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Comparative performance of recycling tunnel and conventional sprayers using standard and drift-mitigating nozzles in dwarf apple orchards

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ABSTRACT

The use of tunnel sprayers should be encouraged because they can potentially reduce pesticide input and drift in orchards. They could also allow smaller plot size in multifactorial trials in which fully randomized or randomized block designs are recommended. However, the effectiveness of plant protection products applied with tunnel sprayers cannot be reliably assessed without a thorough investigation into spray distribution in tree canopies. A set of three experiments was undertaken in an apple orchard to compare a new type of recycling tunnel sprayer with a standard axial fan sprayer, both of them fitted with either conventional hydraulic hollow cone nozzles (ATR) or drift-mitigating air induction cone nozzles (TVI). Its performance was assessed in terms of 1) spray deposit and coverage in the canopy, 2) sedimentation drift (spray drift to the ground) and 3) collection and recycling rate of the liquid sprayed in the tunnel. Artificial targets composed of cellulose papers and water-sensitive papers were used to evaluate the spray deposit and coverage at similar target positions for each treatment. A fluorescent dye was used as the spray tracer.

The study showed that, when using the ATR nozzles, the spray deposit, at each sampling point in the tree canopy, produced by the tunnel sprayer was not significantly different from that produced by the standard sprayer. The spray deposited on the top of the trees when using the TVI nozzles, however, was significantly less than with the standard sprayer. At the same spray deposit level, the spray cover on the canopy, estimated by image analysis, was relatively better with the standard sprayer than with the tunnel sprayer. At the same spray deposit level, the TVI nozzles resulted in significantly poorer spray cover of the canopy than the ATR nozzles. At low wind speeds, the sedimentation drift varied on average from 5.8 to 9.1% of the total sprayer output, irrespective of the type of sprayer or nozzle. The overall mean of the sedimentation drift was not significantly different for the two types of sprayers. The recovery system, which included a continuous recycling process in the tunnel sprayer, led to average savings of 28 and 32% of the applied spray mixtures for the ATR and TVI nozzles, respectively. The tunnel sprayer might therefore be suitable for small-scale apple orchards when fitted with traditional ATR nozzles rather than with air-induced TVI nozzles.

1. Introduction

The axial fan air-assisted sprayer fitted with hydraulic hollow cone nozzles is the predominant design of sprayers used in orchards. It produces a large radial spray plume, which could involve a significant risk of off-target contamination by spray drift and losses on the ground, a subject of increasing public concern. Several authors have reported losses in excess of 50% of the spray applied by axial fan sprayers (Cross et al., 2001). In apple orchards, spray losses on the ground can range from less than 2–39% of the total amount applied, and drift losses can account for 23–45%, depending mainly on leaf development and weather conditions (Vercruysse et al., 1999).

Other sprayer designs have been developed, including over-the-row tunnel spray systems. Although various studies have reported substantial savings in pesticides and a reduction in drift resulting from various types of tunnel spray systems (Peterson and Hogmire, 1995; Porskamp et al., 1994; Doruchowski and Holownicki, 2000; Planas et al., 2002; Ade et al., 2007), these sprayers are used only to

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a limited extent because of increased cost and reduced operational flexibility. In addition, few studies have looked at the spray distribution on the canopy and spray lost on the ground from a modern tunnel sprayer compared with a standard fan sprayer. The uniformity of deposition has been reported, in some cases, to be less satisfactory than that from conventional axial-fan sprayers (Porskamp et al., 1994; Planas et al., 2002). It has proved difficult to design a tunnel sprayer that distributes spray uniformly on the trees and significantly reduces losses on the ground (Molari et al., 2005). In general, the results from non-conventional orchard spray technologies are still debatable because little information is available, and what there is tends to be controversial.

Apart from environmental concerns, another benefit of tunnel sprayers would be to reduce plot size in treatment trials using complex experimental designs following the EPPO guidelines. In order to conduct reliable evaluation trials using the tunnel sprayers, more information is needed about the spray distributions on the tree canopy.

A new promising option for drift mitigation in orchards could be the use of air induction cone nozzles, which provide larger drop sizes. Coarser droplets reduce the air-borne drift losses by mixing less readily with the surrounding atmospheric boundary layer (Walklate, 1992; McArtney and Obermiller, 2008). Spray distribution can be improved, however, by applying greater numbers of finer droplets which are more easily carried by the forced airflow of the sprayer (Cross et al., 2001; Derksen et al., 2007). Finer droplets with a smaller diameter give a greater coverage for any given level of spray deposit. The net result of these counteracting effects has been investigated only to a limited extent in orchards. According to Cross et al. (2001), the coarse sprays produced slightly greater mean deposits and smaller spray losses, and were preferable from this point of view. Further work is needed to establish the effect of biological efficacy of these spray patterns, although it has been shown that the effectiveness of insecticides is inversely proportional to drop size, and the limited data for fungicides suggest similar conclusions (Chapple et al., 1997; McArtney and Obermiller, 2008).

The objectives of this study were to assess the tunnel sprayer and the drift-mitigating nozzle performances compared with reference treatments using standard technologies. The amount and macro-distribution of spray deposits on the canopy, together with spray losses on the ground (sedimentation drift), were measured in a modern apple orchard system in two experiments. In a third set of experiments, the recycling rate obtained with the tunnel sprayer was assessed.

2. Materials and methods

2.1. Orchard and equipment

The study was conducted in an experimental dwarf apple orchard (cv. 'Pinova') planted in 2002 in Gembloux, Belgium (Jamar et al., 2008). Inter-row spacing was 3.5 m and intra-row spacing was 1.5 m. Orchard maintenance included a classical spindle shape training system. In 2008, the trees reached an average of 3.25 m high and 2.1 m wide.

Applications were performed with a standard axial fan air-assisted sprayer (Arbo AX 1000, Berthoud Agricole, 69 220 Belleville sur Saône, France) and a recycling tunnel sprayer (Type 115, Munckhof, 5961 CV Horst, The Netherlands), including the so-called 'Closed Loop System Technology'. Both sprayers were fitted with two sets of six nozzles. For the air assistance system of the standard sprayer, the fan rotational speed was 1600 rpm (low gear position). With the air assistance system of the tunnel sprayer, the air is sucked from inside the tunnel, producing an under-pressure area which helps eliminate most of the forward or backward spray drift. Air-borne droplets are partly intercepted by the tunnel's special design features and partly sucked back in by six axial-flow fans for subsequent re-use. The recovered spray is sucked in at the bottom of the collector walls using a Venturi system and transported to the sprayer tank after filtering. The internal opening of the tunnel was set at 2.40 m wide for all experiments, so the distance between the nozzles and the centre of the row was kept constant at about 1.2 m. The air outlets were angled at 45° upwards. For each sprayer, two types of spray nozzle were tried: the classical hollow cone nozzle (yellow Albuz ATR 80) and the air induction cone nozzle (green Albuz TVI 80-015) manufactured by Céramique Techniques Desmarquest from Evreux in France. For all the experiments, the power take-off (PTO) speed was fixed at 560 rpm, with a travel speed of 6.6 km h^{-1}. The working pressures were held in position at 10.5 and 12 bars for the ATR and TVI nozzles, respectively (Table 1).

During each experiment, air temperature, relative humidity, wind velocity and wind direction were recorded within the orchard at 3.5 m above the ground, using an iMETOS® AG IMT300 weather recorder (Pessl Instruments GmbH., 8160 Weiz, Austria, 2007). The local weather conditions were electronically monitored at the time of each spray application.

2.2. Treatments

The experiment involved four treatments: (i) standard sprayer with ATR nozzles, (ii) standard sprayer with TVI nozzles, (iii) tunnel sprayer with ATR nozzles and (iv) tunnel sprayer with TVI nozzles. In order to avoid external sources of variability, all the working parameters were kept as constant as possible in all treatments. The sprayers were calibrated to apply a constant rate of 350 l ha^{-1}. The spray liquid consisted of a mixture of 2 g l^{-1} of the water-soluble dye (fluorescein-sodium tracer, C.I. 45 350, Merck, Germany) in water for the canopy distribution experiment and 9 g l^{-1} for the sedimentation drift experiment. A sample tank liquid was taken immediately before and after completing each spraying to determine the exact concentration of the tracer in the spray tank.

2.3. Spray deposits in the canopy

The first experiment was carried out at full-leaf development stage during summer 2008 and was repeated four times, on 25 July, 1 August, and 2 and 10 September under varying weather conditions. For each treatment, four sampling repetitions in space were carried out, obtaining a completely randomized experimental design. Four

Table 1
Treatments.

Treatment	1	2	3	4
Sprayer	Standard	Standard	Tunnel	Tunnel
Nozzle trademark and type[a]	Albuz ATR	Albuz TVI	Albuz ATR	Albuz TVI
Size	Yellow	Green	Yellow	Green
Number of nozzles	12	12	12	12
Pressure (bar)	10.5	12	10.5	12
Measured spray liq. flow rate (l min^{-1})	1.12	1.12	1.12	1.12
Forward speed (km h^{-1})	6.6	6.6	6.6	6.6
Spray volume[b] (l ha^{-1})	350	350	350	350
Volume median diameter VMD (μm)[c]	78	507	78	507
PTO speed (rpm)	560	560	560	560

[a] ATR = ceramic hollow cone nozzle, TVI = air induction cone nozzle.
[b] Calculation based on 2857 m per ha.
[c] D50 values at 10 bars measured by the Cemagref on Dantec calibration.