Dust drift reduction effect of an air conveyor kit (dual pipe deflector) mounted on different maize pneumatic drills

Abstract

BACKGROUND: All maize drills produce a fine dust due to the abrasions of the seed coating that occur inside the seeding element. Nevertheless, the air stream generated by the fan of pneumatic drills – necessary to create a depression in the sowing element of the machine and to guarantee a correct seeds deposition – can blow away the solid particles detached from the seeds. In order to reduce this phenomena, coated maize seeds company (Syngenta®) has set up an ad hoc kit "dual pipe deflector" that easy a fits different pneumatic drills (also old drills). In this study, the efficiency of this kit and the influence of different drills types on the kit effects in reducing the environmental contamination, were evaluated using three different pneumatic seed drills models.

RESULTS: The research showed that dual pipe deflector installed on the drill in standard configuration did not change the seeder performance and using this kit on pneumatic drills, independent of their design, it is possible to reduce up to 69% the amount of dust drift with respect to the conventional machine set up.

CONCLUSION: Dual pipe deflector, under conditions explained in this experimentation, showed good performances with all types of maize pneumatic drills used. Independent of the seeder model on which is mounted, it is able to obtain similar results highlighting an high operative versatility.

Keywords: pneumatic drills, dual pipe deflector, maize seed, dust drift

1. Introduction

All maize drills produce a fine dust due to the abrasions of the seed coating that occur inside the seeding element.[1] Nevertheless, the air stream generated by the fan of pneumatic drills – necessary to create a depression in the sowing element of the machine and to guarantee a correct seeds deposition – can blow away the solid particles detached from the seeds.[2-3]

On the basis of this situation, some European countries (e.g. Italy) have banned the use of toxic substances in the seed dressing, while other (e.g. France) have required the use of appropriate air conveyors able to address the exhaust air towards the soil. In fact, adopting these kits, it is possible to reduce dust drift and, consequently, to increase the environment safeguard.[4]

During the last years, research stations and manufacturers have proposed different solutions to reduce dust drift effect.[5] Generally, these solutions consist in specific kits for the drills which convey the air exiting from the fan of the sowing machine to the soil [4,6] or which are able to filter the exhaust air and to bury underground the dust particles.[7-9] Nevertheless, manufacturers prefer to use the kit only for conveying air because they are easier to install and have low production costs.

All air conveyor kits are mainly composed by three different elements: 1) an air conveyor mounted on the outlet of seeder fan; 2) one or more pipes to convey the air; 3) an air dispersion system positioned close to the soil.[4,6] The main problems in the kit installation are attributable to the fan sealing and to the different air outlet conformations. If the solution to the first problem is easier to find (it is sufficient to put a seal in all junction points of the parts), it is more difficult to solve the second problem. In fact, in the course of the years, each manufacturer has designed the fan only in function of his needs and production cost and, for this reason, it is impossible to design a specific air conveyor to use on all types of drills. Nevertheless, coated maize seeds company (Syngenta®) has set up an ad hoc kit “dual pipe deflector” that easy a fits different pneumatic drills (also old drills) because the air conveyor is adaptable to all fan of commercial drills.

In order to evaluate the efficiency of this “dual pipe deflector” kit and the influence of different drills types on the kit effects in reducing the environmental contamination, experiments were carried out with the kit installed on three different pneumatic seed drills models.

2. Materials

2.1. Dual pipe deflector kit

The kit is a commercial kit composed by an adapter device to be mounted at the fan air outlet, which conveys the air stream to a principal flexible pipe having 125 mm internal diameter. This pipe can assume a different length in function of the seeder frame structure and it ends with a "Y" shape fitting in order to split the air flow in two different secondary flexible pipes having the same diameter (125 mm). Output of secondary pipes must be placed close to the soil (100-120 mm) in vertical direction exhausting in a vertical down facing direction as stated in the manufacturer's recommendations. Air outlets show a correct position when they are placed between the central seeding elements. After the kit installation it is necessary to seal all components connection (pipes and adapter device) (Fig. 1).

2.2. Seeders used

Tests to assess the performances of dual pipe deflector were made using three pneumatic seeders (1 – 2 – 3), representative of the Italian context. The sowing machines were different in fan design, especially in air output direction (Table 1). Each machine was tested either in its standard configuration or in modified configurations with the kit installed. It was assumed to operate the seeding with a distance of 0.75 m between the maize rows and to apply 75,000 seeds per hectare.

3. Methods

Three series of tests were performed to assess the dual pipe deflector's performance: 1) influence of the kit on the seeder's performance; 2) effect of three different kit configurations on air outlet splitting and primary pipe length; 3) effect on dust drift mitigation.

2.1 Influence of the kit on the seeder's performance

The correct quality of sowing of the pneumatic drills is guaranteed by the amount of vacuum level inside the seeding elements – 4.2 kPa for maize seeds[10] – and, for this reason, the influence of the kit on the seeder's performance was evaluated by determining the vacuum level in the seeding elements.[3] This measurement was made using a water manometer placed in the connection hose between the seeding element and the fan. The water manometer was made with two vertical tubes each with a 16 mm internal diameter and 2 m height. The difference in the water level in each tube was determined using a ruler with 1 mm accuracy. Tests were performed with and without the kit installed with only one configuration (configuration 1) on the three sowing machines (drills 1, 2, and 3).

2.2 Kit performance in different configurations

The goal of these tests was to evaluate the influence of different inclinations of the air splitter (± 30°) and the primary pipe length on the kit performance. In fact, during the kit installation, in function of the drills type and model, sometimes it needs to change the "conventional" configuration (configuration 1) and to follow different geometries (configurations 2 and 3) (Fig. 2). In addition, for the same reason, it is possible to have different primary pipe length. On the basis of this, tests were carried out using different primary pipe length (0.4, 0.6, 0.8 and 1.0 meteres), in order to evaluate its influence on air flow rate subdivision into the two secondary pipes.
During the tests it was evaluated:

a) The air velocity exiting from the two secondary pipes
b) The amount of dust particles exiting from the secondary pipes

All tests were carried out in laboratory using only the drill model 1 (it was the only machine that allowed the installation of the kit in the different testing designs) adopting a 450 PTO revolution per min as indicated by manufacturer.

The air velocity measurament was performed by an anemometer (Allemano Testo 400) with an accurancy of 0.1 ms^{-1}. Measurament point was sited in corrispondence of pipes air outlet section.

The amount of dust exiting from the pipes was determined using the method proposed by Balsari et al, (2013) to estimate the deposit area size of dust expulsed from air fan. That methodology provides to collect the dust with Petri dishes calculating the amount of dust particles deposited by weight difference before and after the test. In detail, in this study a PVC tank of 1 m^2 (1 m x 1 m) was used to collect dust particles because, differently from tests carried out by Balsari et al (2013), in this case all dust in exit from the fan was collected and quantified. Since the pipes outlets were positioned close to the soil (about 0.2 m), therefore at the base of PVC tank, the tank surface was covered with an appropriate cellulose filtering material (Camfil CM 360) in order to avoid the dust dispersion. This material was adopted as it was already successfully used in previous studies to capture the dust particles.[7] Weights were determined using a precision balance with a readability of 0.01 g (Ohaus® EX10202).

Tests were carried out with an inert material (Tartrazine E102) simulating dust particles of seeds dressing as proposed by Manzone et al[7] during the performance evaluation of a cyclone to clean exhaust air in exit from pneumatic drills. In fact, this material presents similar particles size and density of real dust of dressed seeds, but it is not toxic and it can be used without specific safety precautions. In addition, the mass balance evaluation is very difficult using coated seeds, because it is impossible to predict the real amount of dust that can be released during the test. For this reason, in the trials no coated seeds were used. In each test, an amount of 30 g of Tartatrize E 102 was introduced by a powder feeder (BHT® BD20) into the drill fan at a rate of 3 g per min.

2.3 Kit effect on dust drift mitigation.

The efficiency of the tested kit in terms of dust reduction dispersion was performed using a specific methodology that consists in simulating in a wind tunnel the environmental air stream produced by an axial fan and downwind collection of the tracer emitted from the seeder's fan outlet.[4] In detail, the methodology provides that drill must be sited in static position in the middle of a tunnel 50 meter long where an axial fan generates a constant "artificial wind" of about 3.0 ms^{-1}. Dust particles blown by the air stream are collected in the downwind area using plastic Petri Dishes (138 mm diameter) placed on the ground at different distances from the drill's edge (1, 3, 5, 10, 15 and 20 m). The trials were carried out with the three different drills models and installing the kit in its standard configuration adopting a length of primary pipe of 0.6 m (minimum length that permits an equal air flow rate subdivision into the two secondary pipes).

Tests were conducted filling hoppers with no coated seeds and then inserting the discs of the seeding elements into the soil at 45-50 mm depth. Also in these tests, fan was run maintaining the drill in static position and using an inert material (Tartrazine E 102) in substitution of real seed dressing dust. The Tartrazine E102 was introduced in the fan air inlet at a rate of 3 g min^{-1} for 10 minutes using a powder feeder (BHT® BD20) with the wind tunnel fan activated.

The amount of tracer deposited on each Petri dish was determined in laboratory by spectrophotometry analysis. Contaminated samplers were washed with 50 ml of deionised water and washings were then analysed with a spectrophotometer (Biochrom Lybra S11) set up at a wavelength of 434 nm, corresponding to the peak of absorption of the dye. The absorbance value read on the instrument enabled the corresponding amount of tracer to be calculated. Tests were performed with and without the kit installed on the sowing machines.

3. Results

3.1 Influence of the kit on the seeder's performance

Dual pipe deflector installed on the drill in standard configuration did not change the seeder performance. The vacuum levels measured in the seeding element in all drills object of this study with and without kit tested ranged between 6.1 and 6.2 kPa. The measured values were approximately 30% greater than the optimal value (4.2 kPa) recommended for maize seeding (Fig. 3).[10] The values obtained with and without the kit installed were not statistically different.

3.2 Kit performance in different configurations

Air velocity values measured at the two secondary pipes outlets were different in function of the configuration adopted during the kit installation and of the length of the primary pipe. When the primary pipe was long up to 0.6 meters, the air velocity values resulted different (over 30%) between the two secondary pipes, independent of kit configurations. In contrast, the air velocity values resulted similar when the primary pipe was longer (5.2 ± 0.1 m s^{-1}) (Table 2).

Anova table confirm a higher influence of primary pipe length on the air velocity compared to the configuration type (Table 3)

3.3 Kit effect on dust drift mitigation.

Drill 1 in its basic standard configuration, with the fan outlet oriented upwards, pointed out tracer deposits values increasing at downwind distances from the machine up to 15 m. A similar trend of tracer deposit values increasing according to the downwind distance from the machine edge was obtained also for sowing machine 3 operated in its standard configuration. Data collected with drill 2, in its original design, showed a lower drift effect than the other models tested, because this seeder model was already originally equipped with a fan outlet oriented downwards. When all these three drill models were equipped with the Dual Pipe Deflector, a similar decreasing ground deposition trend in function of the downwind distance was observed (Fig. 4, 5, and 6).

Independent of the drill type on which the tested kit was installed, similar results were obtained in terms of tracer deposits. In fact, any statistical difference was found at the different downwind distances using different sowing machines (Table ~~5~~4).

The research showed that using dual pipe deflector on pneumatic drills, independent of their design, it is possible to reduce up to 69% the amount of dust drift with respect to the conventional machine set up (Fig. 7).

5. Discussion

It was observed that the presence of the tested kit did not interfere negatively on drill performance. In fact, the vacuum level inside the seeding element did not change significantly when the kit was mounted on the drill and the resulting values were higher than the minimal value considered for a correct seeding (4.2 kPa).[10]

The tested kit was able to reduce up to 69% the dust drift effect. This value is in line with those observed in other work focused on the performances of kits for drills air conveyors using the same method.[4] That value is lower than those observed in other works where kits were tested in the field. In fact, in these latter cases, the tested kits resulted able to reduce the dust drift effect more than 90%.[11-12] Moreover experimental data pointed out that the Dual Pipe Deflector was able to reduce the downwind dust deposits at the same level, even if using different drill types; this is of considerable importance because adopting this kit it is possible to minimise the environmental contamination independent of the drill design.

Nevertheless, this study also pointed out that the kit performances are linked to the length of primary pipe: the best performances were obtained with a length of at least 0.8 meters. For this reason, in order to guarantee the best kit performances, during its installation on the drill, the primary pipe should have a minimal length of 0.8 meters independent of the kit configuration adopted and of the drill type used.

In contrast to other devices specifically designed for reducing the dust drift effect,[7-9] this kit does not enable to reach 100% dust drift reduction. On the other hand thanks to its simple design it can be marketed at a lower price and requires lower maintenance with respect to the other kits that are more sophisticated.[8] In addition, thanks to the simple kit structure, its installation on drills can be easily done by any mechanic qualified to work on agricultural machinery.

Finally, for a complete evaluation of kit performance, it could be interesting to carry out specific tests with coated seeds[6,13-14] and in field conditions.[15-16] In addition, it could be interesting to analyse also the kits performance adopting different pipe diameters combined with different distances between the secondary pipes outlets and the soil, in order to identify the best deflector configuration enabling to minimize drift.

4. Conclusions

Dual pipe deflector, under conditions explained in this experimentation, showed good performances with all types of maize pneumatic drills used. Independent of the seeder model on which is mounted, it is able to obtain similar results highlighting an high operative versatility. Furthermore, this study also showed that adopting the tested kit, it is possible to limit up to 69% the dust dispersion. Nevertheless, during kit installation it is essential to maintain a length of primary pipe higher than 0.8 meters in order to get a similar air stream distribution into both secondary pipes independent of the design adopted.

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Figures captions

Fig. 1. Dual pipe deflector kit installed on drill.

Fig. 2. Different kit configurations considered during the test

Fig. 3. Vacuum level of the different drills with and without the kit tested installed

Fig. 4. Amount of drift material of the drill 1 with and without dual pipe deflector presence at different distances

Fig. 5. Amount of drift material of the seeder 2 with and without dual pipe deflector presence at different distances

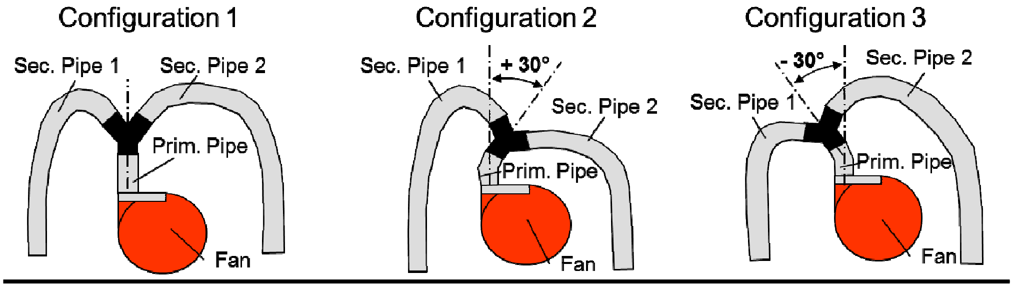
Fig. 6. Amount of drift material of the seeder 3 with and without dual pipe deflector presence at different distances

Fig. 7. Total deposit collected in downwind area

Figure 1

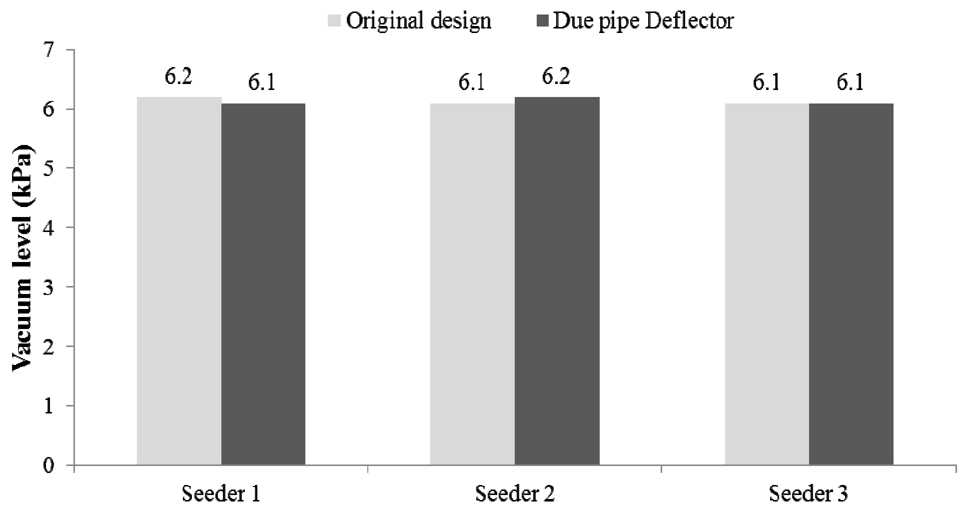
Notes for the editor: to be rendered in black and white

Figure 2



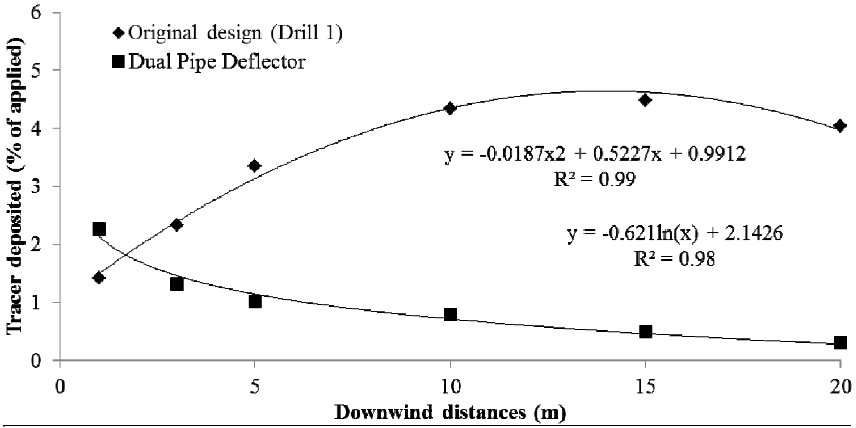
Notes for the editor: to be rendered in black and white

Figure 3



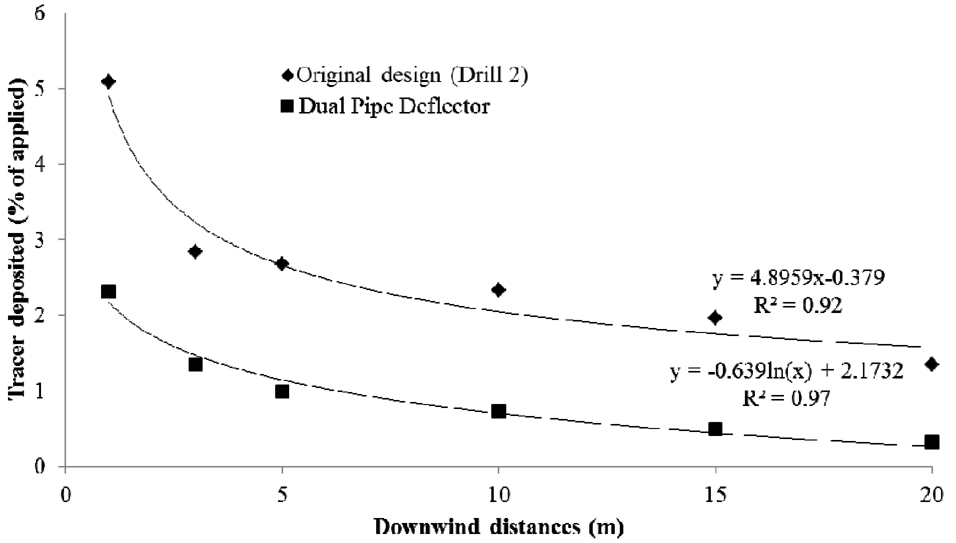
Notes: any statistical difference was observed with a significant level of 0.05.

Figure 4



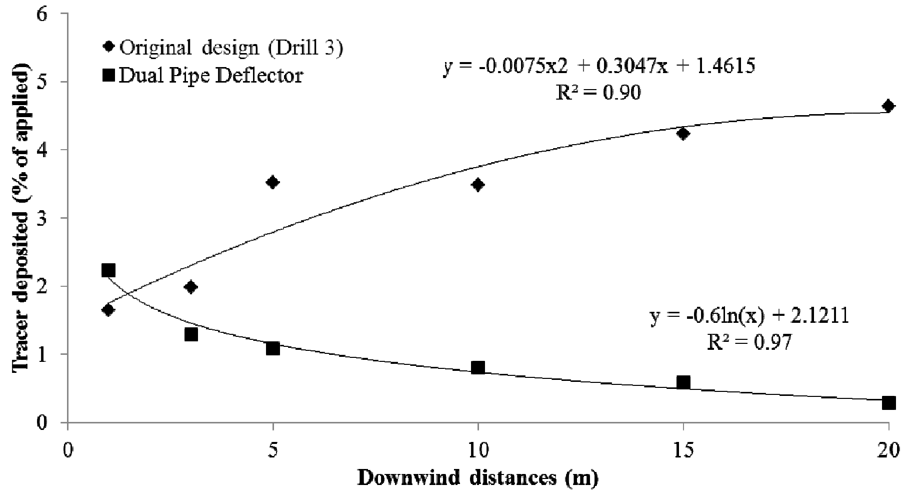
Distance (m)	1	3	5	10	15	20
Original design (SD)	0.03	0.05	0.06	0.09	0.08	0.06
Dual Pipe Deflector (SD)	0.03	0.04	0.04	0.04	0.05	0.07

Figure 5



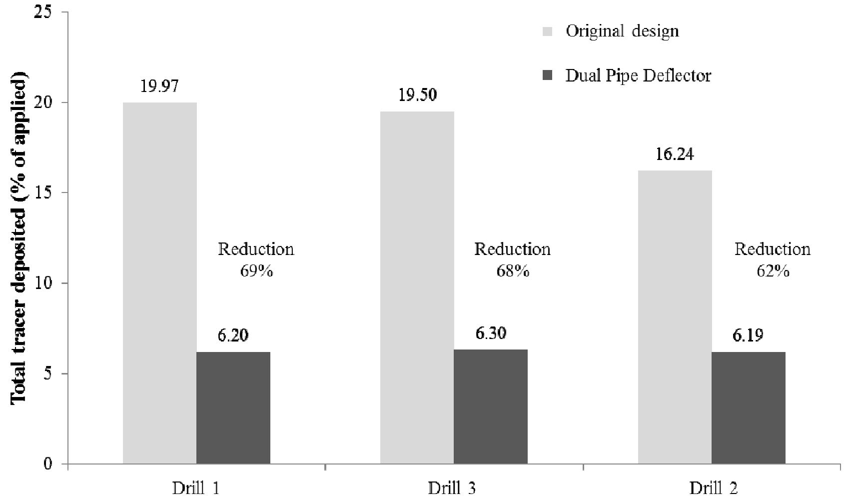
Distance (m)	1	3	5	10	15	20
Original design (SD)	0.08	0.05	0.10	0.06	0.06	0.11
Dual Pipe Deflector (SD)	0.06	0.05	0.06	0.04	0.03	0.03

Figure 6



Distance (m)	1	3	5	10	15	20
Original design (SD)	0.06	0.07	0.06	0.04	0.06	0.04
Dual Pipe Deflector (SD)	0.08	0.05	0.07	0.07	0.04	0.05

Figure 7



25
20
15
10
5
0
Total tracer deposited (% of applied)
Original design
Dual Pipe Deflector
19.97
19.50
16.24
Reduction
69%
Reduction
68%
Reduction
62%
6.20
6.30
6.19
Drill 1
Drill 3
Drill 2

Table captions

Table 1. Main technical features of the fans present on the pneumatic seeders tested

Table 2. Air velocity (ms^{-1}) in exit of secondary pipes (pipe 1 and pipe 2) considering different kit configurations and lengths of primary pipe.

Table 3. Anova table

Table 4. Tartrazine E102 deposited at different distance using Dual Pipe Deflector installed on different type of drills.

Table 1

Manufacturer	1	2	3
Seeding elements (n°)	4	4	4
Fan diameter (mm)	420	410	440
Fan width (mm)	80	60	45
Blades (n°)	8	10	10
Blade inclination (°)	0	31	30
Blade width (mm)	45	30	30
Air outlet size (mm)	135 x 80	230 x 60	105 x 45
Air out put direction	upwards	downwards	lateral
Fan rotation speed (rev min^{-1})	4,500	5,400	5,000
Air velocity (m s^{-1})	4.4	2.2	3.2
Air flow rate (m^3 h^{-1})	150	150	160

Table 2

	Primary pipe length (m)															
	0.4				0.6				0.8				1.0			
Configuration	pipe1		pipe2		pipe1		pipe2		pipe1		pipe2		pipe1		pipe2	
	mean	*SD*	mean	*SD*	mean	*SD*	mean	*SD*	mean	*SD*	mean	*SD*	mean	*SD*	mean	*SD*
1	6.4	*0.25*	4.3	*0.23*	5.9	*0.12*	4.8	*0.18*	5.3	*0.21*	5.3	*0.09*	5.4	*0.12*	5.3	*0.11*
2	7.4	*0.21*	3.0	*0.21*	6.1	*0.16*	4.3	*0.16*	5.1	*0.19*	5.2	*0.10*	5.3	*0.08*	5.1	*0.07*
3	2.5	*0.19*	8.0	*0.25*	3.4	*0.15*	7.1	*0.13*	5.1	*0.13*	5.3	*0.15*	5.2	*0.08*	5.3	*0.09*

Table 3

Effect	SS	DF	SM	F-value	P-value	Power
Configuration	0.206	2	0.103	5.614	0.006	0.836
Primary pipe lenght	0.022	3	0.007	0.404	0.751	0.124
Interaction	0.025	6	0.004	0.23	0.965	0.104
Residual	0.880	48	0.018			

Table 4

Seeder	Downwind distances (m)					
	1	3	5	10	15	20
1	2.24a	1.29b	1.08c	0.81d	0.58e	0.29f
2	2.31a	1.35b	0.99c	0.73d	0.49e	0.32f
3	2.26a	1.31b	1.01c	0.78d	0.52e	0.31f

Notes: Different letters indicate significant differences between deposits for $\alpha = 0.05$.