Evaluation of seed dressing dust dispersion from maize sowing machines

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Abstract

The present study analysed the constructive and operative parameters of pneumatic seeders and researched and assessed possible technical solutions for limiting the unwanted dispersion of dust from seed dressing during sowing of maize seeds. Tests were made on several maize pneumatic seeder models. The air flow rates and the air velocities at the fan outlet were assessed, the sizes of the areas contaminated with the material from the maize seeds was evaluated and the air velocities along the contour of the sowing machines were measured. Results showed that by decreasing the fan air flow rate by 30% it was possible to consistently reduce the size of the area contaminated by seed dressing dust while maintaining a good quality of seeding. They also showed that the technical solutions proposed by the seeder manufacturers reduced the environmental contamination with the pesticide-containing dust by more than 90%.

Key words: Sowing machine, maize seed, neonicotinoids, bee.

1. Introduction

In the last few years several honey bee poisoning incidents have been reported that were related to sowing maize seeds treated with neonicotinoid insecticides using pneumatic seeders (Altmann, 2003; Greatti et al., 2003; Schnier et al., 2003; Greatti et al., 2006; Baldessari et al., 2008, Girolami et al, 2009). The air stream generated by the fan of the seeders in order to create the necessary depression in the sowing element of the machine, in fact, is considered responsible for blowing the solid dust particles detached from the seeds towards the areas adjacent to the seeded field. Actually, the use of maize seed dressed with neonicotinoids is currently banned in Italy, while it is allowed, with some limitations, in other European countries (Table 1).

This paper reports experimental tests to study the constructive and operative parameters of maize pneumatic seeders and to assess technical solutions enabling to limit the seed dressing material dispersion from these machines.

2. Materials and Methods

Preliminary tests were conducted in order to assess the main seeder parameters influencing the dispersion of dust material. In detail, for each sowing machine tested, the following measurements were made: 1) fan air flow rate, 2) depression in the seeding elements and 3) air velocity along the contour of the seeders. These parameters were determined either according to the machine setup suggested by the seeder manufacturer or in operative conditions enabling guaranteeing a high quality seeding with a reduced environmental impact.

Tests were made using three pneumatic seeders (A – B – C), representative of the Italian context (Table 2). Each machine was tested either in its standard configuration or in modified configurations with the purpose of limiting dust dispersion. The seeding was done at a distance

of 0.75 m between the maize rows and at a (seeding) rate of 75,000 seeds per hectare. Seeder A was tested in its standard configuration and in a modified one where the air was conveyed between the wheels of each seeding element. In particular, in the standard configuration, the seeder had an “air deflector” on the fan outlet to deflect the air towards the soil.
Seeder B was tested, in addition to in its standard configuration, in two further configurations aimed at reducing dust dispersion: one had four 100 mm diameter air hoses conveying the air towards the soil, the second had one 55 mm diameter air hose for each seeding element, conveying the air close to the share of the seeding furrow. Seeder C was tested in its standard configuration and in a modified one where the fan air outlet was conveyed toward the soil by two hoses of 125 mm diameter.

2.1. Fan air flow rate

The fan air flow rate was measured both at the fan outlet and at the fan inlet using a 110 mm diameter conveyor 1 m long where a propeller anemometer (Allemano Testo 400) with 0.1 m s^{-1} accuracy was positioned. Tests were made with and without seeds present in the hopper.
Measurements were carried out at the PTO revolutionary speeds recommended by the manufacturers (540 rev min^{-1} for seeder A, 540 rev min^{-1} for seeder B, 450 rev min^{-1} for seeder C).

2.2. Depression in the seeding element

The depression 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 from two vertical tubes of 16 mm internal diameter and 2 m height. The difference in the height of the two different water levels was determined using a ruler with 1 mm accuracy.

Measurements were carried out at five different PTO revolutionary speeds (300, 350, 400, 450, 500 and 540 rev min^{-1}) and using only the pneumatic seeder B with one to six seeding elements.

2.3. Air velocity along the contour

The measurements were done with the seeders in a static position and placed indoors, using the propeller anemometer (Allemano Testo 400) described above mounted on a rigid support and making measurements at different heights from the ground. For machines A and B the air velocity was measured at heights of 0.05, 0.50 and 1.00 m in steps of 0.30 m along the machine contour. For seeder C, which had an upwards – directed air outlet (therefore with a different air flow rate profile), the air velocity measurements were made out following a grid of measurement points at distances ranging from 0 to 3 m from the machine and at heights from 0 to 3 m from the ground. Intervals between measuring points within the grid were 0.25 m (Fig. 1).
In all tests, for each measuring point, the anemometer was oriented to detect the maximum air velocity with respect to the air stream. Tests were conducted employing the sowing machines with and without seeds in the hoppers, using the fan rotational speed recommended by the manufacturer and using 4 or 6 seeding elements. Each trial was carried out with environmental conditions of 20-25°C air temperature and 65-70% relative humidity.

2.4. Footprint of the dust material

In order to measure the footprint of the dust material dispersed from the seeders, tests were carried out in the laboratory simulating the seeding operation with the machine in a static position and using an experimental powder instead of the insecticide seed dressing material. The powder used in the tests was selected after analysing the particle sizes of the dust material expelled from the air outlets of the seeders when using dressed maize seeds (KWS® and

Pioneer®). To collect this dust material a "cyclone vacuum cleaner" (characterized by vacuum air flow rate of 260 $m^3 h^{-1}$ and 97% efficiency separation) was used and the particles size analysis was made through an image analysis system (Image Pro Plus®).

In order to select the inert material for simulating the dress maize powder, tests were made using wheat flour "00" (a cheap and widely available material) and considering the Volumetric Median Diameter (VMD) value.

For each material (maize seed dressing and wheat flour "00"), the diameters of the granules were determined using the specific software Image Pro Plus® on five samples of at least 2000 particles obtained from 50 images acquired by a Epix Sv 5 C10 5 Mpixel camera with a 1.4 µm $pixel^{-1}$ resolution equipped with a Nikon® AF Micro Nikkor 60 mm lens.

Statistical analysis (ANOVA) showed that the wheat flour "00" had physical characteristics very similar to the maize seed dressing material and therefore it was used to assess the dust dispersion from the sowing machines (Table 3).

Wheat flour powder was then manually introduced in the fan inlet, through a branch of the pipe that connected the fan to the seeding element, at a rate of 35 g in 10 minutes. The amount of powder introduced in the fan inlet was weighed using a balance (Kern, abs 220-4) with 0.1 mg accuracy. The material dispersed on the ground around the machine, collected on Petri dishes (138 mm diameter) positioned at intervals of 100 mm under and around the seeders up to a distance of 4 meters from the machine, was determined by weight. Based on the deposits detected on the Petri dishes, the area of the dust footprint was calculated and expressed in m^2. A powder rate of 35 g per 10 min was used because this was the minimum quantity that enabled detection of deposits on Petri dishes using a balance (Kern, abs 220-4) with 0.1 mg accuracy.

All tests were made using A, B and C sowing machines either in their standard configuration or mounting the devices to convey the air towards the soil and keeping a depression of 42 mbar in the seeding elements, a value that according to G. Bragatto (pers. comm.) is considered optimal for correct maize seeding. For each test, five replicates were made and dust footprint areas were statistically analysed with Ryan-Einot-Gabriel-Welsch test with an α coefficient of 0.05.

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3. Results and discussion

3.1. Fan air flow rate

For each seeder tested, the air flow rate did not differ when measured at the fan inlet or at the fan outlet (Table 4).

Tests made without the maize seeds in the seeding hopper showed higher air flow rates for the C and the B machines (75 and 80 m^3 h^{-1} per seeding element, respectively). The presence of the seeds in the hopper decreased the outlet air flow rate by about 55% (Fig. 2).

3.2. Depression in the seeding element

The depression value, measured in the seeding element, recorded at the PTO revolutionary speeds recommended by the manufacturers (ranging from 450 to 540 rev min^{-1} depending on seeder model), was between 60 and 67 mbar, about 30% more than the optimal value (42 mbar) suggested for a good quality of maize seeding (Bragatto, pers. comm.) (Fig. 3). Optimal depression values were generally obtained when the PTO revolutionary speed was set between 350 and 400 rev min^{-1}. The depression value in the seeding element that resulted was influenced by the fan rotational speed but was independent of the number of seeding elements mounted on the machine (Fig. 4).

3.3. Air velocity around the sowing machine

Air velocity measured along the contour of the machine differed according to the position and the shape of the fan outlet. Tests carried out on sowing machine A in the standard configuration and equipped with six seeding elements showed that the air stream generated by the fan was biased towards the soil on the right side of the machine (Fig. 5). The air velocities measured at the right edge of the machine were about 1.0 m s^{-1} up to 0.05 m height from the ground. At heights over 0.05 m from the ground, the air velocities recorded did not exceed 0.5 m s^{-1} (Fig. 5). B sowing machine, that had its fan outlet oriented downwards, generated an air stream oriented towards the soil on the left side of the machine, with a velocity, measured in correspondence of the left edge of the machine, of 2.2 m s^{-1} when the seeder was equipped with four seeding elements and of 1.3 m s^{-1} when it was equipped with six elements. It was observed that, even if the air outlet was oriented towards the right side of the machine, the highest air velocities were, however, measured on the opposite side due to the reflection effect caused by the machine frame (Fig. 6).

Seeder C, which had six seeding elements and had the fan outlet oriented upwards, produced an air stream oriented towards the right side of the machine. In this case, air velocities higher than 0.5 m s^{-1} were recorded even at a distance of 3 m from the machine edge (Fig. 7).
Independent of the sowing machine model, when the devices provided by the different manufacturers to convey the air close to the soil were mounted, the resultant air stream always kept within the machine contour. The solution proposed by the manufacturer of seeder A, which conveyed the air in the chamber between the wheels of each seeding element, contained the air stream within the chamber itself (Fig. 5, 6 and 7)

3.4. Footprint of the dust material

Tests carried out using the B sowing machine showed that the dust blown out by the fan deposited on a surface of about 6 m^2 and that most of it (90%) was within the machine footprint when equipped with six seeding elements (Fig. 8). When the A and C seeders were employed, the dust footprint that resulted was larger and most of the material was collected on the left side of the machine (Fig. 9 and 10). By adopting the devices to convey the air towards the soil, the area of the dust footprint was considerably reduced (by more than 90%) with respect to the standard configuration and it was always within the machine footprint (Table 5).

In conclusion, the use of devices conveying the air generated by the fan of pneumatic seeders towards the soil reduced the air stream profile by 80% and therefore the size of the ground area contaminated with dust.

Moreover, test results showed that, for all types and configurations of seeders it is also possible to reduce the environmental contamination due to maize seed dressings just by lowering the fan revolutionary speeds on pneumatic seeders. For example, experiments revealed that decreasing by about 1000 rev min^{-1} this parameter (that corresponds to a decrease of about 100 rev min^{-1} of the PTO), resulting air flow rate and air velocity generated by the fan were reduced by about 30% and this significantly limited the surface contaminated by the seed dressing material, guaranteeing at the same time the necessary depression in the seeding elements.

In order to assess other constructive and operative parameters and other solutions proposed by maize seeders manufacturers, further tests will be carried out at DEIAFA .

6 References

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Acknowledgement

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Figure captions

Fig. 1 - Measuring points of the air velocity around the C seeders

Fig. 2 - Fan outlet air flow rate measured on the seeders with and without the maize seeds in the hopper of the seeding element.

Fig. 3 - Depression inside the seeding element measured in the tested seeders

Fig. 4. - Depression measured inside the seeding element as a function of the number of seeding elements present on the machine and of the PTO revolution speed.

Fig. 5 – Characteristics of the air stream generated by the fan of A seeders (front view of the machine)

Fig. 6 - Characteristics of the air stream generated by the fan of B seeders (front view of the machine)

Fig. 7 - Characteristics of the air stream generated by the fan of C seeders (front view of the machine)

Fig. 8 - Dust deposits on the ground measured using the B sowing machine.

Fig. 9 - Dust deposits on the ground measured using the A sowing machine.

Fig. 10 - Dust deposits on the ground measured using the C sowing machine

Figures

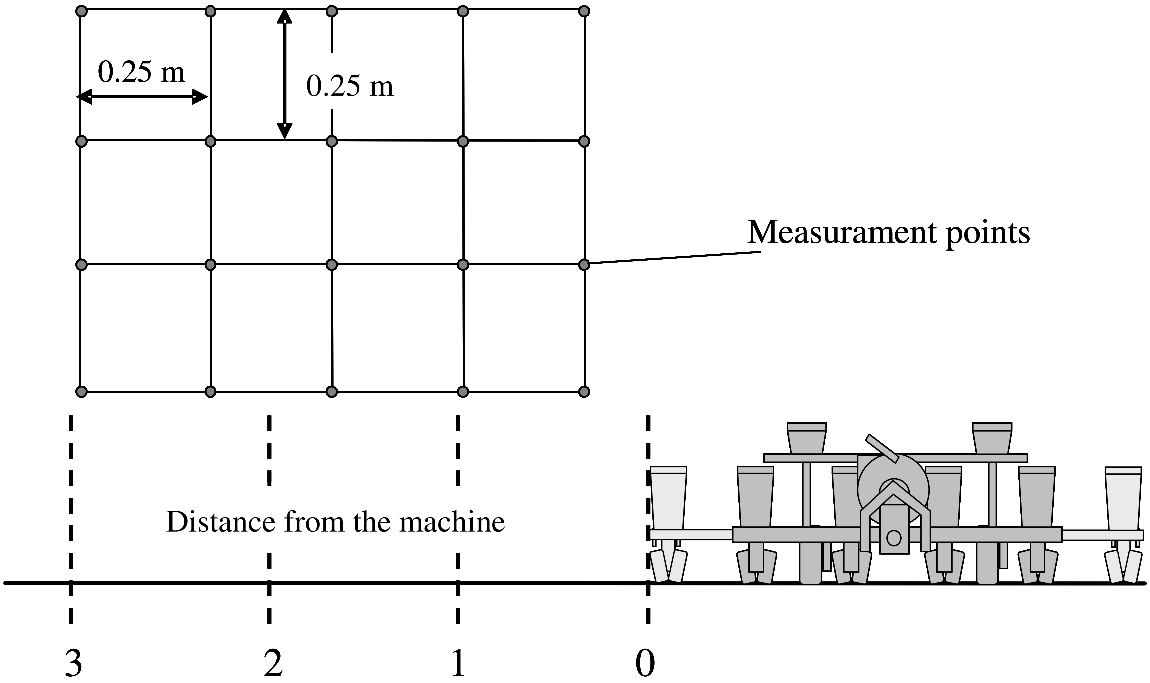
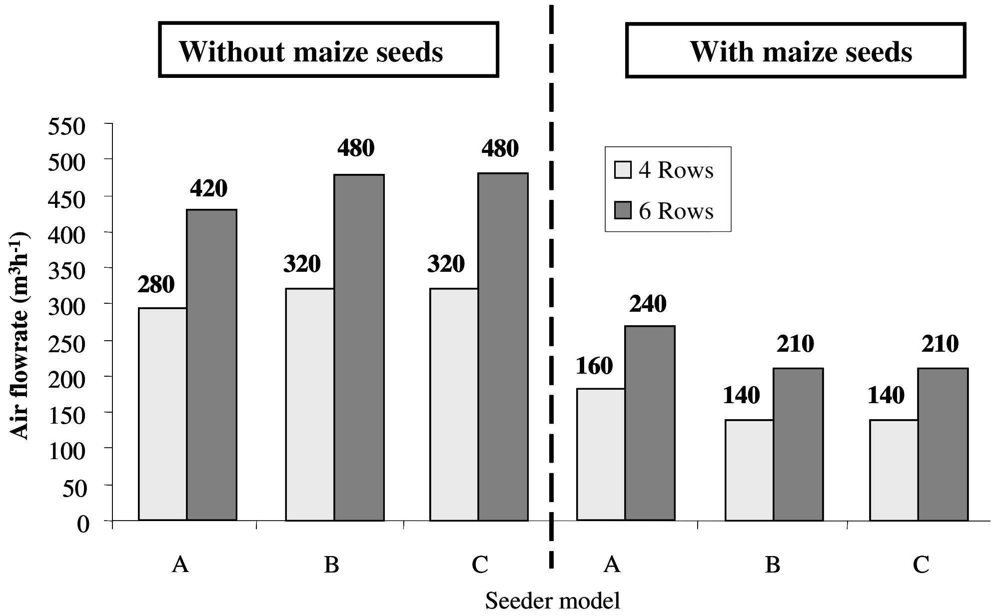
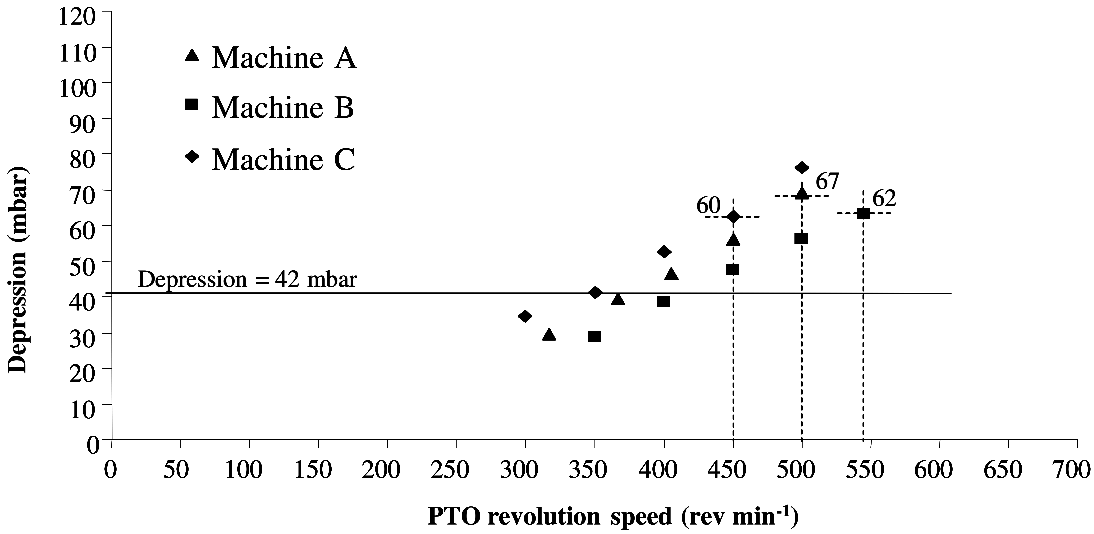


Figure 1



Without maize seeds
With maize seeds
Air flowrate (m3h-1)
550
500
450
400
350
300
250
200
150
100
50
0
4 Rows
6 Rows
280
420
320
480
320
480
160
240
140
210
140
210
A
B
C
A
B
C
Seeder model

Figure 2



Machine A
Machine B
Machine C
Depression = 42 mbar
60
67
62
Depression (mbar)
PTO revolution speed (rev min-1)

Figure 3

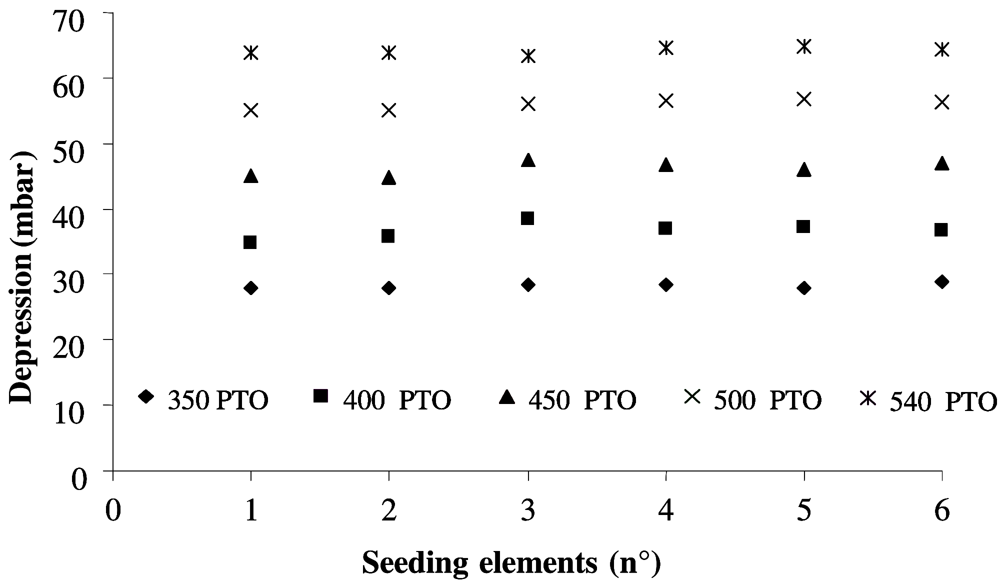

Depression (mbar)
Seeding elements (n°)
350 PTO
400 PTO
450 PTO
500 PTO
540 PTO
0
10
20
30
40
50
60
70
0
1
2
3
4
5
6

Figure 4

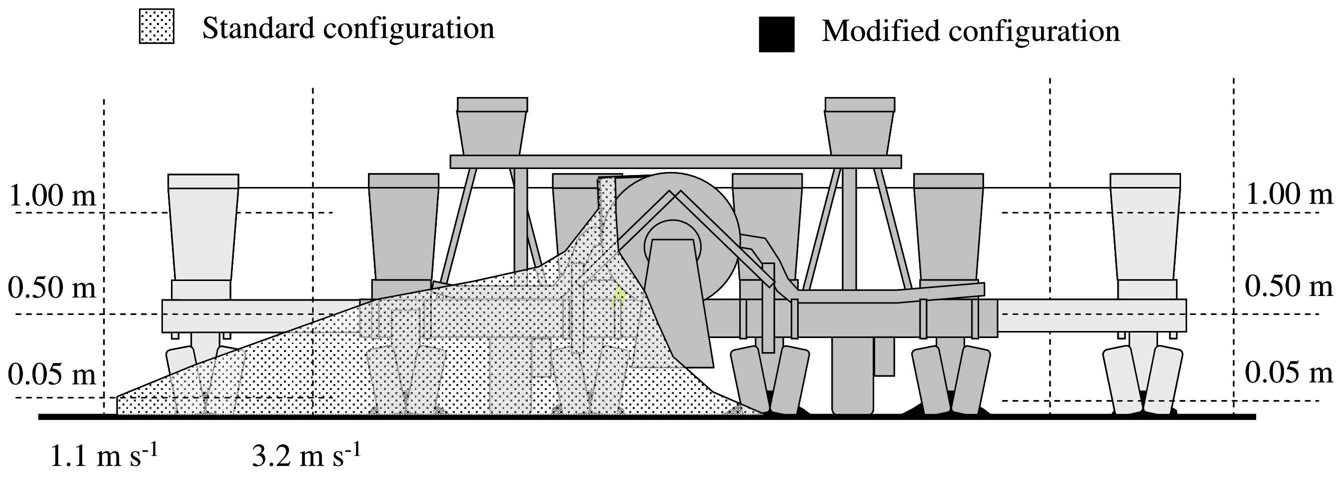

Standard configuration
Modified configuration
1.00 m
0.50 m
0.05 m
1.00 m
0.50 m
0.05 m
1.1 m s-1
3.2 m s-1

Figure 5

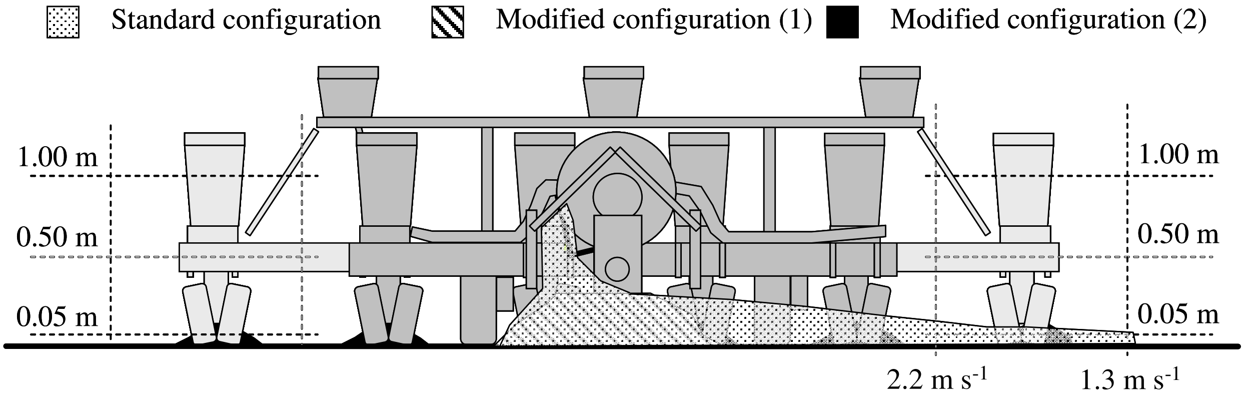

Standard configuration
Modified configuration (1)
Modified configuration (2)
1.00 m
0.50 m
0.05 m
1.00 m
0.50 m
0.05 m
2.2 m s-1
1.3 m s-1

Figure 6

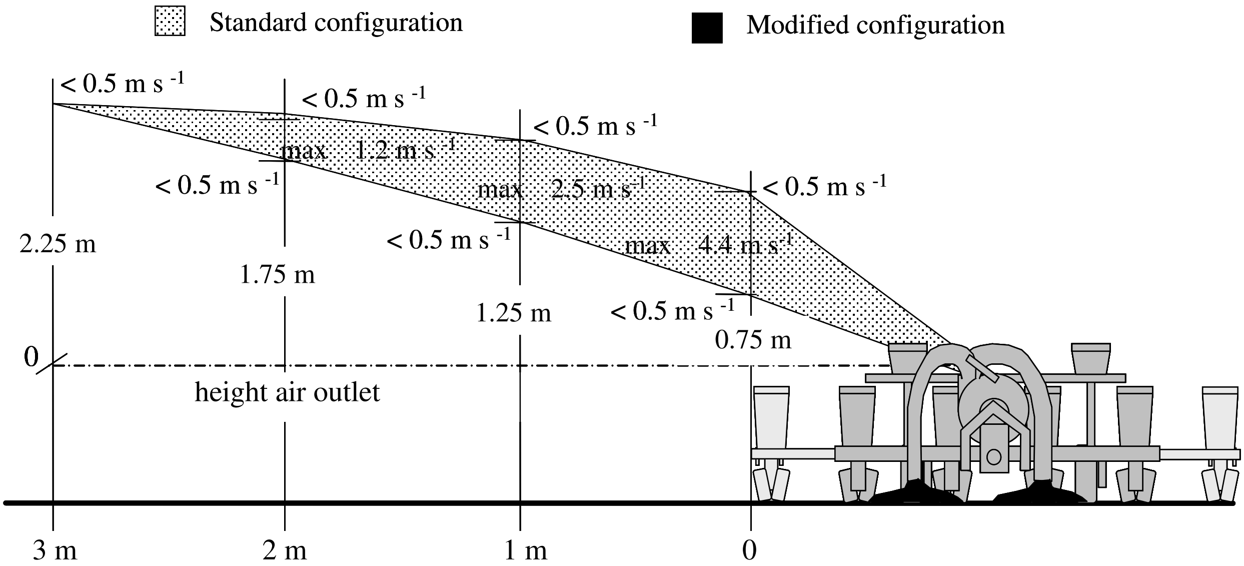
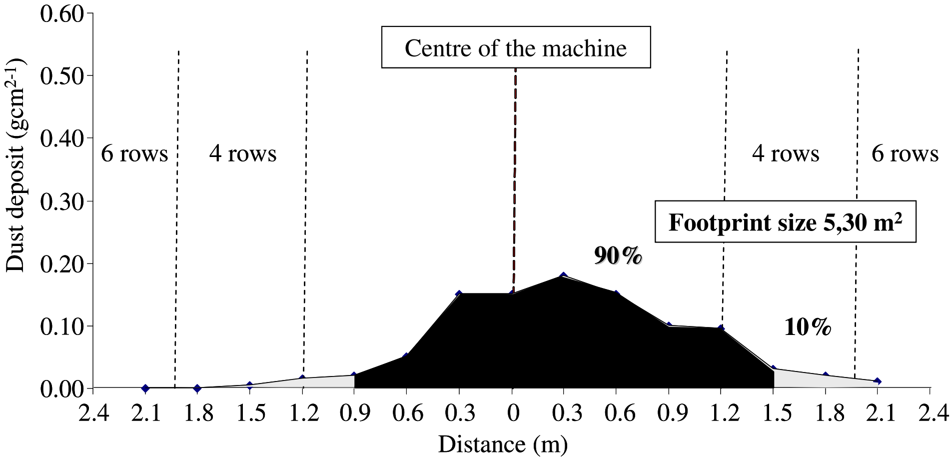

Standard configuration
Modified configuration
< 0.5 m s^{-1}
< 0.5 m s^{-1}
< 0.5 m s^{-1}
max 1.2 m s^{-1}
< 0.5 m s^{-1}
max 2.5 m s^{-1}
< 0.5 m s^{-1}
< 0.5 m s^{-1}
max 4.4 m s^{-1}
< 0.5 m s^{-1}
2.25 m
1.75 m
1.25 m
0.75 m
0
height air outlet
3 m
2 m
1 m
0

Figure 7



0.60
0.50
0.40
0.30
0.20
0.10
0.00
Dust deposit (gcm$^{2-1}$)
Centre of the machine
6 rows
4 rows
4 rows
6 rows
Footprint size 5,30 m^2
90%
10%
2.4 2.1 1.8 1.5 1.2 0.9 0.6 0.3 0 0.3 0.6 0.9 1.2 1.5 1.8 2.1 2.4
Distance (m)

Figure 8

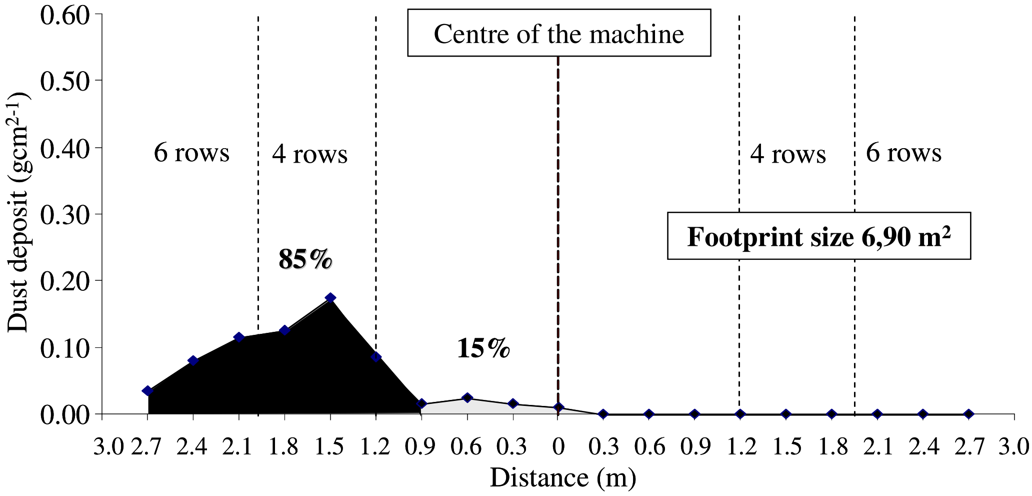

Centre of the machine
6 rows
4 rows
4 rows
6 rows
Footprint size 6,90 m²
85%
15%
Dust deposit (gcm2-1)
0.60
0.50
0.40
0.30
0.20
0.10
0.00
3.0 2.7 2.4 2.1 1.8 1.5 1.2 0.9 0.6 0.3 0 0.3 0.6 0.9 1.2 1.5 1.8 2.1 2.4 2.7 3.0
Distance (m)

Figure 9

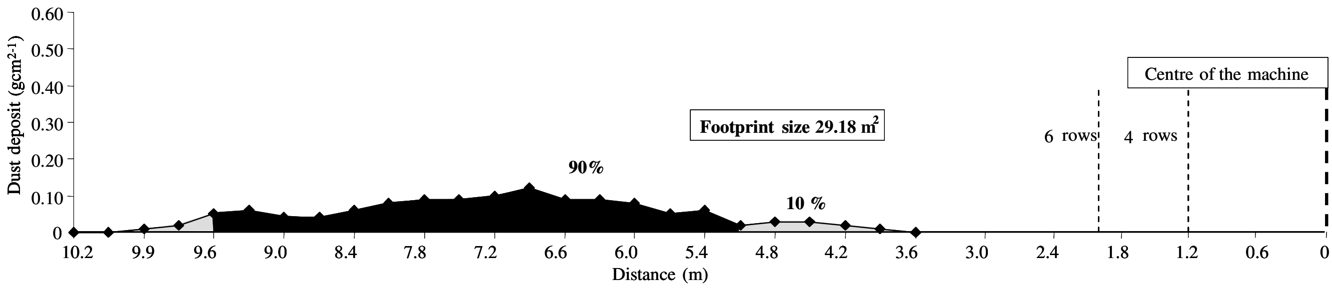

Dust deposit (gcm2-1)
0.60
0.50
0.40
0.30
0.20
0.10
0
Centre of the machine
Footprint size 29.18 m2
6 rows
4 rows
90%
10 %
10.2
9.9
9.6
9.0
8.4
7.8
7.2
6.6
6.0
5.4
4.8
4.2
3.6
3.0
2.4
1.8
1.2
0.6
0
Distance (m)

Figure 10

Table captions

Table 1 – Neonicotinoides insecticides use allowed in European countries (Pioneer®, 2010)

Table 2 - Main technical features of the fans present on the pneumatic seeders tested.

Table 3 - Physical characteristics of the dressing seed dust and of the selected tracer (wheat flour "00"). No significant difference - Statistical analysis ANOVA unvaried, $p > 0.05$.

Table 4 - Air flow rate ($m^3 h^{-1}$) measured at the fan inlet and at the fan outlet of the pneumatic seeder B

Table 5 - Size of the dust contaminated surface assessed with the conventional pneumatic seeders and with the modified ones, equipped with devices to convey the air towards the soil (REGW, Alfa= 0.05)

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	Clothiandin	Fipronil	Thiamethoxan
Austria	yes	yes	yes
Belgium	no	yes	yes
UK	no	no	yes
France	no	no	yes (*)
Germany	yes (*)	no	yes (*)
Italy	no	no	no
Netherlands	no	no	yes
Slovenia	yes	no	yes
Spain	no	yes	yes
Switzerland	yes	no	yes

(*) Only if the seeding operation is performed with pneumatic seeders equipped with a kit for convey the air stream toward the soil

Table 1

Manufacturer	A	B	C
Model	Ma/ag-SD05	Gaspardo-MT	Monosem -NG-plus
Rows (n°)	4-6	4-6	4-6
Fan diameter (mm)	440	410	420
Fan width (mm)	45	60	80
Blades (n°)	10	10	8
Blade inclination (°)	30	31	0
Blade width (mm)	30	30	45
Air outlet size (mm)	105 x 45	230 x 60	135 x 80
Air direction	lateral	downwards	Upwards
Fan rotation speed (rev min^{-1})	5000	5400	4500

Table 2

Size particles	Dressing seed	Wheat flour
D_{10} (µm)	34,1 ns	35,4 ns
D_{50} (µm)	84,1 ns	74,1 ns
D_{90} (µm)	180,9 ns	163,5 ns
Density (g cm^{3-1})	0,41 ns	0,45 ns

Table 3

PTO (rev min^{-1})	N° seeding elements											
	1		2		3		4		5		6	
	inlet	**outlet**	**inlet**	**outlet**	**inlet**	**outlet**	**inlet**	**outlet**	**inlet**	**outlet**	**inlet**	**outlet**
350	279	276	280	281	285	285	283	282	280	280	290	288
400	348	349	358	360	384	385	370	370	372	371	368	367
450	450	449	448	447	447	475	468	468	460	461	470	470
500	550	550	550	548	560	561	566	565	568	569	562	563
540	638	637	640	640	633	632	645	646	648	648	644	644

Table 4

	Surface contaminated (m^2)	**Reduction (%)**
Machine A conventional	5.27 c	-
Machine A modified	0.70 e	87
Machine B conventional	6.92 b	-
Machine B modified (1)	0.54 e	92
Machine B modified (2)	0.63 e	91
Machine C conventional	29.18 a	-
Machine C modified	1.23 d	96

Table 5

Highlights

- We studied the influence of different seeder parameters on dust dispersion.
- Reduction of seeder air flow rate decreased dust dispersion.
- Use of devices enabling the direction of the air flow towards the soil minimized dust dispersion.