Crop Protection 74 (2015) 56–64

Contents lists available at ScienceDirect

Crop Protection

journal homepage: www.elsevier.com/locate/cropro

A device for pneumatic precision drills reducing the drift of the abrasion dust from dressed seed

Daniele Pochi [a], Marcello Biocca [a,*], Roberto Fanigliulo [a], Pietro Gallo [a], Marco Fedrizzi [a], Patrizio Pulcini [b], Cinzia Perrino [c], Francesca Marcovecchio [c]

[a] Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria, CRA-ING Unità di Ricerca per l'ingegneria agraria [Agricultural Engineering Research Unit], Via della Pascolare 16, 00015 Monterotondo, Rome, Italy

[b] Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria, CRA-PAV Centro di ricerca per la patologia vegetale [Plant Pathology Research Center], Via C.G. Bertero 56, 00156 Rome, Italy

[c] CNR-IIA, Institute for Atmospheric Pollution Research, Consiglio Nazionale delle Ricerche, Via Salaria, Km 29.300, Monterotondo St., Rome 00015, Italy

ARTICLE INFO

Article history:
Received 9 September 2014
Received in revised form
20 February 2015
Accepted 21 February 2015
Available online 11 April 2015

Keywords:
Neonicotinoids
Honeybee
Seed coating
Particulate
Aerosol
Gaucho™

ABSTRACT

The effect of drift of dust containing insecticide active ingredients (a.i.) derived from dressed seed and observed mortality or sub-lethal effects on honey bees (*Apis mellifera* L.) has been recently investigated. Pneumatic precision drills used in maize sowing were considered among the main causes of the phenomenon. To reduce dust spread, the drills have subsequently been equipped with air deflectors that redirect the vacuum fan air outlet towards the ground, resulting in an unsatisfactory 50% reduction of a.i. concentration, with continuing sub-lethal effects on honey bees. We developed an effective prototype device for pneumatic drills, which uses partial recirculation and filtration of the air. Static tests (simulating sowing of maize seed treated with imidacloprid) were carried out to evaluate the prototype's efficiency and to provide information on the main characteristics of dust particles. Gravimetric and chemical analyses of samples showed, respectively, reductions of 98% of the total dust and of 97%. of the a.i which resulted from the application of the prototype. Particles with diameter >5 μm were nearly completely eliminated. For particles with diameters <4 μm, a lower reduction was observed, the effect of which, anyway, was counterbalanced by the lower overall mass of fine particles.

1. Introduction

Maize (*Zea mays* L.) is a major Italian cereal crop with 808,317 ha cropped in 2013 (Istat, 2014). In order to control pests and diseases at early stages of plant growth, maize seeds are usually dressed with small doses of pesticides, including the imidacloprid (Elbert et al., 2008), a neonicotinoid systemic insecticide world widespread (Jeschke et al., 2010) because of its effectiveness against a broad range of pests (Elbert et al., 1990). In recent years, toxicity of imidacloprid to honey bees (*Apis mellifera* L.) and other pollinating insects was reported (Gill et al., 2012; Goulson, 2013; Medrzycki et al., 2003).

According to Iwasa et al. (2004) the acute toxicity by contact (LD_{50}) of imidacloprid is 18 ng bee^{-1}. Suchail et al. (2001) reported that LD_{50} values of imidacloprid were about 60 ng bee^{-1} at 48 h and about 40 ng bee^{-1} at 72 and 96 h after the treatment. As to sub-lethal effects, it is difficult to define threshold values, particularly in social insects (Suchail et al., 2001; Desneux et al., 2007), because cases of toxicity were observed at doses of imidacloprid up to 6000 times lower than those observed in acute intoxication. Bortolotti et al. (2003) observed sub-lethal effects by the ingestion of a solution with 100 ppb of imidacloprid. Sub-lethal doses (0.21 ng bee^{-1}) of the active ingredient (a.i.) can alter the waggle dance of the bees (Eiri and Nieh, 2012). Imidacloprid seems also to be involved in colony collapse decline (CCD), a multifactorial syndrome that has caused losses of honey bee colonies in North-America and Europe (Maini et al., 2010; Chensheng et al., 2012).

Pneumatic drills used for sowing dressed seed cause the dispersion of abrasion dust originating from the dressing treatment (Tapparo et al., 2012; Nuyttens et al., 2013), harming honey bees (Greatti et al., 2006; Tremolada et al., 2010) through different modes of exposure (Bortolotti et al., 2003; Colin et al., 2004; Pistorius et al., 2010), such as ingestion during feeding, including consumption of guttation drops (Girolami et al., 2009), and contact

* Corresponding author. CRA-ING, Via della Pascolare, 16 – 00015 Monterotondo, Rome, Italy.
E-mail address: marcello.biocca@entecra.it (M. Biocca).

http://dx.doi.org/10.1016/j.cropro.2015.02.026

with aerosols during flight (Vaknin et al., 2000; Tremolada et al., 2010; Krupke et al., 2012). The drift of abrasion dust and a.i. can affect large areas, potentially harming the health of agricultural workers and bystanders.

To reduce dust dispersion, pneumatic drills were equipped with air deflectors, flexible pipes directing the air (and the dust) outflow from the vacuum fan opening towards the ground (Balsari et al., 2010; Foquè et al., 2014a). The air deflectors result in a drift reduction varying from 30% to 70% (Biocca et al., 2011), but the residual a.i. concentrations are too high to exclude the occurrence of sub-lethal effects on honey bees (Apenet, 2011; Pochi et al., 2012).

To achieve a more effective reduction of abrasion dust emissions, CRA-ING developed an innovative device applicable to pneumatic drills combining partial recirculation and filtration of the air outflow from the centrifugal fan.

The paper reports the results of tests assessing the efficiency of a prototype in reducing dust emissions and for achieving information on dust particles, with particular reference to their dimensions, in order to explore their relationship with the results of sowing tests and to improve the performances of the prototype.

2. Materials and methods

2.1. Seeds

Commercial maize seed (Pioneer Hy-Bred PR32G44) was employed in the tests. It was packed in sacks of 25,000 seeds and dressed with Gaucho™ (a.i. imidacloprid: 1-[[6-Chloro-3-pyridinyl] methyl]-Nitro-2-imidazolidinimmina; empirical formula: $C_9H_{10}ClN_5O_2$; molecular weight: 255.5; density: 1.54 g cm^{-3}) and a fungicide (Celest™, a.i.: fludioxonil and metalaxyl). The application rate of imidacloprid, was 1.00 mg seed^{-1}. A cellulosic binder/colorant (Sepiret) was used for the dressing. The quality of the dressing treatment was verified through the Heubach test (Esa Stat, 2011), a standard method for assessing the tendency of production of abrasion dust. The test was carried out at CRA-ING, after the delivery of the seed. Despite the manipulations suffered by the seed during the transport, the test sample contained 1.67 g 100 kg^{-1} of seed, higher than the value declared by the manufacturer of 0.96 g 100 kg^{-1} at plant level, but far below the conventional limit of 3 g 100 kg^{-1} of seed (Pochi et al., 2011).

2.2. Pneumatic seed drills

The sowing machine was a six-row, precision pneumatic seeder manufactured by Gaspardo (mod. Magica). It was set for a planting layout of 0.75 × 0.18 m, approximately corresponding to 75,000 seed ha^{-1}. The drill was originally equipped with a system of four air deflector pipes, tested in previous works (Biocca et al., 2011; Pochi et al., 2011). In this work, the drill was also fitted with a prototype dust drift reducer (Fig. 1) developed at CRA-ING.

The function of the prototype is to maintain the abrasion dust, as much as possible, inside the machine by means of a system that recirculates the normal fan air output. The air deflectors were employed to convey the air into a PVC main collector (diameter 118 mm), serving as a compensation chamber of air pressure. From here, the air flows into the six hoppers, provided with airtight gasketed lids. The air in excess in the system is channelled outwards from the lower side of the main collector, through a box near the soil surface. The box supports an anti-pollen filter with activated carbon (ap/ac filter), used for air filtration in car cabs. After being filtered, the air can exit, at low speed, directed downward. In the process, the air undergoes a slight heating (4–5 °C). The device is the subject of the international patent application No. PCT/IB2011/053736 (August 25th, 2011). Fig. 2 shows the drill working configurations.

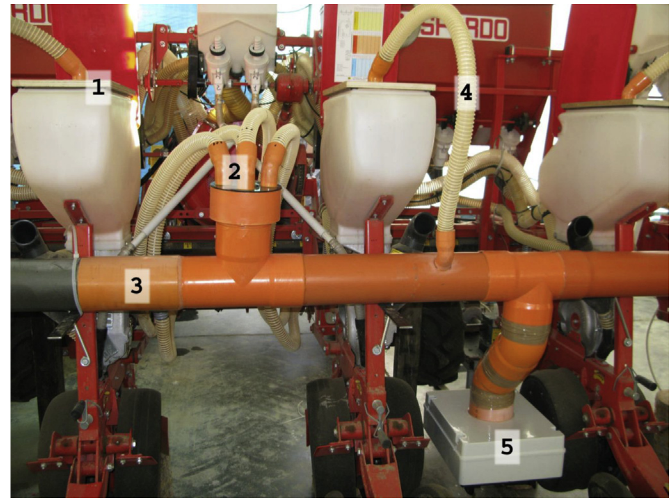

Fig. 1. The drill with the prototype device developed at CRA-ING. (1) airtight gasketed lids replacing the normal lids and provided with pipes (4) channelling the air from the main collector (3) into the hoppers. (2) collector of pipes coming from the drill's fan; (3) main pipe collector. The excess air passes through the box with filter (5) and is directed towards the ground.

2.3. Test methods

2.3.1. First test session

The first session aimed at providing information on the dimensions of the particles in the fan air outlet and at assessing the performance of the prototype. As said in the description of the drill, the deflectors were applied directly by the manufacturer. In these tests, we used the deflectors for channelling the air according to the following configurations (Fig. 3): configuration A: the unfiltered air directly flowed from the deflectors to the sampling pipe; configuration B: the air passed from the deflectors into the box with the ap-ac filter, then into the sampling pipe; configuration C: the air from the deflectors was recirculated into the pneumatic system, filtered into the box with the ap-ac filter, then passed into the sampling pipe.

The amounts of dust and a.i. observed in the configuration A were compared with the amounts in the configuration B (evaluation of the ap/ac filter efficiency) and C (synergic effect of filtration and recirculation). The tests also provided information on the particle size distribution of the dust. The drill was tested under static conditions, lifted from the ground, executing a simulated sowing. Each sowing cycle consisted of the distribution of two sacks of seed, divided among six hoppers. The virtual sowed surface was 6666.7 m^2. The Power Take Off of a 60 kW tractor operated the centrifugal vacuum fan to generate a −45 mbar pressure. An electric engine, connected to the sowing driving wheel by means of 40/1 gear-reducer, was powered by an inverter (Omron Varispeed V7) to obtain the desired working velocity: the value of 2.06 m s^{-1} (7.2 km h^{-1}) was adopted for all tests. The seeds released under the six sowing units were collected in vessels suitably placed and shielded from the side wind. Each sowing cycle required approximately 12 min.

The particles contained in the air outflow from the drill, in the three different configurations (A, B, C), were collected according to four different sampling setups, depicted in Fig. 3. The first setup (S1) consisted in an assembly containing a 0.45 μm PTFE Millipore diskette filters (diameter of 47 mm), subsequently analyzed for the