Performance evaluation of different axial fans configurations

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Summary
Despite airflow properties are of fundamental importance for the success of treatments and for reducing environmental impact due to drift effects, fan performances appear to attract less attention than other sprayer components such as nozzles. Farmers often ignore the amount of airflow delivered from, and adjust amount and flow direction in function of their subjective opinion about. When in excess, airflow produces dangerous environmental dispersion of pesticides and high energy consumption, whereas when it is insufficient penalizes the uniformity of pesticide application. The most recent machines and technologies, supported by geolocalized information, require diversified configurations to implement choices suited to canopy characteristics and circumstances in which they operate.
The first goal of this research is to gather information about the airflow in function of different fan configurations. Preliminary tests were carried out at a Service Workshop and Sprayer Inspection Center using a conventional sprayer machine (hydraulic pulverisation). The methodology followed the International standard ISO/FDIS 9898 for the measurement of the airflow rate at the intake and outlet side of the fan. In particular, a pipe connected to the suction side of the fan and a purposely designed frame were used for measuring the airflow rate at the intake and at the outlet side of the fan respectively. A torquemeter was used to investigate the power needed during fan working.
Keyword: air-assisted sprayers; airflow; fan performances; deflector; inspection; environment.

Introduction
Two are the very basic aspects of spraying: "Wind", as the airflow generated to move the spray into the canopy and "Water", as the pesticide being formed into droplets and propelled at the canopy. In particular, air flow affects the trajectory of the droplets and therefore the drift phenomena (Fox et al., 2008; Salcedo et al., 2015) while number and size of the droplets ensure the correct amount of active substance on the target while minimizing the off-target losses (Cerruto et al., 2016; Cerruto et al., 2017; Nuyttens, 2007) or the run-off.
Drift is impossible to eliminate but it can be minimized by implementing some methods and technologies that can reduce the effects and improve efficiency of spray application, saving time, money, and environmental hazards (Miranda-Fuentes et al., 2018; Moltò et al., 2017).
The amount of airborne drift is influenced by many interrelated factors including droplet size, nozzle type and size, sprayer design, airflow volume and velocity, weather conditions, cultivation features (Balsari et al., 2013; Salcedo et al., 2015).
It is widely shown that it is fundamental to set air volume and velocity correctly to confine airflow, spray pattern and disturbance to the tree canopy to allow the pesticide spreading. With this aim, some studies have investigated the airflow generated by the fan of conventional sprayers by means of stationary measures at the intake and outlet side of the fan, because there is a close relationship between these measures and those of the moving sprayers (De

Moor et al., 2002). Many conclusions have been obtained, but the setting of sprayers accounting for all the interrelating parameters represents, even today, an interesting topic of study.
In order to make possible to identify the most appropriate parameters of use for each farm context, periodic instrumental regulation at authorized test centers, compulsory according to the European Directive 2009/128/EC, is of fundamental importance to make treatments more effective, also reducing drift phenomena.
In this direction, our work was carried out at an Inspection Center for sprayers in order to:

- test a methodology for measuring the air velocity at the outlet side of the fan;
- verify the air velocity at changing feature fan blades (shape, pitch, gear ratio) at the intake and at the outlet side;
- check the influence of the exit opening space of air by regulating its width;
- evaluate the sustainability of the energy consumption level of the fan configuration.

Materials and Methods

The laboratory for experimental measurements is actually under construction at a sprayer machine manufacturer. Preliminary tests were carried out with an axial helical fan, usually mounted on conventional sprayer machines (hydraulic pulverisation), commonly used in vineyard and orchard. A torquemeter was used to investigate the power needed during fan operating (Anderson et al. 2012; Thor et al., 2014). The methodology for air-flow measurement followed the ISO/FDIS 9898 International Standard.
In particular, a pipe connected to the suction side of the fan and a purposely designed frame were used for measuring the air speed at the outlet side of the fan respectively (Figure 1).
Three hot wire thermo-anemometers were used for measuring air velocity at the intake, in the measuring points indicated by the normative (Figure 2). Moreover, a sheet metal plate (deflector) placed behind the fan was designed to allow the air outlet to increase or decrease, moving horizontally from 45 mm to 105 mm (Figure 3).
In particular, the frame is able to make a 180° rotation allowing to measure on both sides of the machine at different distances from the center of the fan (radial adjustment) in two directions. The first allows discrete measurements up to 2 m (horizontal adjustment) while the second (transverse adjustment) allows to position the anemometer transversely, moving away from the air outlet, forwards or backwards.
According to the 3.6 par. of ISO 9898, because the fan under test was equipped with variable pitch blades, these first tests were done with the angle recommended by the manufacturer. Moreover, according to the 3.7 par. of ISO 9898, the tests were done with the width fan outlet recommended by the manufacturer.

Preliminary results

Preliminary tests were aimed at assessing the functionality of all the equipment (frame, pipe, torquemeter, thermo-anemometer, setting of the fan outlet width) used for fan air-flow characterization. The frame for measuring the air velocity at the outlet side of the fan, taking in account the environmental feature where the sprayer is used, is able to provide a precise reference for the placement of the thermos-anemometers. Being able to investigate 180° from the right to the left side of the fan, as well as at different distances from the center of the fan, it allows discovering any asymmetries between the two sides of the sprayer and allows measuring air speed at a distance corresponding to the presence of plant canopy (vineyard, as an example).

The width of exit opening at the outlet side of the fan allows testing its effects on air flow rate and air velocity at both inlet and outlet. An extensive set of measurement may provide guide lines for its optimal adjustment.

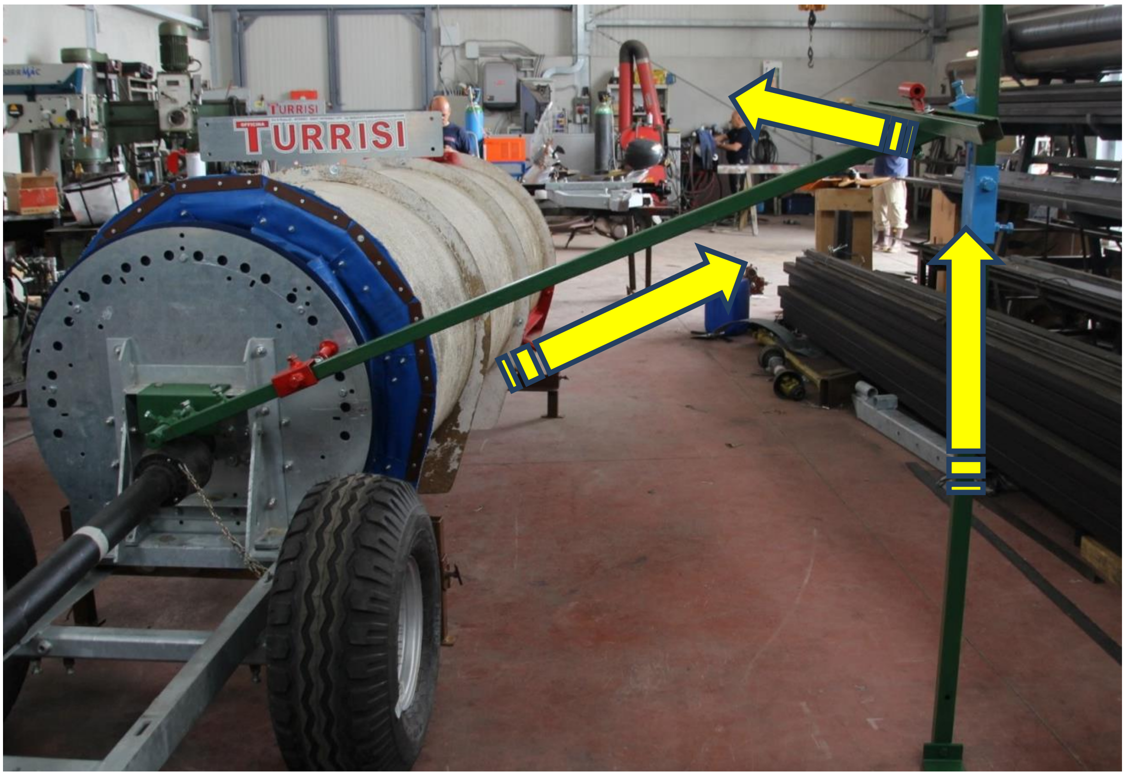

Figure 1: The reference frame for measuring the air speed at the outlet side of the fan along with three directions (radial, vertical, and transversal adjustment).

Figure 2: Measuring pipe of airflow at the intake

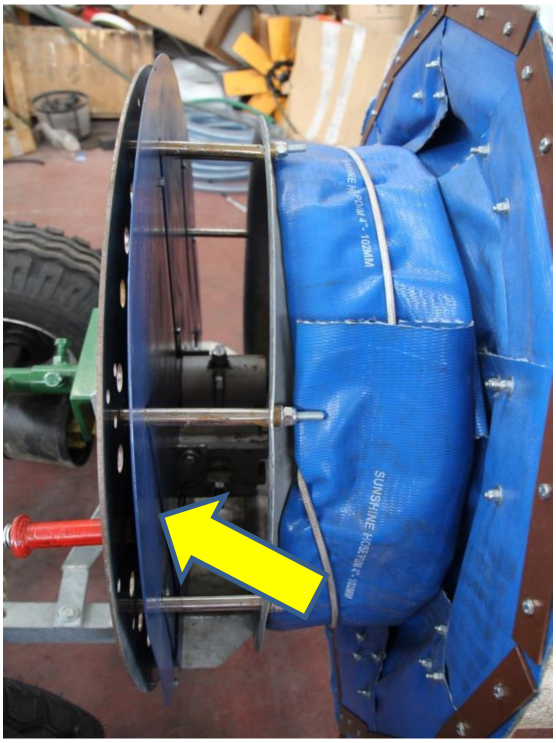

Figure 3: Horizontally variable width fan outlet

Conclusions

In order to minimize the environmental hazards during crop protection treatments, a laboratory test is under realization at a sprayer machine manufacturer that is also Inspection Center for sprayers.
Preliminary tests were carried out to verify the methodology for measuring the air velocity at the outlet side of the fan and which parameters have a greater impact on the airflow.
Further tests are needed to study the relationships between the fan configuration (blade orientation, shape, gear ratio) and the air velocity at the inlet and at the outlet of the fan.
Likewise, for each fan configuration, the analysis of energy consumption by using a torquemeter is under study.

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