Spray Max nozzles; they were significantly lower than those obtained for IDK and AIXR ones. Results indicated that the drift test bench can be used as an alternative to the official standard procedure for drift measurements on boom sprayers (e.g. ISO 22866), as it is able to discriminate the influence of different boom settings (especially nozzle types) on drift. Further studies could be useful in order to prove that the classification of nozzles according to drift risk obtained using the test bench is comparable to the nozzle classifications obtained applying the ISO 22866 test method.

1. Introduction

Spray drift reduction and improvements in the efficiency of pesticide application processes are goals of the 128/2009/EC European Directive for a Sustainable Use of Pesticides (EP, 2009). The imminent and mandatory establishment of National Action Plans by each European Union (EU) member will include the definition, establishment, and quantification of buffer zones, for which quantified information about the drift potential of every single sprayer/configuration should be included. According to ISO 22866:2005 'Crop protection equipment – Methods for field measurement of spray drift' (ISO, 2005b), spray drift is defined as 'the quantity of plant protection product that is carried out of the sprayed (treated) area by the action of air currents during the application process".

Spray drift has been studied extensively in a series of field trials and crops (Ganzelmeier et al., 1995; Rautmann et al., 2001). The results from these studies are currently used in pesticide registration in the EU. Specifically, the 90th percentile of all measured drift values (the amount of drifted residues) is commonly applied in eco toxicological risk assessments. The data include the variability of spray drift between different fields (field trials) and the variability within each field (different Petri dishes placed at the same distance from the field border). Spray drift is highly influenced by many factors, which may be grouped into the following categories: equipment and application techniques, spray characteristics, operator care and skill (Arvidsson et al., 2011) and environmental and meteorological conditions. Several studies have been conducted in the last few years to evaluate and quantify the effect of the different parameters involved in the process; nevertheless, it is a large effort to define a classification method for spray techniques, which always vary greatly because of the influence of environmental conditions (Ozkan, 1998; Zande et al., 2000; Balsari et al., 2007; Zande et al., 2010). Variation is also caused by differences in measuring protocols and techniques.

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Hewitt et al. (2001) studied the effects of the liquid properties and nozzle design on the drift potential and demonstrated that adjuvant use has a direct effect on the break-up of the spray using common types of nozzles, changing the droplet size distribution and drift potential. Nuyttens et al. (2007) analysed the effect of nozzle type, nozzle size, spray pressure and spray boom height on drift, according ISO 22866:2005, concluding that venturi nozzles had the highest drift reduction potential, followed by the low-drift nozzles and the standard flat-fan nozzles. Drift results were closely linked with droplet size characteristics of the sprays and more in particular with the amount of small droplets (Arvidsson et al., 2011; Nuyttens et al., 2010, 2011). Other experiments have demonstrated the influence of operational parameters as droplet size range and air flow rate on airborne spray drift both for field crop sprayers (Zande et al., 2005, 2010) and for orchard sprayers (Cross et al., 2001a, 2003, 2001b). Miller and Smith (1997) and Zande et al. (2005) demonstrated a clear effect of forward speed on spray drift. The higher the driving speed the higher the spray drift, both for airborne drift as for ground deposition downwind of the field.

It appears that efforts to characterize the spray conditions and their influence on drift will help to finally achieve the objective of quantifying the spray emission and its risk of contamination. To quantify the spray emissions in relation to the drift conditions, a wide range of drift measurement techniques have been developed by different authors (Zande et al., 2008; Hoffmann et al., 2010). In most cases, these have followed the standardized protocol established by ISO 22866:2005, resulting in very complicated and time consuming experiments (Phillips and Miller, 1999; Ravier et al., 2005; Carlsen et al., 2006; Schampheleire et al., 2008; Rimmer et al., 2009), and even a high dependence on external factors, which make its adaptation and result repeatability difficult (Arvidsson et al., 2011). Schampheleire et al. (2008) concluded that the drift reduction proportions probably had large standard deviations because of the unevenness of the ground, which can cause horizontal and vertical boom movements (boom bounce) and can give rise to large drift deviations, especially when working with large boom lengths. Effect of sprayer boom height on spray drift (increment of spray drift according to increment of boom height) was also demonstrated by Jong et al. (2000). The fall-out drift measurements presented in the literature (Arvidsson et al., 2011) can, in some cases, differ by as much as a factor of 10 for the same nozzle size and working pressure, which can be attributed to different factors such as weather conditions, spray application technology and different measuring procedures (Nuyttens et al., 2006), and also to the position alongside the field (Zande et al., 2006). For these reasons, different authors have proposed alternatives for drift measurements, in an attempt to develop easy, repeatable, and precise methods as alternatives to actual standards. Different authors (Southcombe et al., 1997; Zande et al., 2002; Herbst, 2001; Nuyttens et al., 2009) proposed several indirect and direct spray drift assessment methods to evaluate the potential drift of spray nozzles. The results showed that with the indirect risk assessments (e.g. wind tunnel and PDPA laser measurement), driftability experiments could be conducted using different spraying systems under directly comparable and repeatable conditions and that both methods were suitable for the relative assessments of drift risk. The droplet size spectrum has also been used to evaluate drift reduction technologies through the development of different drift models that calculate the downwind drift expected from a typical aerial application scenario (Hoffmann et al., 2010), or from boom sprayers (Holterman et al., 1997; Miller and Hadfield, 1989; Butler Ellis and Miller, 2010). Drop sizing and spray drift modelling have been used for nozzle classification in drift reduction classes in the Netherlands (Zande, 2013). Wind tunnel measurements were used to develop a drift classification method for different external-mixing twin-spray nozzles, and a good correlation was obtained with the established drift reduction schemes (Sehsah and Herbst, 2010).

As a complementary methodology to simplify the assessment of spray drift risk, the Department of Agriculture Forest and Food Sciences (DISAFA) of the University of Turin developed a drift test bench to assess the amount of drift generated by field crop sprayers (Balsari et al., 2007; Vanella et al., 2011). The methodology is based on the principle that the potential spray drift is directly related to the initial spray that remains suspended in the air after the sprayer passage. The proposed method allows measuring the potential spray drift, which can be defined as the amount of spray that remains suspended in the air after the sprayer passage and which represents the fraction of spray liquid susceptible to drift out of the treated area by the action of air currents during the application process. The use of the proposed test bench for drift measurements has generated the development of a new standard procedure ISO/FDIS 22369-3 (ISO, 2011). Meanwhile, this procedure has been already published as a new Italian standard procedure for drift measurement for boom sprayers (UNI 11474, 2013). The general objective of this research was to evaluate the capability and performance of the drift test bench for determining the drift reduction values of different nozzles by comparison with a reference nozzle. The specific objectives of the described experiments were as follows: a) determination of the influence of the nozzle size and nozzle type on drift, b) evaluation of the performance of some newly developed spray nozzles in terms of drift reduction, and c) evaluation of the capability of the test bench and the repeatability of the results through parallel field trials at two different research spray laboratories in two different EU member states.

2. Materials and methods

2.1. Technical characteristics of drift test bench

The design and development of the drift test bench were carried out at the Department of Agriculture Forest and Food Sciences (DISAFA) of the University of Turin. Further details about the technical characteristics and way of functioning were widely described in Balsari et al. (2007). In the following lines a short description of the characteristics and functioning of the bench is given.

The bench consists of a 12 m × 0.5 m steel frame with slots for collectors situated at intervals of 0.5 m (Fig. 1). Each slot is equipped with a sliding cover, which makes it possible to cover/reveal the collector as needed. Once the field boom sprayer has passed by the entire bench, a pneumatic system automatically opens the collectors (Petri dishes) to capture the spray fraction that remains suspended in the atmosphere behind the boom and falls out after some time. The purpose of the bench is to collect and quantify, in absence of wind, the potential drift fraction, defined as the spray fraction that remains suspended over the bench just after the sprayer pass and which can be carried out of the target zone by environmental air currents.

The 12-m long stainless steel bench was placed at the centre point of the right section of the sprayer, 2.5 m away from a concrete flat lane used as a tractor race area (Fig. 2). Artificial collectors with a capture area of 153.86 cm^2 (Petri dishes 14 cm in diameter) were placed at intervals of 0.5 m along the bench slots. Sample's position was 0.30 m above the soil, as recommended in ISO FDIS 22369-3. The first two collectors were permanently uncovered while the rest of the collectors on the bench (10 m in length) were initially covered using the sliding plates of the test bench. The sprayer started the application, spraying a solution of water and tracer (yellow Tartrazine E 102), 20 m before the bench and then moved