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Dust Emissions During the Sowing of Maize Dressed Seeds and Drift Reducing Devices

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Abstract: Mortality and sub-lethal effects on honey bees have been related to the sowing of maize seeds dressed with neonicotinoid insecticides. Pneumatic precision drills, used for commercial seed sowing, play a role in the dispersion of the abrasion dust because abrasion dust is emitted with the airstream generated by the drill's fan. The paper provides the results of the assessment of dust drift both from a conventional and a modified drill with a novel filtering-recycling system developed at CRA-ING. We employed maize seed treated with thiamethoxam, imidacloprid, clothianidin and fipronil. The tests assessed the residues produced both at soil level and in the air, during static sowing simulation tests carried out at fixed point. The results show that the use of the prototype allows a remarkable reduction of dust drift of about 86%, at ground level, and of 85% in the air, with respect to the conventional drill.

Keywords: Honey bees, insecticide-treated seed, neonicotinoids, pneumatic drills.

INTRODUCTION

In recent years spring mortality of honey bees (*Apis mellifera* L.) and sub lethal effects were related to sowing of maize (*Zea mays* L.), seeds treated with neonicotinoid insecticides and fipronil. The seed dressing (or coating) controls a wide range of maize pests with a small quantity of insecticide in comparison with other application techniques [1]. However, minor amounts of abraded dust of the seed dressing (containing active ingredients – a.i.) expelled by pneumatic sowing seeders (drills) can cause the exposure of honey bees and other pollinating insects [2-5]. The exposure may cause direct mortality [6] or sub-lethal or subtle effects [7-9]. The insect exposure might occur by feeding on flowers and by contact with particulate matter containing pesticide residues, during their flight. The honey bee's body, covered by hairs that electrostatically trap the airborne particulate, enhances direct exposure of wind dispersed-dust during flight [10, 11].

The precision pneumatic drills contributes to the dispersion of dust because the abrasion dust released during storing, manipulation and sowing of dressed seed is vented with the airstream produced by the drills to obtain the vacuum necessary to allow the adherence of the seed to the distribution disk [12]. Manufacturers have proposed some devices to decrease the dust drift generated by the drill. These include: 1) air deflectors (including "dual pipe deflector" proposed by Syngenta as an aftermarket solution applicable to different drill models and similar devices directly applied by seeder manufacturers); 2) the Bayer SweepAir® system [13]; 3) the Bayer AirWasher® system [14].

The deflector system consists of a steel frame, applied at the fan opening, from which the air is directed into the furrows opened by the two central sowing units, by means of flexible plastic pipes (generally 2 or 4). In previous work, we tested the dual pipe deflector system, applied to a Matermacc drill [15, 16] and the deflectors mounted by Gaspardo [15, 17, 18] obtaining an average emission reduction of about 50% (see Table **1** for a synthesis of the percentage reductions induced by drill with deflectors). With this level of drift, the occurrence of sub-lethal effects to honey bees cannot be excluded [19].

Therefore, to contribute to find engineering solutions to reduce (or avoid) the dust emissions from drills, we have developed a novel filtering-recycling prototype system. This paper provides results of assessment of the dust drift deriving from the prototype in comparison with the standard drill.

MATERIALS AND METHODS

Seed

The trials were carried out using maize seed (Pioneer Hy-Bred PR32G44) dressed with four different insecticides and a fungicide (Celest™; a.i.: fludioxonil and metalaxyl). The quantities of a.i. provided by the manufacturers are shown in Table **2**.

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Table 1. Average percentage reduction of the a.i. detected at soil level incited by the employment of the modified drill with deflectors, in different experiments (references are reported in the text).

Experiment	Drill	Year	Plot Area [ha]	Imidacloprid	Clothianidin	Thiamethoxam	Fipronil
Field	Matermacc	2009	0.16	14.6%	42.8%	48.2%	-
Field	Gaspardo	2010	~ 3.0	71.7%	35.2%	39.8%	61.9%
Fixed point	Gaspardo	2010	-	72.8%	53.4%	53.5%	60.7%

Table 2. Maize seed employed in the trials.

Commercial Name	Active Ingredient (a.i.)	a.i. Application Rate
		[mg seed^{-1}]
Gaucho™	imidacloprid	1.00
Poncho™	clothianidin	1.25
Cruiser™	thiamethoxam	0.60
Regent™	fipronil	0.50

Drills

In the trials, we have employed a six-row pneumatic precision drill Gaspardo (mod. Magica) compared with the prototype developed at CRA-ING (Fig. **1**). The prototype consists of a device, mounted on the standard drill that works by partially re-circulating the air generated by the drill's fan. A plastic pipe works as a collector receiving the air expelled by the fan by means of four deflector pipes and redirecting the airflow into the hoppers. The air in excess is forced outward through an opening fitted with an activated charcoal filter for automotive use (anti-pollen filter, APF). These device can be easily removed, restoring the "conventional drill" conditions and allowing the comparison between conventional and modified machinery. A patent was issued on this device (international patent application No. PCT/IB2011/053736 - August 25th, 2011).

Experimental Setting

The tests have been carried out operating the sowing statically and detecting the dust drift produced by means of samplers placed along a sampling area. The sowing simulation tests were carried out in the workshop's porch of CRA-ING, as described in Biocca *et al.* [17], with some modifications described below. In the test site, artificial side wind conditions were produced by means of an axial fan (0.735 m diameter) operating at a speed of 1358 rpm by means of an electric motor, to generate a wind tunnel with a 22.5 m long sampling area, downwind with respect to the drill position. The average wind speed in the sampling area was 1.3 m s^{-1} measured at 2.0 m from the soil (min 0.8, max 2.0 m s^{-1}). Five series of Petri dishes were placed along the sampling area at an increasing distances of 4.5 m from the line of sowing, perpendicularly to the air flow; each series consisted of three dishes spaced 1.5 m; therefore a grid of 15 sampling points was obtained. Before each test, the Petri dishes were filled with an acetonitrile-water solution.

Moreover, to detect the air concentration of a.i., five active samplers consisting of air pumps (TCR Tecora model "Bravo"), with PTFE membrane filters (porosity 0.45 µm; diameter 47 mm), were set for sucking 100 L of air with a constant flow, over the course of the experiment. They were placed downstream of the airflow at the same distance as the Petri plates (4.5, 9.0, 13.5, 18 and 22.5 m). Each trial was replicated three times for each a.i. Each replication consisted of the distribution of two sacks of seed, corresponding to a 0.67 ha surface, and lasting 21 min.

Because in the static tests the drill is lifted, the seed is released at about 25 cm from the soil surface (whereas in the operative conditions in the field the seed is deposited into the open furrows). Therefore, in order to avoid additional drift of dust during the seed falling, the terminal parts of the seed distributors were wrapped with plastic bags, to reproduce the shield effect of the soil.

Chemical Analyses

The determination of a.i. was carried out as described in the previous work [17]. After extraction of the samples with acetonitrile, solutions were vibrated in an ultrasonic bath for 10 min and then filtered with a 0.45 µm filter. The analyses were carried out by means of HPLC coupled to an MSD (Mass Spectrometry Detector) operating with an ES+ (Electrospray Ionisation Interface, positive mode), and the relative methods were validated in compliance with GLP (Good Laboratory Practice) procedures. The following instruments

Fig. (1). Modified drill with the recycling-filtering device. (**1**) tight lid; (**2**) collector of pipes coming from the drill's fan; (**3**) main pipe collector; (**4**) recycling pipe from hopper to main collector; (**5**) box containing the anti-pollen filter.

were utilized: Waters Alliance 2695 Separation Module and 2695 Autosampler; Micromass 4 micro Triple Quadrupole Mass Spectrometer with Electrospray Ionisation (ESI) probe; and Waters X-Terra MS column C18, 5 µm 150 x 4.6 mm, flow 0.3 mL•min^{-1}, gradient elution with water (0.1% acetic acid) and 10% acetonitrile (0.1% acetic acid) up to 90%, in MRM (Multiple Reaction Monitoring) mode. The mass spectrometer detector was tuned in the MRM mode at the maximum sensitivity for each of the parent ions m/z and polarity; two product ion fragmentations for each were followed and detected. All reagents were of analytical grade quality (Merck, Darmstadt, FRG).

RESULTS

The prototype, with respect to the conventional drill operating with the same setting, exhibited a remarkable reduction of abrasion dust drift. The plots in Figs. (**2** and **3**) show the comparison between drills in terms of concentrations of a.i. at soil level (in the Petri dishes) an in the air (in the PTFE filters). The prototype exhibited an overall reduction of a.i. emissions observed for the four active ingredients of 86%, at ground level, and of 85% in the air. In detail, the percentage reductions at ground level were: 74% for clothianidin, 92% for fipronil, 86% for imidacloprid and 91% for thiamethoxam. As for the air concentrations, the reductions were similar: 86% for clothianidin, 95% for fipronil, 71% for imidacloprid and 88% for thiamethoxam.

Fig. (**2**) shows the values of the dry ground residues represented as concentration per surface area (µg m^{-2}); in the case of static tests these amounts are referred to the quantity of seed necessary for sowing a surface of 0.67 ha. According to the calculations proposed by Biocca *et al.* [17], this data can be utilized to estimate the quantities that the drill will emit under field sowing conditions. These estimated values, at a distance of 4.5 m from the emission source (i.e., sowing drill), are reported in Table **3**.

Regarding the air concentrations of a.i., Fig. (**3**) shows the comparison of values recorded in the static tests in terms of µg m^{-3}.

CONCLUSION

Among the different factors that contribute to the dispersion of dust during the sowing of dressed seed, a key role could be played by innovative engineering solutions

Fig. (3). Comparison between drift values in the sampling area obtained with the conventional drill and the prototype. Values are expressed in terms of air concentrations (µg m^{-3} ± standard error).

The study also contributes to find a standardized method to verify the capability of drills to release abrasion dust during the sowing. The determination of the quantity of a.i. (i.e., real amounts of a.i.) expelled by the drills during the sowing, represents the starting point for further studies to define threshold value of drift that could allow the development of a drill evaluation system.

In conclusion, further studies are necessary to improve the prototype and to study the exposure of the environment and of the operators during the dressed seed sowing.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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