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FILTRATION SYSTEM PERFORMANCE CLEANING EXHAUST AIR OF PNEUMATIC MAIZE SEED DRILLS

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Abstract

BACKGROUND: In the agricultural sector, toxic substances can be released into the atmosphere. In recent years, Europe has encountered a significant environmental issue related to the dispersion of pesticides during maize seeding, especially when performed with pneumatic seed drills. This phenomenon can be very dangerous for insects, as the dispersed dust contains pesticides (insecticides, fungicides, etc.) used to dress maize seeds. On the basis of these considerations, experimental tests have been carried out using a filtration system to clean the airflow that exits from the fan of pneumatic maize seed drills.

RESULTS: The tested filtration system does not interfere with the seeding quality because the vacuum level observed within filtration system assembled on the seeder (5.7 kPa) is 27% higher than the correct vacuum level to guarantee good seeding quality (4.2 kPa). In addition, it enables the reduction of the risk of environmental contamination as no dust deposits were found at different distances from the machine.

CONCLUSION: The use of a filtration system shows advantages in term of environmental and operator safety because dangerous materials are contained in the filter case, thus avoiding contamination of neighbouring areas and the machinery used (tractor and seed drill).

Keywords: Filtration system, pneumatic seeders, maize seeds, drift dust

1. Introduction

Air pollution harms human health and the environment. Recently, many studies have focused on the amount of emissions of toxic substances produced by vehicles[1-5] or on air polluting emissions in urban areas; [6-9] meanwhile, very little research has been done in the agricultural sector.

Toxic substances can also be released into the atmosphere as a result of agricultural processes, especially those linked to fuel consumption in cultivation activities[10-12] and the use of pesticides in crop protection.[13-15] The main factors affecting the emission of pesticides can be summarised as follows: the types of machine used in pesticide applications, the physiochemical properties of the chemical product applied, the material in which the pesticide is carried, and environmental conditions.[16-17]

In recent years, Italy has encountered an increase in significant environmental problems related to the dispersion of pesticides during maize seeding, especially if this is performed with pneumatic seed drills.[18] In fact, this kind of sowing machine produces a fine dust due to abrasions on the chemical coating of maize seeds.[19] ~~Seeds are usually dressed with pesticides to~~ avoid ~~them~~ seed and seedling ~~being~~ damage from insect and diseases by using ~~and to prevent diseases in their growth stage by using~~ small doses of chemical product.[20-21] The air stream generated by the fan of the pneumatic seeders, which is used to create a depression in the sowing element of the machine, is responsible for blowing away solid particles detached from the seeds.[22] This phenomenon can be ~~very~~ dangerous to beneficial ~~for~~ insects, as the dust created can contain several of the pesticides (insecticides) that are used to dress the maize seeds.[23-24]

Until now, many studies have been carried out to evaluate the performance of different types of seed drills and specific devices used to reduce dust dispersion.[25-26] These devices are not able to clean the airflow exiting from the fan or to use this exiting airflow for other applications (for example fertiliser distribution). These devices, in fact, only direct the air towards the soil[27-29] or do not allow the choking air outlet to be reused.[30]

In addition to solving its environmental impact, cleaning the air emitted from a sowing machine's fan would also solve the problem of machine contamination, which is an especially serious problem when the machine operator has to fill the seed hoppers or perform maintenance. One solution could be to use a car air filter to trap any abraded dust dispersed during sowing. In fact, some years ago Schnier et al.[22] used a commercial car filter to collect the chemical dust leaving a seeder's fan in order to examine the composition of the dust.

On the basis of these considerations, experimental tests have been carried out using a filtration system that cleans the airflow exiting from the fan of a pneumatic maize seed drill. The results ~~obtained~~ from this test are described in this study.

2. Materials and methods

The filtration system tested is a filter used to purify the air intake of endothermic engines according to Schnier et al.[22] These types of filter are especially suitable for this purpose because they are ~~more~~ very efficient at capturing soil particles and toxic substances until particles with 1 µm in diameter.[31] Specifically, this car air filter is usually mounted on machines that work in the agriculture sector as this type of filter has a higher capacity for trapping dust particles compared with a car filter.[32] Tests were carried out using a commercial six-row vacuum seed drill (Monosem® NG plus). The sowing machine was calibrated with a distance of 0.75 m between the rows and to drill 75,000 seeds per hectare (Table 1). The seeder was tested in its standard configuration and in a modified version where the air exiting the fan was conveyed into the filtration system (Fig. 1).

In order to use an appropriately sized filter for the test, one was designed for an endothermic engine due to the engine's theoretical intake air at maximum rotation speed being equal to the airflow rate of the sowing machine during drilling. The airflow rate of the seeder was measured following the methods used by Balsari et al. (2013). Specifically, airflow rate was measured as it passed through a pipe with a diameter of 110 mm where a propeller anemometer (Allemano Testo 400) with an accuracy of 0.1 m s^{-1} had been placed. Tests were carried out at Power Take Off

(PTO) revolution speeds of 450 min^{-1} (as recommended by the seeder manufacturer) with the presence of seeds in the seeding elements. Successively, this value was compared with the theoretical amount of air intake of agricultural endothermic engines. In the present work, the theoretical air intake of the endothermic engine (A) was calculated with the following simplified formula:

$$A = (Rs \times D) / (2^{*} \times 60 \times 10^{6})$$

where:

A = air flow rate (m^3s^{-1})

Rs = maximum rotation speed of the engine (revolutions per minute)

D = total engine displacement (cm^3)

(*) = half of the strokes (times) engine number

The measured airflow rate of the seeder (0.058 m^3s^{-1}) gave results similar to the theoretical air intake of a 3,500 cm^3 engine with a rated speed of 2,200 rpm (0.064 m^3s^{-1}). For this reason, the filter used in the trials was a dry air filter that is usually used for agricultural engines of the same displacement (Cermag 12330) (Table 2).

~~For an easier filter dimensioning, it could be possible to~~ For filter dimension determination, one can consider the flow rate of each sowing element that equipped the seed drill as similar to the theoretical airflow intake rate of an agricultural engine with a total displacement of about 600 cm^3.

2.1. Seeder performance

Tests were performed in order to assess the influence of the filter's presence on the seeder's performance. Since a sowing quality is guaranteed with a vacuum level of 4.2 kPa in the seeding element,[33] this parameter was measured with and without the filter placed on the fan exit of the seed drills, following Balsari et al.[28] The vacuum level in the seeding element was measured through a water manometer placed in the connection hose between the seeding element and the fan. The water manometer was made of two vertical tubes that had an inner diameter of 16 mm and a height of 2 m. The height difference of the two water levels was determined using a ruler with an accuracy of 1 mm.

All measurements were carried out at the PTO revolution speed recommended by the manufacturer (450 min^{-1}).

2.2. Filtration system efficiency

Filtration system efficiency was performed using the specific methodology set up by Manzone et al.,[27] where the deposit of potential dust in the exit vent of the seeder's fan was measured at different distances downwind of the seed drills. The method required a "tunnel" (5 m wide, 3 m high, and 50 m long) where at one side an axial fan was placed. The air stream generated by the fan was used to invest the seeder positioned in the middle of the tunnel. Dust deposits were then collected on samples placed on the ground at different downwind distances from the sowing machine. In order to guarantee a uniform air stream in all the tunnel areas close to the tested seed drill, this latter was placed roughly 20 metres from the axial fan outlet. Downwind from the seeder's position, arrays of 5 collectors (Petri dishes, 138 mm in diameter) spaced a metre apart, were placed on the ground at a distance of 1, 3, 5, 15, and 20 metres.

The seed drill was placed in a static position with the seeding element insert into the soil. The potential abraded dust from the coated seeds was simulated using ~~an inert material~~ <u>the yellow food dye Tartrazine E102</u>.[27] The use of an inert material was preferred to dressed maize seeds in order to eliminate the variability in the amount of dust abraded from the coated seeds and to improve reproducible test conditions. Moreover, Tartrazine E102 was not require specific operator safety precautions.

The Tartrazine E102 was introduced into the fan air inlet at a rate of 3 g/min^{-1} for 10 minutes, with the fan activated using a volumetric dry feeder (BHT® BD20). The amount of tracer deposited on each Petri dish was determined in laboratory by spectrophotometry analysis. The Petri dishes were washed with 50 ml of deionised water and the washings were analysed with a spectrophotometer (Biochrom Lybra S11) ~~set up with a wavelength of~~ at 434 nm, corresponding to the absorption peak of the dye. Absorbance values read on the instrument were used to calculate the amount of Tartrazine E102 present in the Petri dishes. The limit of detection (LOD) of this methodology was considered to be 0.25 μg per Petri dish. This limit is related to the accuracy of the our measuring system (minimum amount of water for washing the Petri dishes coupled with the resolution of the spectrophotometer). Samples with a lower value were considered clean.

As the vacuum level directly correlates to the airflow rate, tests were carried out when the filtration system was both clean and dirty. The filter was considered dirty when there was a vacuum level of only 4.2 kPa in the seeding elements (the minimum vacuum level needed to guarantee effective maize sowing). The filter was "dirtied" by introducing soil dust collected by same filter during a previous sowing operation on dry sandy soil with non-coated seeds in the fan air inlet at a rate of 3 g/min^{-1} until the vacuum level dropped to 4.2 kPa.

2.3. Field test

The filtration system was also tested in the field, in real working conditions, in order to evaluate sowing time before the vacuum level dropped due to the filter becoming clogged. The vacuum level inside the seeding element (as in the previous test) and the amount of dust collected by the filter were evaluated at regular surface intervals during the seeding. The determinations were made every hectare until the vacuum level dropped to 4.2 kPa. The amount of dust collected by the filter was determined by weighing the filter using a certified digital scale (accurate to 0.05 g) before, during, and after the tests. The weight difference was considered as dust collected during the trials was. The vacuum level was determined using the same method described in Section 2.1.

The sowing operation was performed using non-coated seed and a forward speed of 1.8 ms^{-1}. Tests were carried out on two different plots of land located in north-west Italy (close to Turin).

Each plot had an extension of 30 hectares and was on flat land. The first plot was situated on sandy soil and the second plot was situated on clay soil. The plots were only 1 km away from one another and for this reason ~~showed~~ had the ~~same~~ similar environmental conditions. In order to establish the filter performances in the presence of different amounts of soil dust, the trials were carried out with dry soil (water content of 4–8% in the sandy soil and 10–15% in the clay soil) and moist soil (water content of 14–18% in the sandy soil and 30–35% in the clay soil). The soil water content was measured using the gravimetric method by collecting 10 soil samples in representative zones of the areas using for the test. Each sample was collected with a steel cylinder (50-mm diameter and 50-mm height) from the upper layer (maximum depth of 100 mm) of the soil. This depth is the maximum working depth of the seed drill used.

Tests were carried out on different days but in the ~~same~~ similar environmental conditions, i.e. the absence of wind (< 0.1 ms^{-1}), air humidity of 65–75%, and an air temperature of 15–20°C. These environmental conditions are commonly present during maize sowing in southern Europe.

Each ~~thesis has been~~ experiment was replicated 3 times on the same plot. All the collected data were processed with Microsoft Excel and analysed with the SSPS 21 (2014) advanced statistics software. The statistical significance of the eventual differences between the treatments was tested with the Ryan-Einot-Gabriel-Welsch (REGW) test, as it has a higher statistical power for this data distribution.

3. Results

3.1. Seeder performance

In general, the tested filtration system influenced the performance of the seed drill in that it caused a significant reduction (0.4 kPa) to the vacuum level inside the seeding elements. In fact, the measured vacuum level value (recorded at the PTO revolution speed of 450 min^{-1}) was of 6.1 and 5.7 kPa, respectively, with and without the filter mounted in the fan outlet. Nevertheless, 5.7 kPa is approximately 30% more than the optimal value (4.2 kPa) suggested for good quality maize seeding,[33] and therefore the filtration system tested does not influence the machine's sowing quality (Fig. 2).

3.2. Filtration system efficiency

The seeder in its standard configuration, with the fan outlet oriented upwards, highlighted a tracer deposit value that increased with distance from the machine for up to 15 m. Deposit values can be considerable until 4.3% of applied (value registered at a distance of 15 metres), while at a distance of 20 metres the values were lower but still higher than 3.1% of applied. Higher deposit values were obtained at a distance of 10 to 15 m from the drill contour, as the output of the air was oriented upwards.

Using the tested filtration system, it was possible to avoid the drift effect. No deposits were found in the Petri dishes at the different distances from the machine with the spectrophotometry analysis (Fig. 3).

3.3. Field test

In the field test, data processing highlights that, in clay soil, the filter can collect up to 46.9 g/ha^{-1} of dust; values 20% lower can be obtained in sandy soil. In moist soil, all values are lower than those obtained in dry soil: 17.5 g ha^{-1} for clay soil and 19.2 g ha^{-1} for sandy soil. Furthermore, statistical analysis showed no significant operating difference between moist clay and sandy soil (Table 3).

A decreasing vacuum level inside the seeding elements due to dust collection by the filter was observed by sowing a different surface in function of soil types and soil water contents. In the test conditions, a vacuum level of 4.2 kPa (the minimum vacuum level needed to guarantee good maize seeding quality) was recorded after a seeded surface of 48 ha in moist clay soil and 30 ha in moist sandy soil. These values were lower (up to 23% in sandy soil) in dry soil (Table 4).

Moreover, data processing highlighted a linear reduction of vacuum level during sowing progress with a good correlation level ($R^2 > 0.95$) between all treatments (Fig. 4).

4. Discussion

In contrast to other devices set up to mitigate dust dispersion from seed drills, the tested filtration system reduced the vacuum level inside the seeding element.[28] However, this modification does not interfere with the seeding quality because the vacuum level observed with the filtration system assembled on the seeder (5.7 kPa) is 27% higher than the correct vacuum level needed to guarantee good seeding quality (4.2 kPa).[33]

In this experiment, contrary to the results of other studies carried out with deflectors to air conveying,[27,34-35] no detectable Tartrazine E102 deposits were found at the different distances downwind from the seeder. Moreover, these results are better than those published by Vrbka et al.[30] using specific devices (AirWasher® and SweepAir®) for cleaning the air exiting a seeder's fan, where 2% of the applied pesticide was always found deposited downwind. This situation could be caused by different materials used in the trials, because in this study a tracer (Tartrazine E102) was used, while the trials carried out by Vrbka et al.[30] used coated seeds. Furthermore, considering the results observed in this work and similar particles size of tracer used and coated seed dust, it is possible to assert that by using the tested filtration system it is possible to completely remove the risk of dust emissions from seeders, and consequently the contamination of neighbouring areas, when seeds coated with pesticides are used. This finding is ~~very~~ important because in other agricultural sectors where pesticides are used, researchers are working ~~properly~~ on ~~the~~ drift mitigation effect to reduce buffer zones.[36]

Another advantage of using the filtration system, in comparison to others device set up for drift dust mitigation, is the possibility of fixing the device at any point on the seeder's frame, because it can be connected to the fan outlet by a flexible pipe and its position does not interfere with its efficiency.[37] In fact, after correct sizing the filter performed on the amount of airflow rate exiting the seeder's fan, it can be used on different types of pneumatic sowing machines.

In the field, the filtration system does not present any operational problems and provides significant operation time before it requires cleaning. In the worst conditions (dry sandy soil), the filter must be cleaned after 23 hectares, which, considering a seed drill equipped with 6 sowing elements (working at a width of 4.5 metres) and an average forward speed of 6 km/h^{-1}, is equal to about 4 hours. This ordinary maintenance, which requires a small amount of time (10 minutes), does not interfere with work productivity.[38-39] In addition, filter maintenance is well known by all farmers because they perform it on all farm tractors periodically.[40] Operators must wear suitable protective clothing during filter maintenance operations and the waste from the filter must be disposed of properly.

Pesticide deposition on the machine's frame is a big problem for workers and the amount of this can change depending on the function of the machine's design.[41] The adoption of the filter, aside from preventing the release of toxic substances (fungicide, insecticides, etc.) in the atmosphere, ~~always~~ keeps the sowing machine clean from pesticides by eliminating ~~the presence of~~ these potentially toxic substances on the frame. These working conditions are very important, as they make it possible to carry out usual operations (installing the seeder and refilling the seed and fertiliser hoppers) and maintenance (routine and special maintenance) without coming into contact with these dangerous substances can also contaminate the tractor.[42] Furthermore, it must also be highlighted that during pesticide distribution, toxic substances are released into the atmosphere by the wind drift effect, which can invest also the tractor.[43] With the filter applied to the pneumatic seed drills to clean the exhaust air, the tractor is also kept clean This aspect should not be underestimated, as in many situations the tractor can be used with other equipment and other operators. ~~This possibility could be dangerous:~~ If the operator of the machinery does not know that there may be toxic substances on the tractor, they will not take the necessary precautions.[41,44]

Having a clean air stream available his ~~also appreciable for its possible use in~~ other possible applications, e.g. facilitating the sliding of fertiliser granules within different pipes.[45] In recent years the use of pneumatic seed drills equipped with pneumatic fertilizer is very common because it allows two operations to be carried out with a single passage.[46]

The use of the tested filtration system compared with other devices that clean the exhaust air of seed drills has revealed another advantage. When the filteris clogged the seeder does not sow – if there is no air stream, there is no vacuum in the seeding element – but toxic substances are not released into the atmosphere .[37,47] In this regard, it is advisable that operators equip their machines with a vacuum gauge, in order to monitor the vacuum level and be able to clean the filter before it interrupts sowing operations.

It is essential that the fan and all pipes are hermetically sealed so as not to disperse material before it reaches the filter, and it is important to remember that the filter can contain potentially dangerous substances.

5. Conclusions

The experiment conducted showed that it is possible to reduce the dispersion of harmful substances during the sowing of dressed maize seeds with the use of an industrial air filter. Furthermore, the efficiency of the filtration system obtained in this work was higher than the efficiency in devices that cleaned the air exiting from the drill's fan which have been developed and tested in other studies. This situation is ~~very~~ advantageous in terms of environmental and operator safety. Dangerous materials are contained in the filter case, avoiding contamination of neighbouring areas and the machinery used (tractor and seed drill). However, the dust collected in the filter, even though it is largely composed of inert material (soil), must be disposed of in accordance with the rules in force, because it is contaminated by the pesticides that the seeds were treated with.

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Figures

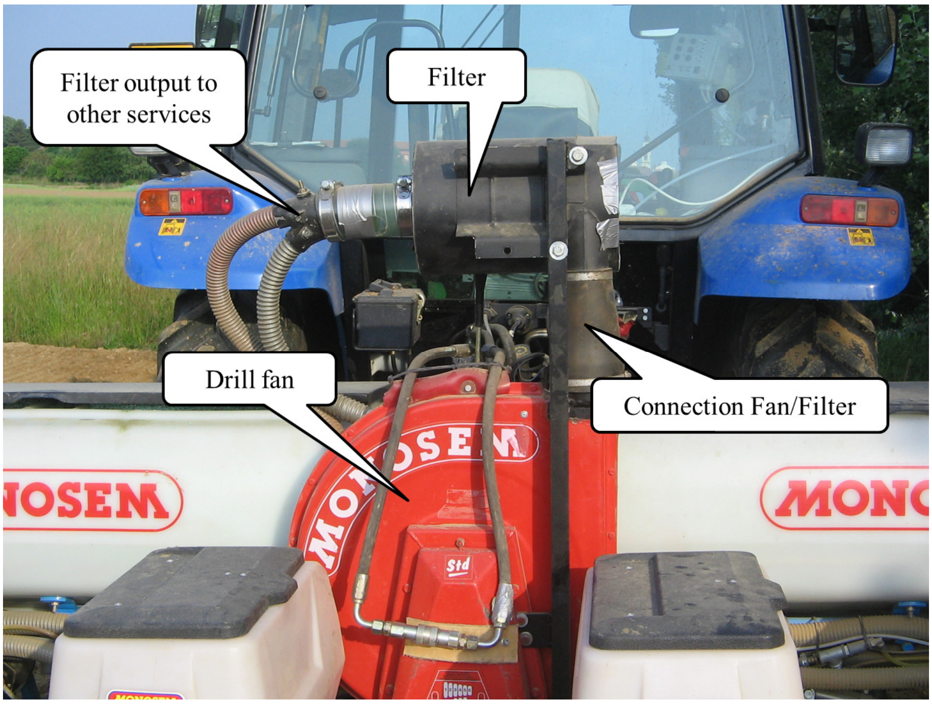
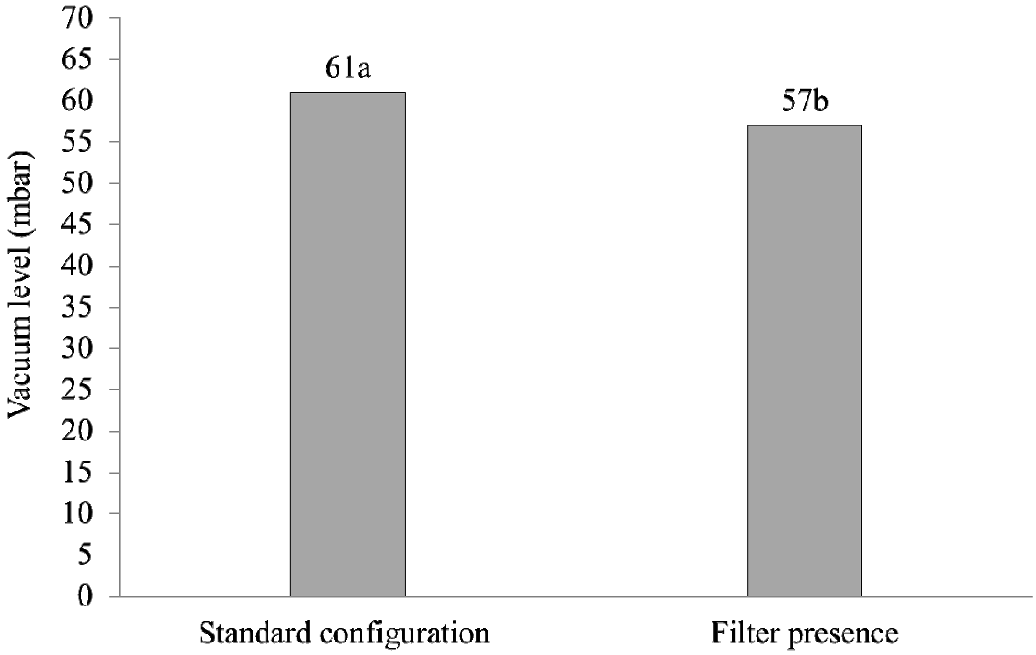
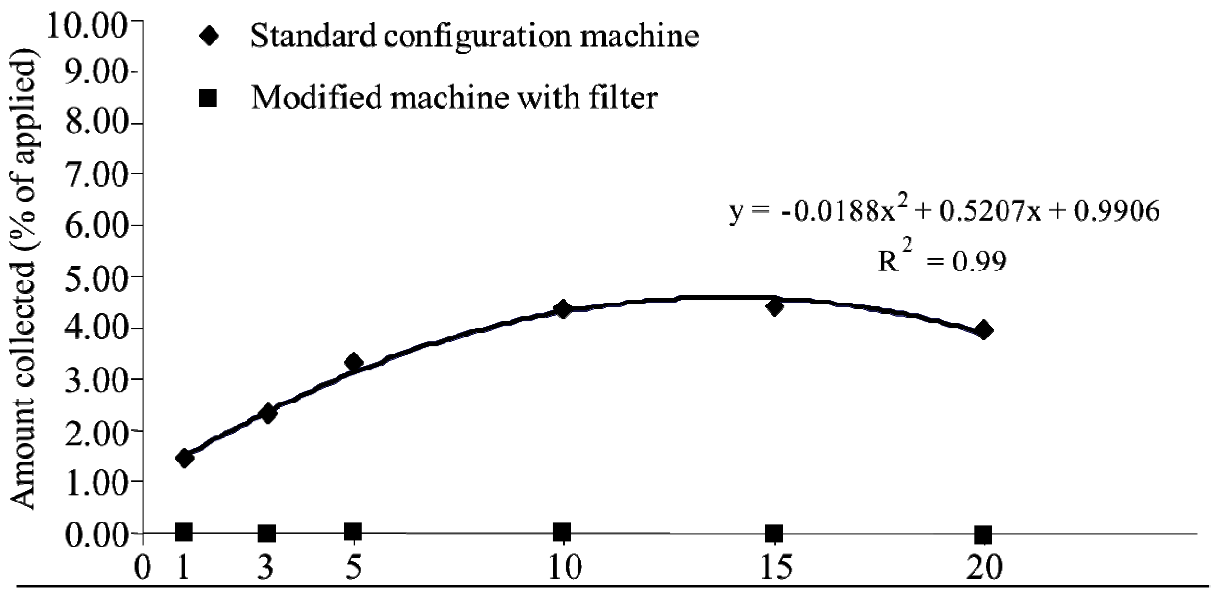


Fig. 1. Filtration system installed for purifying the exhaust air from the drill's fan.



Note: Different letters indicate significant differences between treatments for $\alpha = 0.05$

Fig. 2. Vacuum level measured inside the seeding element with the machine in standard configuration and equipped with the filter.



Distance (m)	*1*	*3*	*5*	*10*	*15*	*20*
Standard (SD)	0.03	0.02	0.08	0.06	0.09	0.08
Filter (SD)	0.00	0.00	0.00	0.00	0.00	0.00

Notes: SD = Standard Deviation

Fig. 3. Tartarzine E102 deposited up to 20 metres from the drill in its standard configuration and modified with the filtration system.

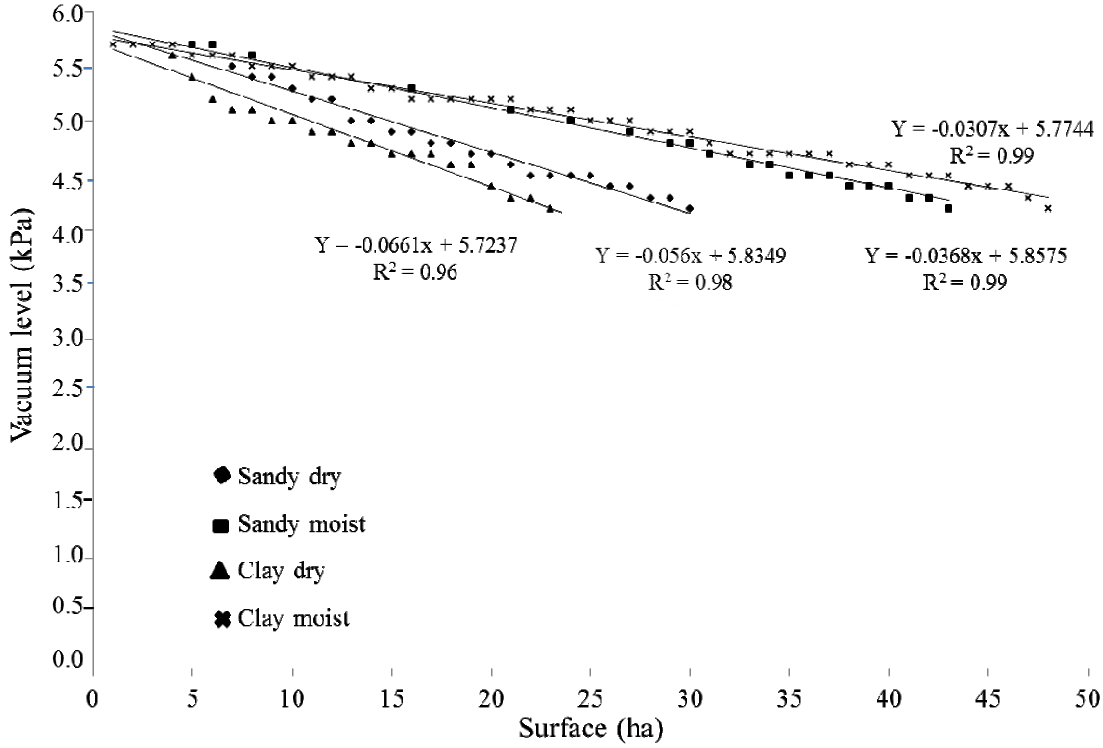


Fig. 4. Seeded surface versus vacuum level (until drop to 4.2 kPa) relative to soil features.

Tables

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

Manufacturer	Monosem® NG plus
Seeding elements (#)	6
Row distances (mm)	700
Fan diameter (mm)	420
Fan width (mm)	80
Blades (#)	8
Blade inclination (°)	0
Blade width (mm)	45
Air outlet size (mm)	135 x 80
Outlet air direction	Upwards
Fan rotation speed (rev min^{-1})	4,500
Air velocity (m/s^{-1})	4.4
Airflow rate (m^3/h^{-1})	210

Table 2. Technical characteristics of the filter used in the test.

Filter case	Cermag 12330
Filter element	Cermag 10810
Length (mm)	300
Diameter (mm)	166
Inlet pipe diameter (mm)	63
Outlet pipe diameter (mm)	58

Table 3. Amount of dust collected in the filter in different soils type.

Soil		Dust (g/ha^{-1})		
Type	Water content	Mean	SD	IQR
Clay	Dry	46.9a	2.7	48.3
	Moist	17.5c	1.1	18.1
Sandy	Dry	35.0b	1.9	35.6
	Moist	19.2c	1.7	20.1

Notes: SD = Standard deviation; IQR = interquartile range; Different letters indicate significant differences between treatments for $\alpha = 0.05$

Table 4. Seeded surface to obtain a vacuum level of 4.2 kPa.

Soil		Surface (ha)		
Type	Water content	Mean	SD	IQR
Clay	Dry	43b	1.5	44
	Moist	48a	1.0	49
Sandy	Dry	23d	0.6	24
	Moist	30c	0.6	31

Notes: SD = Standard deviation; IQR = interquartile range; Different letters indicate significant differences between treatments for $\alpha = 0.05$