# DUST DRIFT MITIGATING DEVICES APPLIED ON PRECISION PNEUMATIC SEED DRILLS: A MINI-REVIEW
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# *DISPOSITIVI PER LA MITIGAZIONE DELLA DERIVA DELLE POLVERI APPLICATI ALLE SEMINATRICI PNEUMATICHE: UNA MINI REVIEW.*

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## ABSTRACT

*The treatment of seed (seed dressing) is an effective way to control pests and diseases in the early stages of plant life. However, during sowing operations, emission of abraded pesticide-containing dust particles can occur, causing contamination of air, water and other natural resources, including honeybees and other pollinating insects. Among several factors involved in dust drift, a central role is played by the seeder machines. This review article presents an overview of various aspects linked to the phenomenon of dust emission and drift from pesticide seed dressing during sowing and its consequences. The review focuses on the dust drift mitigating devices applied on precision pneumatic drills, highlighting the contribution of agricultural engineering studies on this specific topic.*

## RIASSUNTO

*Il trattamento delle sementi (concia del seme) è un modo efficace per controllare i parassiti e le malattie nelle prime fasi della vita della pianta. Tuttavia, durante le operazioni di semina, possono verificarsi emissioni di particelle di polvere contenenti pesticidi, che causano la contaminazione di aria, acqua e delle risorse naturali, comprese le api e altri insetti impollinatori. Tra i vari fattori coinvolti nella deriva delle polveri, un ruolo centrale viene svolto dalle macchine seminatrici. Questa review presenta una panoramica di vari aspetti legati al fenomeno della deriva di polveri di abrasione derivante dall'impiego di semi conciati e delle sue conseguenze. L'articolo si concentra sui dispositivi di mitigazione della deriva di polveri applicati a seminatrici pneumatiche di precisione, evidenziando il contributo degli studi dell'ingegneria agraria su questo specifico argomento.*

## INTRODUCTION

The seed dressing (or coating) is a common technique to protect seeds in the early stages of plant growth against pests and diseases. The seed treatments show the advantage to deliver the active ingredient (a.i.) directly on the target, the seed, and the phenomenon of a.i. transportation from the treated area to the surrounding environment is greatly reduced. A disadvantage of the technique is that a certain amount of pesticides can be dispersed by means of the abrasion dust produced during storage, manipulation and sowing of dressed seeds.

The seed treatment consists of the application of one or more a.i. and coformulates and typically, a dressed seed appears covered by a thin film of coated product, made by adhesive and colorant products.
Many seed crops are usually treated; they include maize, rapeseed, wheat, sunflower and many others cereal and horticultural crops *(Jeschke et al., 2011; Hauer et al., 2017).* In particular, maize is a major crop across European Union (EU) with more than 8 million cultivated hectares of which about 30% in Romania in 2017 *(FAO, 2019).* The efficiency of seed treatment has been largely investigated and studies report successful cases of control by means of seed treatment along with other cases of ineffectiveness *(Furlan et al., 2006).*

Neonicotinoids (that include imidacloprid, acetamiprid, nitenpyram, thiamethoxam, thiacloprid, clothianidin and dinotefuran) have been extensively employed for seed treatments. They are systemic insecticides, effective against a broad range of pests *(Elbert et al., 2008)*. In particular, the three neonicotinoids: imidacloprid, clothianidin, thiamethoxam and the fipronil (belonging to the phenylpyrazole chemical family) employed for maize seed dressing have been largely investigated about their potential toxicity to honeybees and other pollinating insects *(Goulson D., 2013; Gill et al., 2012; Krupke and Long, 2015; Giorio et al., 2017; Wood and Goulson, 2017).*

During sowing, the quantity of dispersed dust is relatively small.

The amount of residues of insecticides clothianidin and imidacloprid were detected in the adjacent non crop areas. After drilling of maize (using a pneumatic precision seed drill) in adjacent non crop areas in 1-5 m distance between 0.02 and 0.40 g a.i. ha$^{-1}$ of neonicotinoids and in the adjacent oil seed rape a total of 0.05–0.80 g a.i. ha$^{-1}$ were detected. After drilling oil seed rape or barley these values were only 0.02–0.06 g a.i. ha$^{-1}$ in non-crop areas and 0.03-0.08 g a.i. ha$^{-1}$ in total in adjacent white mustard. In samplers installed vertically at 3 m distance in non-crop areas up to seven times higher values were detected compared to ground residues (*Heimbach et al., 2014*).

Other Authors (*Xue et al., 2015*) found that neonicotinoid (clothianidin and thiamethoxam) exhaust emission rates were 0.0036 and 0.1104 g ha$^{-1}$ (two different experiments), captured on horizontal traps and 0.0029 g ha$^{-1}$ sampled on vertical traps. *Biocca et al. (2015b*) estimating amounts per hectare of a.i. at soil level based on the depositions observed at 4.5 m, obtained similar figures: 0.1859 for clothianidin, 0.0189 for fipronil, 0.0378 for imidacloprid and 0.0842 g ha$^{-1}$ for thiamethoxam.

*Devarrewaere et al. (2016; 2018)* proposed a model based on computational fluid dynamics and estimated a total dust emission rate around 5 g ha$^{-1}$, corresponding to 1.5 g ha$^{-1}$ of a.i. deposition. *Schnier et al. (2003)* obtained higher estimations (around 3 and 4 g of imidacloprid per hectare), but applications with adjuvants diminished abrasions by more than 50%. *Tapparo et al. (2012)* reported an emission factor ranging from 0.43 to 1.53 g ha$^{-1}$ for clothianidin, 0.74 g ha$^{-1}$ for thiamethoxam and 0.46 g ha$^{-1}$ for fipronil. After a series of field experiments, *Schaafsma et al. (2018)* recovered up to 2.4 g ha$^{-1}$ of clothianidin from planter exhaust.

The seed dressing with such active ingredients (a.i.), may lead to exposure of honeybees (*Apis mellifera* L.) and other pollinating insects during sowing, due to losses of dust containing a.i. escaping from the outflow air fan of the pneumatic sowing machines. There are multiple routes for insect exposure *(Krupke et al., 2012; Samson-Robert et al., 2014)* leading to both direct poisoning *(Pistorius et al., 2009)* and sub-lethal effects *(Bortolotti et al., 2003; Colin et al., 2004; Bonmatin et al., 2005).* The direct exposure during flight *(Marzaro et al., 2011; Pochi et al., 2012a)* is enhanced by the honeybee's anatomy, characterized by thick hairs on the body, that work as an electrostatic trap for airborne particulates *(Prier et al, 2001; Tremolada et al., 2010).*

In response to the studies, the European Commission recommended a restriction of their use across the European Union, and on April 2013 a law stated the ban of imidacloprid, clothianidin and thiamethoxam (and fipronil) for seed treatment *(European Union, 2013; EFSA Panel on Plant Protection Products and their Residues (PPR), 2012).*

The entity of dust drift phenomenon is related to the seed dressing quality, to the employed machinery, to the meteorological conditions and to the physicochemical characteristics of the abrasion dust *(Nuyttens et al., 2015).* Hereafter, some of these arguments will be reviewed, highlighting the role of drill precision seeders and the contribution of dust drift mitigating devices in the reduction of dust drift.

## DUST PARTICLES CHARACTERIZATION

Regarding the quantitative assessment, the Heubach test *(JKI, 2008; ESA STAT Dust Working group, 2011)* is the most employed method to evaluate the aptitude of a dressed seed to produce dust *(Zwertvaegher et al., 2016).* The allowed maximum quantity of dust in the commercial seed is generally indicated as 3 g (100 kg)$^{-1}$ of seed.

An Heubach dustmeter consists in a rotating drum where treated seeds are mechanically stressed. A continuous air flow running through the dustmeter transports the abraded dust particles out of the rotating drum and through a connected glass tube and an attached filter unit, that retains the floating particles. The coarse powder coming from the Heubach test represents the fraction of dust not retained by the measuring tube of the apparatus. However, also this fraction is expelled by the seed drill during sowing, contaminating the machinery itself and the surrounding areas. Authors have suggested taking all drift-sensitive particles into account, in order to estimate the total drifted dust *(Biocca et al., 2011; Foqué et al., 2017a).* To assess the abrasion potential of seeds alternative methods were proposed such as mechanical sieving and individual sowing element on which cyclones filters are mounted *(Foqué et al., 2017a).*

Apart from the quantity, a detailed characterization of dust from dressed seed in terms of particle size distribution, texture and shape, density, surface and aero-dynamical characteristics appears as essential to perform a good risk analysis *(Foqué et al., 2017b).*

The size affects particles' lifetime and persistence in the atmosphere. Coarse particles are mostly responsible for punctual pollution, as fine particles drift can travel hundreds of kilometres, investing large areas, with unknown effects on the environment and on the human beings. Moreover, particle size is related to a.i. content *(Foqué et al., 2017c)* and the finest size fraction (< 1µm) contains a higher content of a.i. (*Biocca et al., 2017*).

As for particles characterization, different techniques are employed. They include light microscopy analysis *(Pochi et al., 2015),* X-ray microtomography *(Devarrewaere et al., 2015),* multistage impactor and laser spectrometry *(Biocca et al., 2017),* sonic sieving *(Foqué et al., 2014a).*

## THE SEEDERS

The role of seeders is a key factor in the phenomenon of honeybee's toxicity by abrasion dust from dressed seed. The machines can be distinguished according to their method of seed placement *(Foqué et al., 2014b).* Broadcast seeding, based on centrifugal distribution, is mainly used for cover crops. Bulk drills, principally used for cereals and grasses, place the seed in furrows with a given distance between two adjacent rows but the seeder puts the seeds without a fixed distance in the row. Since bulk drills are often used to sow crops when honeybees are not active, they were considered to be less dangerous for honeybees. Then, it is believed that bulk drills cause less problems regarding dust drift because no air is used (mechanical seeders) or the air is released close to the ground (pneumatic seeders). For these reasons, bulk drills have rarely been considered in relation to dust drift although the emission of coating material remains a serious problem *(Biocca et al., 2015a)*. *Foqué et al. (2014a)* indicated that the dust drift risk from seeds sown with bulk drills could be just as big, or even bigger than sowing done with pneumatic drills, also because winter crop seeds, such as wheat and pea, show a higher potential abrasion than maize *(Foqué et al., 2017b).*

In precision seeding, the seeds are planted in rows and the spacing of seeds within the rows is uniform in and between the rows. Precision seed planters can be divided into three main categories based on the seed singulation mechanism: vacuum, mechanical and overpressure *(Nuyttens et al., 2013).* The most common models for maize sowing are vacuum based seeder. In these types of machinery, a negative pressure is created by a centrifugal fan actuated by the power of the tractor and connected to each element sower by a pipe. The seed drills have a specific distributor system made of a vertical disk (with suitable holes) placed on the bottom of each seed hoppers. During the rotation of the distributor disk, the vacuum holds only one seed per hole. The seeds remain applied in correspondence of each hole of the disk for the duration of the suction effect in the stages of supply and distribution, and subsequently fall, through an inlet pipe, in the open furrow in the soil. This causes a vertical drop of the seed by gravity, without any inertia due to the rotation of the disk and therefore no rebounds *(Fanigliulo and Pochi, 2011).*

The pneumatic drills contribute 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 seed drill to obtain the vacuum effect *(Nikolakis et al., 2009; Marzaro et al., 2011; Biocca et al., 2011).* The airstream outlet is generally placed directly on the fan and the different models of seed drills can have the outlet directed upwards, lateral or downwards, which results in different potential dispersion of abraded dust *(Manzone et al., 2014).*

Another factor to be considered for reducing the dispersal of dust in pneumatic seed drills is the maintenance of the seed drill *(Pochi et al., 2012b).* In fact, there are different points through which the dust can be expelled, and these parts should be checked periodically to maintain the machine efficiency. A possible list of such controls should include: 1) the status of the seeder's pipes; 2) the status of the gasket sealing the connection between the flange supporting the deflector pipes and the outlet opening of the vacuum fan; 3) the functionality of the pressure gauge (correct depression value helps to limit dust dispersion).

Additionally, it is also possible to reduce drift by reducing the fan revolutionary velocity and, as consequence, air flow rate and air velocity generated by the fan *(Balsari et al., 2013).*

## DRIFT REDUCING DEVICES

Manufacturers and researchers have proposed some devices to decrease dust drift emissions generated by the pneumatic drills. The deflector system consists of a steel frame, applied at the fan opening, from which the air is directed close to the soil or into the furrows opened by the sowing units, by means of flexible plastic pipes (2 or 4). Generally, deflectors are an aftermarket solution applicable to different seed drill models and they can be easily mounted and dismounted on the seeder. The reduction of dust drift is due both to the position of air exit and to the reduction of the air speed by ejecting the air via several pipes instead of one single outlet. The “dual pipe deflector” by Syngenta splits the air coming from the drill’s fan in two secondary pipes which convey the air stream close to the soil, between the central seeding elements (Fig. 1).

**Fig. 1 - The deflectors proposed by Syngenta (dual pipe system)**

According to *Manzone et al. (2017)* who tested the device using a tracer to simulate particles of seed dressing, these deflectors reduced the dust drift by up to 69% in comparison with the conventional machine set-up.

Another deflector system consists in a four pipes system (Fig. 2). According to *Nikolakis et al. (2009)* the deflectors can reduce the ground deposition of dust by more than 90%.

**Fig. 2 - The deflectors mounted by the drill manufacturer Gaspardo**

Similar results were reported by *Herbst et al. (2010),* who proposed a testing system based on the use of a tracer to replace the dressing of seeds to certificate the drills in terms of their drift reduction performance. The modified drills that achieve a drift reduction of 90% against standard machines with high drift, are included in an official list of “drift reducing maize sowing machines”. During indoor tests carried out employing a tracer instead of chemical dressing, *Manzone et al. (2014)* showed that the use of devices enabling the conveyance of the air towards the soil reduced the drift by more than 70% if only the area between 5 and 20 m downwind of the machine is considered. These findings were in line with previous studies from the same group *(Balsari et al., 2010).*

Other Authors studied the efficacy of deflectors both in static tests (with the machinery at fixed point) and in the field, with different a.i. employed for seed treatment *(Biocca et al., 2015c).* It was found that, in average, the use of deflectors resulted in a reduction in the dust emissions by around 50%., with a maximum of 72.8% of reduction when tested at fixed point with imidacloprid treated maize seed, to a minimum of 14.6% when tested in small field plots with imidacloprid dressed seeds *(Biocca et al., 2015b; Apenet, 2011; Biocca et al., 2011; Pochi et al., 2011).*

With this level of drift, it is likely that direct poisoning of honeybees should be excluded but still remains the possibility of the occurrence of sub-lethal effects on honeybees and on other pollinating insects *(Girolami et al., 2012; Tapparo et al., 2012; Pochi et al., 2012a)*. In conclusion, *Sgolastra et al. (2012)* stated that “the a.i. concentration dispersed at the edge and over the field from the pneumatic seeder equipped with deflector, used as mitigation action, cannot be considered sufficiently safe for bees and further tests are required”.

It is also reported that, mainly during dry periods, many farmers prefer to work without deflectors because of their high generation of soil dust, resulting in a low visibility of the drilling operations and contamination of the machinery *(Nuyttens et al., 2013).* Besides, the rising of soil that occurs during sowing in fields with a history of seed treatment use, can be an additional source of contamination risk *(Schaafsma et al., 2015; Limay-Rios et al., 2016; Schaafsma et al., 2016).*

Other systems are based on different principles: *Pessina and Facchinetti (2010)* suggested using water filter to filter the exhaust air and then using the loaded water as a pesticide in the soil.

Similarly, the Bayer AirWasher® system is based on the use of sprayed water to reduce the dust drift *(Vrbka et al., 2014)*. It can be used as an upgrade to any deflector kit since the system is equipped with a water tank, a pump and a nozzle that sprays water into the exhaust.

Bayer has also developed a system (SweepAir® system) *(Chapple et al., 2014; Vrbka et al., 2014)* based on a cyclone filter. Exhausted air from the pneumatic drill's fan is conveyed through a “primary pipe” that connects the fan outlet to the cyclone inlet (Fig. 3). The separated dust is conveyed downwards in the cyclone and then deposited into the soil. The tests, carried out using tracer materials to simulate the seed dressing dust, showed that the cyclone system effectively separated 99.4% of the inert material *(Manzone et al., 2015).*

**Fig. 3 - The cyclone based system proposed by Bayer (sweep air system)**

Another system based on mounting small cyclones between the fan and each individual seed drill head was proposed by *Foqué et al., (2017a)* (Fig. 4) who found that the efficacy in dust recovery of the small pre-fan cyclone was determined to be 84% for sugar beet seeds, 99% for maize and 100% for pea.

The system was then mounted on a drill and it showed a reduction of 99% of dust residues collected at ground level and of 90% to 92% when the drift was assessed in the air, depending on the sampling method (active or passive samplers) *(Foqué et al., 2018).*

**Fig. 4 - The small cyclone mounted before the seed heads proposed by ILVO**

*Manzone and Tamagnone (2016)* inserted a filter used to purify the air intake of endothermic engines before the air fan outlet obtaining the total filtration of the tracer (Tartrazine) added to the seeds to simulate the abraded dust. The same Authors conveyed the exhaust air coming from the seed drill’s fan into the fertilizer hoses, to obtain a dust drift reduction of 68%, about 20% lower than dual pipe deflectors (tested during the same experiment) *(Manzone and Tamagnone, 2018)*.

The filtering-recirculating system by CREA is a device that works as an “impactor”, decreasing the air speed and favouring the dust deposition inside the pneumatic circuit; finally, a filter retains particles before the final air expulsion (Fig. 5 and 6).

**Fig. 5 - Modified drill with the recycling-filtering device proposed by CREA.**

*1) hoppers' tight lids replacing the normal lids; 2) collector of pipes coming from the seed drill’s fan; 3) main collector pipe; 4) recycling pipes from each hopper to main collector; 5) box containing the anti-pollen filter with activated carbon filter; 6) electrostatic filter and filtered air outlet*

The device is applicable to pneumatic drills, and capable of achieving a significant reduction in abrasion dust emissions *(Pochi et al., 2013).* A first version of the device (based on air recirculation followed by filtration with an anti-pollen single filter) was tested at a fixed point *(Biocca et al., 2015b)* on seed dressed with imidacloprid, and it obtained a reduction of 98% in total dust and of 97% in a.i. by comparison with the unmodified seed drill *(Pochi et al., 2015a).* The last version of the prototype device (filtration with a two-stage filter, ie. anti-pollen filter followed by an electrostatic filter) was tested in the field using seed dressed with thiacloprid, showed a percentage reduction of around 100% if measured around the sowed field *(Pochi et al., 2015b).* Apart from testing the prototypes in realistic operating conditions, the field test also showed that the seed drill's performance was not affected using the tested prototype.

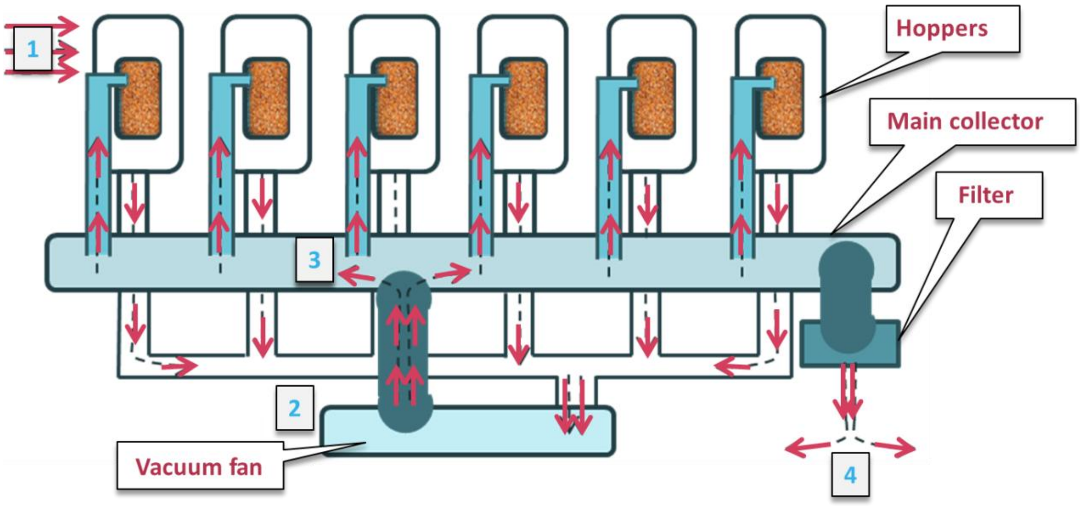

**Fig. 6 - Scheme of the CREA-IT prototype**

*1) Air enters via seed distributors; 2) Fan pushes the air into the main collector; 3) Air is recirculating inside the hoppers; 4) Air excess exits via filter's box (two-stage filter).*

## CONCLUSIONS

Seeders remain a major factor in the phenomenon of dust drift of particles coming from dressed seeds. During the sowing operations, amounts of dust containing active ingredients are transported with the air generated by the fan of pneumatic seed drills or can be released by gravity from mechanical drills. The event was dramatically evident when dust containing neonicotinoid insecticides and fipronil contaminated pollinating insects, such as honeybees, which are very sensitive to this class of pesticides. Different authors have showed that small quantities of dust can cause direct mortality or sub-lethal effects on honeybees. For this reason, efforts were made to find solutions to mitigate the dust drift. One of the most important ways to achieve an efficient strategy of drift mitigation has been the development of innovative mechanical devices to decrease or avoid losses of dust from the seed drills.

Machinery modifications are based on different principles. The deflectors just favour that the air flow coming from the fan of vacuum-based pneumatic drills is directed towards the soil, avoiding a direct release in the atmosphere. Other proposed systems include filtering of air flow, realized both with water and with different type of filters (cyclones, filters derived from automotive sector, electrostatic filters or a combination of them). Recycling the air flow produced from the seed drill's fan into parts of the drills is another method adopted. However, each system presents pros and cons. For example, the methods based on the use of filters need an appropriate procedure to dispose the exhausted filter, since they contain chemical toxic residues. In the same time, deflectors or other systems that allow to a certain fraction of dust to be released in the environment can be insufficient to avoid honeybee exposure.

The percentage reduction of the dust drift caused by the different systems was variable, ranging from a minimum of 14.6% employing the deflector to values around 100% of reduction with systems that are based on filtering with cyclone filter or filtering-recirculating systems. However, the comparison of the different devices is complicated by the different test method employed.

The reviewed literature did not report the costs of these devices, since they are generally described at a stage of developing prototypes. Nevertheless, it can be stated that their costs are affordable, since the device costs represent a little part of the cost of the machinery on which they are mounted.

Moreover, it is important to consider as implicit costs also the aptitude of these devices to be easily mounted and dismounted on the seeder. For this purpose, the deflectors (that are the most common devices employed) seem to be the devices most suitable for a rapid application to the seeders.

In conclusion, all these studies have showed the central role of agricultural engineering science in contributing to effective drift reducing measures. However, researches are still highly demanded to better clarify the complex issue of dust drift.

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