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Reducing pollutant drift from a pneumatic maize seed drill using exhaust air into the fertilizer system

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ABSTRACT

In recent years, serious environmental issues have resulted from the dispersal of pesticides during maize seeding, especially when performed with pneumatic drills. This phenomenon can be detrimental to insects because the products used to dress maize seeds contain pesticides. In this experiment, the conveying of exhaust air into the fertilizer hoses was tested as a potential solution to reduce the dispersion of seed dust. The use of exhaust air through the fertilizer system created a dust drift reduction of 68%, about 20% lower than dual pipe deflectors (specific devices developed to reduce dust drift). In addition, conveying the exhaust air into the fertilizer system reduced the pressure-level into the seeding element by 5 kPa, but this did not interfere with the seeding quality as the vacuum level (58 kPa) was greater than the minimum value required to perform a good quality maize seeding (40 kPa). The conveying of the exhaust air into the fertilizer system demonstrates how the drift of potentially harmful substances can be reduced during sowing of pesticide-dressed maize seeds using pneumatic drills. In fact, this system showed dust drift mitigation performance similar to devices set up especially for this purpose.

1. Introduction

At present, air pollution is one of the major problems that affects the environment and, consequently, human health in Europe. Air pollution from toxic substances is mainly released by vehicles (Ropkins et al., 2009; Weiss et al., 2011),particularly in urban areas where the air quality is lower compared to open spaces (Marcazzan et al., 2001; Mircea et al., 2005). The agricultural sector is also considered a source of air pollution. In fact, toxic substances can be produced by fuel and lubricants during cultivation activities (Blengini and Busto, 2009; Snyder et al., 2009; Safa and Samarasinghe, 2012) along with the pesticides used in crop protection (Girolami et al., 2012, 2013; Lichiheb et al., 2014; Barbosa et al., 2015). Factors that need to be considered when focusing on the emission of pesticides during their application include the machines used for application, the physiochemical properties of the pesticide applied, and environmental conditions during pesticide application (Van den Berg et al., 1999; Krupke et al., 2012; Pisa et al., 2015).

In the last decade in Italy, significant environmental problems have been linked to the dispersion of pesticides into the atmosphere (Marzaro et al., 2011; Nuyttens et al., 2013). This problem can arise from the residual dust that occurs from the chemical coatings on maize seeds during seeding with pneumatic seed drills (Herbst et al., 2010; Sgolastra et al., 2012; Xue et al., 2015). Seeds are commonly dressed with pesticides as it is possible to protect plants using a smaller amount of active ingredient per unit surface compared to conventional application (Ahmed et al., 2001; Koch et al., 2005). In pneumatic drills, the exhaust air exiting the fan used to create the vacuum in the seeding elements is responsible for blowing away solid particles detached from the coated seeds (Schnier et al., 2013). In many cases, the dispersion of this material is dangerous to beneficial insects because the "dust" can contain several pesticides (insecticides) used in coating seeds (Greatti et al., 2006; Biocca et al., 2011).

Several studies have focused on performance evaluation of different pneumatic drills and specific devices developed to limit this form of air pollution (Giffard and Dupont, 2009; Tapparo et al., 2012; Chapple et al., 2014; Pochi et al., 2015). These devices work differently to reduce dust dispersion. For example, some devices convey the exhaust air towards the soil (Rautmann et al., 2009; Balsari et al., 2013; Manzone et al., 2014), while others are able to clean the airflow exiting from the fan (Manzone et al., 2015; Manzone and Tamagnone, 2016).

Another important aspect of the sowing operation is the mineral fertilizer distribution. At present, drill manufacturers provide a specific fertilizer kit made of additional hoppers, a metering system, hoses, and a coulter system (necessary to bury the fertilizer granules in the soil). Sometimes, especially when sowing machines have a telescopic frame

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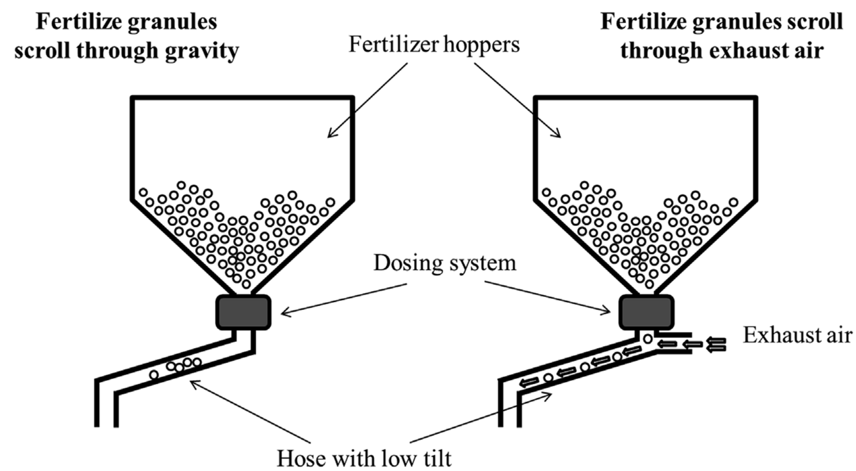

Fig. 1. Drill used in the trials.

(used to limit the transport width), the fertilizer granules are not able to reach all coulters (namely external ones)because the hoses have too little tilt and the gravity force is not sufficient to scroll the single granules into the hoses. To address this, manufacturers have been equipping sowing machines for 20 years with a specific device able to convey the air that exits from the pneumatic drill fan into the fertilizer hoses to guarantee the scrolling of the fertilizer granules in all coulters (Fig. 1). Unfortunately, most devices used to reduce dust drift do not permit the reuse of air exiting from drill fans in fertilizer systems, causing operative problems to farmers in the fertilizer distribution. The aim of this research was to evaluate if the exhaust air conveyed into the fertilizer hoses reduces the seed dust dispersion.

Table 1
Main technical features of the pneumatic drill used for tests.

Manufacturer	Monosem® NG plus
Seeding elements (n°)	6
Row distances (mm)	700
Fan diameter (mm)	420
Fan width (mm)	80
Blades (n°)	8
Blade inclination (°)	0
Blade width (mm)	45
Average air outlet size (mm)	135 × 80
Outlet air direction	Upwards
Air velocity (m/s^{-1})	4.4
Airflow rate (m^3/h^{-1})	210

2. Materials and methods

This experiment was performed using a commercial pneumatic drill (Monosem® NG plus) with six seeding elements (Fig. 2). The machine was set with a row distance of 0.70 m to sow 75,000 seeds per hectare (Table 1). The drill was tested in three different working configurations: 1) standard configuration, 2) equipped with a mineral fertilizer spreader and a kit to convey the air exiting from the fan into the fertilizer hoses, and 3) equipped with a specific device able to reduce the dust dispersion (dual pipe deflector). More detail is provided below on each of the three configurations.

In the standard configuration, the drill's basic setting included the frame, fan with pneumatic circuit, and the seeding elements, and the airflow exiting from the fan was upward to a gradient of about 45° with respect to the soil surface (this is the original fan outlet design of the manufacturer). In the second configuration, the fertilizer spreader system and the kit to convey the exhaust air exit from the fan into the fertilizer hoses used in the trials were commercial models made by the same manufacturer (Monosem®). Specifically, the fertilizer spreader system was composed of two hoppers (0.27 m^3) fixed onto the drill frame. Six hoses of 55 mm diameter were linked to the hopper bottom (three for each hopper - one for each seeding element). The air conveyor kit used in the tests was able to convey the exhaust air only into the two hoses linked to the external sowing elements. Commonly, these external hoses show an inclination of less than 30° with respect to the horizontal plane because they are longer than the others and, for this reason, the fertilizer granules did not move down sufficiently by gravity (Figs. 1 and 2). In the third configuration, a dual pipe deflector device was used to reduce dust dispersion because this kit guarantees better performance compared to other air conveyors (Manzone et al., 2014). Schematically, the dual pipe deflector kit is composed of an adapter device fixed to the drill fan, which is able to split exhaust air into two flexible 125 mm diameter hoses with output close to the soil (100–120 mm; Manzone et al., 2017). The two flexible hoses must be placed in a vertical downward-facing direction, as stated in the manufacturer's recommendations. Air outlets show a correct position when they are placed between the central seeding elements.

Fig. 2. Drill used in the trials.

2.1. *Drill performance*

Tests were carried out in order to verify if the drill showed the same performance in the three experimental different configurations. Since a minimum vacuum level of 40 kPa was required in the seeding element to guarantee a high quality sowing (Karayel et al., 2004), the vacuum pressure was measured in all drill configurations, following the procedure of Balsari et al. (2013). These measurements were performed in