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Assessment of dust drift from pneumatic drills in static tests

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Abstract

The pneumatic precision drills for the sowing of maize (*Zea mays* L.) dressed seeds contribute to the emission of dust containing active ingredients (a.i.), such as neonicotinoid insecticides. These chemicals are involved in honey bees (*Apis mellifera* L.) mortality and decline. Some methods have been proposed to reduce the drift of pneumatic drills, including air deflectors, adjustment of sowing parameters, dressing quality enhancement and innovative filtering-recirculating devices. This paper describes a procedure to evaluate the dust drift caused by pneumatic drills, in tests at fixed point. An area of our workshop was arranged to obtain a sort of wind gallery with a 22.5 m long test area. Through the possibility of controlling wind speed and direction, such a system provides reliable data on the drift behavior, useful in comparative tests among different drills or drill's configurations. It is suitable to the observation of both ground residues and air concentrations of a.i. in the test area. The obtained data were compared with a.i. ground depositions observed in real sowing field tests. In conclusion, we propose a method for the estimation of the a.i ground deposition in field from the data observed in tests at fixed point. This method allows to design a standardized test system useful for evaluating the performances of drills and other seeders in terms of dust drift.

Keywords: Neonicotinoids; abrasion dust; honey bees; dressed seeds.

1. Introduction

In pneumatic precision drills the air expelled through the fan opening can carry abrasion dust and seed particles containing dressing (or coating) substances. When the seed are dressed with insecticides (i.e., neonicotinoids - such as imidacloprid, thiamethoxam, clothianidin - or fipronil), the dust drift can be important for the effects on honey bees (*Apis mellifera* L.) and other pollinating insects (Apenet, 2011; Pochi et al., 2012; Nuyttens et al.,

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2013) and for the potential exposure of the operators (Biocca et al., 2013). In fact, it was ascertained a relationship between honey bees mortality and decline and the sowing of maize (*Zea mays* L.) seeds dressed with the previously mentioned insecticides (Greatti et al., 2006; Tremolada et al., 2010; Pistorius et al,. 2010; Tapparo et al., 2012).

Some test methods have been developed in order to verify the capability of drills to release abrasion dust during sowing, mainly based on wind tunnel tests with reference powdery tracer capable to emulate the behavior of abrasion dust (Rautmann et al., 2009; Manzone et al., 2014). The introduction of a standardized method would be useful to establish a classification of the machines and to evaluate their conformity according to harmonized rules (Rautmann et al., 2009). Such a certification method recognized as international standard does not exist.

We have developed a methodology based on static tests in order to obtain reproducible test conditions and results comparability. It is based on the sowing simulation of maize dressed seed under artificial wind conditions.

The method was used for assessing the efficiency of drift reduction devices applied to the seeder in comparison with the emissions of the conventional machine (i.e., the same drill without deflectors) (Apenet, 2011; Biocca et al., 2011). This paper provides evidences of the correspondence between amount of predicted drift at ground level during static tests and the measured residues during field trials.

2. Material and methods

2.1 Seed

The trials were carried out using commercial maize seed (Pioneer Hybreed PR32G44) dressed with four insecticides (Gaucho™, a.i.: imidacloprid; Poncho™, a.i.: clothianidin; Cruiser™, a.i.: thiamethoxam, Regent™, a.i.: fipronil) and a fungicide (Celest™, a.i.: fludioxonil and metalaxyl). According to the standard Heubach test test method (Esa Stat, 2011) seeds showed good dressing quality.

2.2 Drills

A six-rows precision pneumatic drill “Gaspardo Magica” was employed, with and without air deflectors applied at the fan opening. The deflectors are designed to reduce the dust drift by redirecting the air expelled by the drill’s fan towards the soil.

2.3 Test system at fixed point

The static tests were carried out in the workshop’s porch of CRA-ING, in order to obtain a site protected by external influences and enough large to contain the machines, as described in Biocca et al. (2011).

In the site, we isolated a 22.5 m long sampling area, downwind with respect to the drill position, similarly to a wind gallery. The average wind speed in the sampling site was 1.8 m•s^{-1} at 2.0 m from the soil (min 1.6, max 2.5 m s^{-1}). Along the sampling area, five series of Petri dishes (filled with a 50% acetonitrile-water solution), spaced 4.5 m, were placed; each series consisted of three Petri dishes spaced 1.5 m; therefore a grid of 15 sampling points was arranged (Fig. 1).

Each trial was replicated three times for each investigated a.i.

The drill was set in the test site, lifted from the ground, in order to simulate the sowing of 75,000 seed ha^{-1}. It was operated by two electric engines: the first determined the rotation of distribution system wheel, at a speed of 6 km h^{-1}; the second engine operated the drill's fan to produce a negative pressure of -45 mbar.

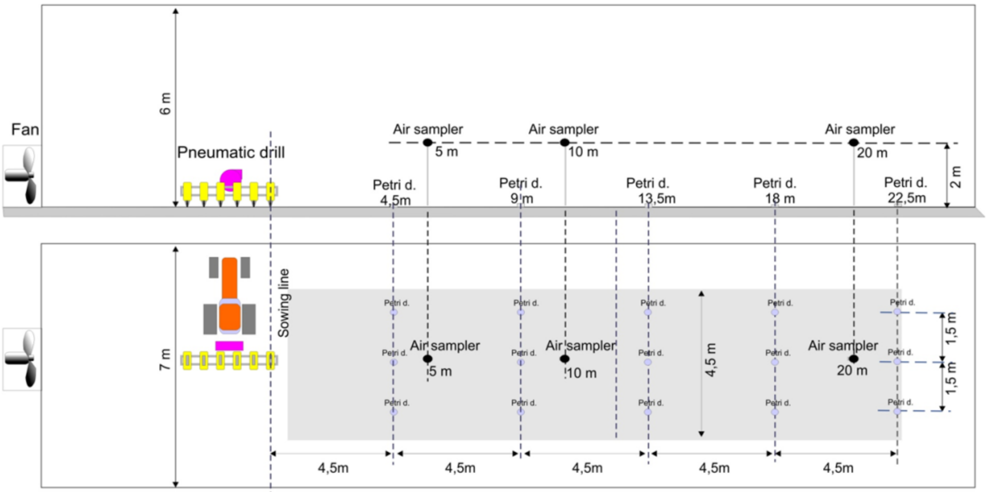

Fig. 1. Layout of the sampling area in the static tests.

2.4 Field tests

In the field trials, the drill was set like in the static tests, to sow the same quantity of seeds (75,000 seed ha^{-1}). During the trials, the main micrometeorological parameters were monitored. The tests were carried out sowing plots of about 3 ha. Petri dishes (like static tests) were employed to sample drifted dust at ground level. To collect the dust at ground level independently from the wind direction changes, a series of samplers were placed each side of the plot (North, South, East and West). Therefore, on each side, three Petri dishes spaced 1.5 m were placed at 5, 10 and 20 m from the field edge; hence a total of 36 sampling points were obtained.
The field trials were replicated one time for each investigated a.i.

2.5 Active ingredients analyses

Active substances were extracted from the samples with acetonitrile. Solutions were vibrated in an ultrasonic bath for 10 min, then filtered with HPLC 0.45 µm filters. The analytical determinations were carried out by means of HPLC - ESI - MS – MS and the relative methods were validated in compliance with GLP procedures.

2.6 Data processing for the assessment of the theoretical concentration in field

The obtained values of a.i. concentrations at ground level during the trials at fixed point were analyzed in order to provide the theoretical a.i. concentration behavior that would occur in field, as described in Biocca et al. (2011). The analysis of the contents of the Petri dishes provided the amount of a.i. in each plate (µg•plate^{-1}). Multiplying this value by 105.23 (virtual number of Petri dishes•m^{-2}) provided the a.i. concentration per surface unit in µg m^{-2}. Considering the virtual forward speed (1.67 m•s^{-1}), the number of employed seed (25,000) and the drill's working swath (4.5 m) we obtain that each static test corresponded to a sowed (virtual) area of 3,333. m^2, equivalent to a plot 740.7 m long and 4.5 m width.

The ratio between the above mentioned distance of 740.74 m and the 4.5 m width of the sampling area (1.5 m x 3), provides the theoretical number of passages, i.e. 164.6, of the drill along the sampling area.

As a consequence, the a.i. concentration after a single passage can be calculated dividing the concentration observed after the test by the number of passages (164.6). This method provides the behavior of the concentration (µg•m^{-2}) after one passage, at the five sampling distances (4.5, 9.0, 13.5, 18.0, 22.5 m).

Under field conditions, the drill distance from the initial sowing line (assumed as zero) and from the Petri dishes of a hypothetic sampling area would increase of 4.5 m (working width) after each passage. For n passages of the drill, the theoretical concentrations that would occur in field can be calculated by means of a matrix obtained repeating the calculated series of values n times, taking care of displacing the series of one place (distance) after each passage.

According to this, since the sampling distances (that are multiple of the working width) are five, the maximum number of passages usable to generate the matrix would be five. In order to have an undefined number of passages, a regression was calculated on the series of five values of concentration as a function of the distance, for both conventional and modified drill. The process provided exponential equations that have been used to calculate the concentration for distances higher than 22.5 m from the initial sowing line. The resulting matrix provided the global theoretical concentrations at ground level (µg•m^{-2}) at distances ranging from 4.5 m to 45 m from the initial sowing line.

The obtained values were then compared with the measured field data and the statistical analyses were computed with the software R (R Core Team, 2013).

3. Results and discussion

As already reported in Biocca et al. (2011) the drill equipped with air deflectors showed a generalized reduction of dust drift.

Fig. 2 shows the pattern of dust drift (at ground level) in fixed point tests after the previously described data processing. The curves show the amount of predicted dust drift from 4.5 m to 49.5 m from the drill, taking in account of 10 drill theoretical passages. These curves were utilized to obtain the values at 5, 10 and 20 m (distances that did not coincide with the sampling distances adopted in static tests) in order to compare them with the measured values in the field. Then, linear regressions between field (measured) and indoor (predicted) values were computed.

In general, static tests data slightly underestimate the measured field data for the three neonicotinoids (absolute average differences: 2.00 µg•m^{-2} for clothianidin; 3.27 µg•m^{-2} for imidacloprid; 0.32 µg•m^{-2} for thiamethoxam). We noted that the result for imidacloprid is largely affected by the single field data at 5 m during the field tests. As for fipronil, we obtained an opposite result (i.e. overestimation of data) with an average of 1.85 µg•m^{-2} more in static tests than in field.

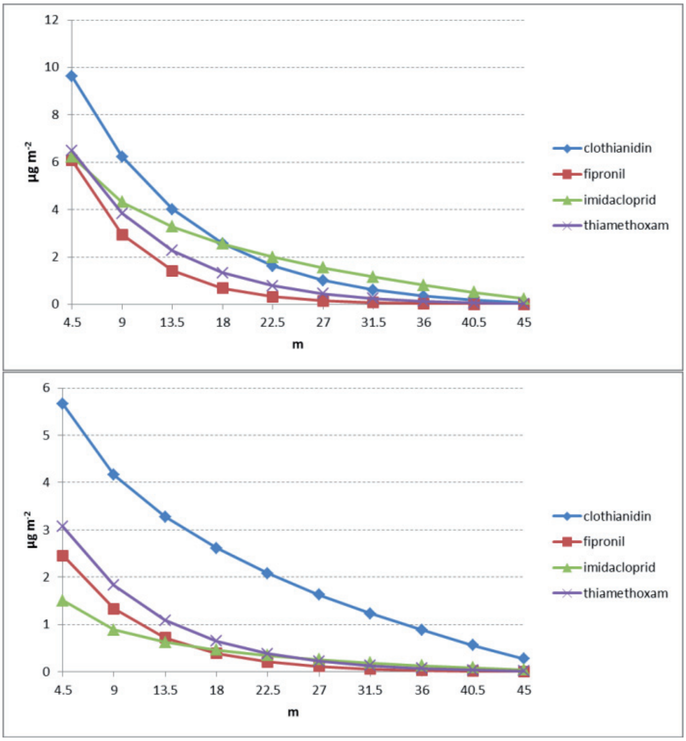

Fig. 2. Calculated pattern of dust drift (up: conventional drill; down: drill with deflectors).

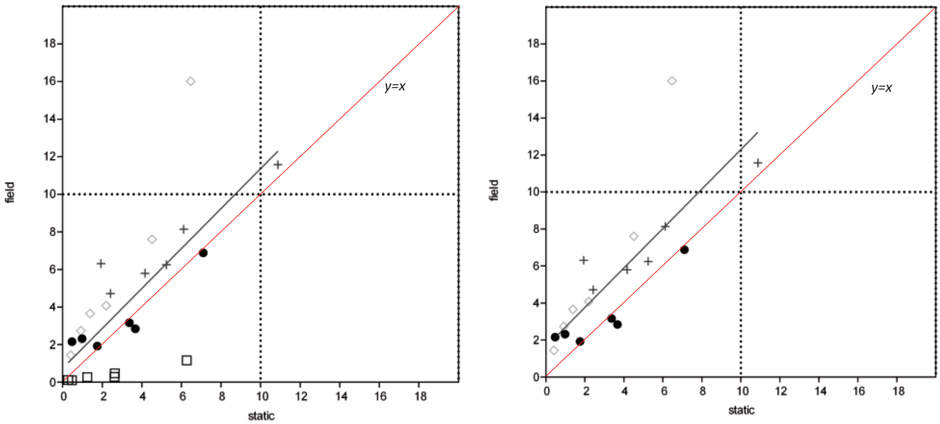

Fig. 3. Linear regression between static and field ground residues. Left, all insecticides: y=1.0632x+0.7346. Adjusted R2: 0.5043 p value=6.097 ×10-5. Right, only the three neonicotinoids (y=1.0666x + 1.6315; Adjusted R2: 0.6063 p-value: 8.529 × 10-5). + = clothianidin; □ = fipronil; ◊ = imidacloprid; ● = thiamethoxam. Red lines shows identity: x=y.

The regressions were performed between field and static data for all a.i. (n = 48) and considering only the three neonicotinoids (n = 36). The results of regressions are showed in Fig. 3, where are reported the adjusted R^2 values, the formula of linear regressions and the result of probability tests (p value). Field and static (indoor) data are significantly linearly correlated (p value = 6.097 x 10^{-5}) with a multiple R^2 of 0.53. The relationship increases by excluding from the regression the a.i. fipronil and considering only the three neonicotinoids. In this case R^2 is equal to 0.63 (with a p value of 8.529 x 10^{-5}).

The described method, based on tests at fixed point with side wind artificially provided, seems reproducible and accurate. It allows to design a standardized test system useful for evaluating the performances of drills in terms of dust drift.

Nevertheless, other points have to be developed in order to employ the proposed method as a standard method. For example, it exists the evidenced necessity of simplifying the analytical phase and of reducing the risk of exposure. This point could be achieved by using seed dressed with a non-toxic and easily-detectable tracer. An essential point is that the seed should be dressed similarly to commercial seed, in order to have results referable to normal operating conditions. The results should be reported in terms of concentrations, both at ground and in the air.

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