

AperTO - Archivio Istituzionale Open Access dell'Università di Torino

**Performance evaluation of a cyclone to clean the air exiting from pneumatic seed drills during maize sowing**

**This is the author's manuscript**

*Original Citation:*

*Availability:*

This version is available <http://hdl.handle.net/2318/1616648> since 2016-11-25T14:14:26Z

*Published version:*

DOI:10.1016/j.cropro.2015.06.002

*Terms of use:*

Open Access

Anyone can freely access the full text of works made available as "Open Access". Works made available under a Creative Commons license can be used according to the terms and conditions of said license. Use of all other works requires consent of the right holder (author or publisher) if not exempted from copyright protection by the applicable law.

(Article begins on next page)

# Performance evaluation of a cyclone to clean the air exiting from pneumatic seed drills during maize sowing

## Abstract

Seed dressing that controls pests by the application of small doses of neonicotinoids directly on the seed is used on a large variety of crops. Although this system is efficient and inexpensive, in recent years it has been banned because small amounts of dust abraded from the seed coating can be released into the atmosphere by sowing machines and which kills non-target insects including honey bee. Bayer Crop Science® has developed a device to clean the air at the exit of the drill's fan (patented as SweepAir®). This system is able to separate the dust from the exhaust airflow and convey it into the soil while the cleaned air is returned to the atmosphere. This paper reports experimental tests on the performance of this system.

The tests showed that the cyclone system effectively separated 99.4% of the inert material, and it did not negatively impact drill performance. The tested kit reduced the contaminated superficial soil area by close to 100% and eliminated dust drift because the abraded seed dust was effectively inserted into the soil. In addition, this system can improve operator and environmental safety because the external surface of the drill was not contaminated by pesticides.

## Keywords

Neonicotinoids, treated seeds, pneumatic drills, pesticides dispersion, SweepAir® kit

## 24 1. INTRODUCTION

25

26 Toxic substances can be released into the atmosphere as a result of agricultural  
27 processes, especially those linked to fuel consumption during cultivation (Blengini and  
28 Busto, 2009; Snyder et al., 2011; Safa and Samarasinghe, 2012) and to the use of  
29 pesticides (Lichiheb et al., 2014).

30

31 Seed dressing that controls pests by the application of small doses of pesticides directly  
32 on the seed is used on a large variety of crops (Elbert et al., 2008). Although this system is  
33 efficient and inexpensive, in recent years it has been restricted for some chemicals (e.g.  
34 neonicotinoids) because small amounts of dust abraded from the seed coating can be  
35 released into the atmosphere by sowing machines which kills insects that are not harmful  
36 to crops including important benefits insects including honey bees (Nuyttens et al., 2013).

37

38 Because the seed coating is abraded inside the seeding element, all seed drills produce a  
39 fine dust that could contaminate the environment. This is especially true for pneumatic  
40 drills, where an air stream generated by a fan is necessary to create a vacuum in the drill's  
41 sowing element. The air stream can blow solid dust particles detached from treated seeds  
42 towards areas adjacent to the field (Altmann, 2003; Greatti et al., 2003; Schnier et al.,  
43 2003; Greatti et al., 2006; Baldassari et al., 2008; Girolami et al., 2009).

44

45 Various authors have studied this phenomenon and have measured dust emission or dust  
46 drift potential under controlled and repeatable conditions by different methods (Giffard and  
47 Dupont, 2009; Biocca et al., 2011; Balsari et al., 2013; Manzone et al., 2014). Based on  
48 those results, drills were classified according to drift risk (Rautmann et al., 2009; Herbst et  
49 al., 2010).

50 In the past few years, several technical solutions applicable to pneumatic drills were  
51 developed to address this problem, but none of them was able to completely eliminate  
52 dust dispersion. These devices were able to contain 80% of the dust dispersed within the  
53 drill contour (Manzone et al., 2014).

54

55 Adopting some precautions during sowing activities also can reduce pesticide dispersion.  
56 Balsari et al. (2013) report that environmental contamination due to maize seed dressing  
57 can be reduced if pneumatic drills use lower fan revolution speeds. If the fan revolution  
58 speed is decreased by 1000 rev min<sup>-1</sup> (corresponding to decreasing the PTO by 100 rev  
59 min<sup>-1</sup>), airflow rate and fan air speed are decreased by 30%, significantly reducing the  
60 surface contaminated by the seed dressing material and also guaranteeing necessary  
61 depression of the seeding elements.

62

63 Previous technical solutions directed the exhaust airflow from the drill outlet toward the soil  
64 but did not eliminate the risk of environmental contamination. Therefore, Bayer  
65 CropScience® has developed a device to clean the air at the exit of the drill's fan  
66 (patented as SweepAir®). This system is able to separate the dust from the exhaust  
67 airflow and convey it into the soil while the cleaned air is returned to the atmosphere  
68 (Vrbka et al., 2014; Chapple et al., 2014). This paper reports experimental tests on the  
69 performance of this system.

70

## 71 **2. MATERIALS**

72

### 73 *2.1. The tested system*

74

75

76 The main component of the tested system is the cyclone, a device able to separate dust  
77 from the airflow. Exhausted air from the pneumatic drill's fan is conveyed through a  
78 "primary pipe" with an 85 mm internal diameter that connects the fan outlet to the cyclone  
79 inlet. The pesticide dust is separated from the airflow in the cyclone. The clean air is  
80 moved upward in the cyclone and emitted into the atmosphere through a "secondary pipe"  
81 with a 150 mm internal diameter. The dust is conveyed downwards in the cyclone and then  
82 deposited into the soil by the furrow system. A rotary vacuum valve is installed between  
83 the cyclone and the furrow system. This valve ensures that the cyclone system properly  
84 functions and guarantees that the collected dust is discharged only when the furrow is in  
85 the soil (Fig. 1).

86

## 87 *2.2. Drill used in the trials*

88

89

90 Trials were conducted with a conventional pneumatic drill normally used for maize sowing  
91 in Europe (Gaspardo®MARTA). During the tests, the drill was configured with four and six  
92 seeding elements and with fertilizer hoppers (Fig. 2). The drill was set to sow 75,000 seed  
93  $\text{ha}^{-1}$  with a distance between the seeding elements of 0.75 m (Table 1). During the test, in  
94 order to fix the tested kit to the drill, a specific support able to maintain in vertical position  
95 the cyclone was provided on its frame. Rotary valve was moved directly by the shaft used  
96 to power all seeding elements. This movement was held in place by a steel chain.

97

## 98 **3. METHODS**

99

100 Two series of tests were performed to assess the system's performance. Firstly, the  
101 efficiency of the system was determined: 1) cyclone dust separation efficiency, 2) vacuum

102 rotary valve life and 3) furrow system efficiency. Second, the influence of the system on  
103 the drill performance was evaluated: 4) fan airflow rate and vacuum level inside the  
104 seeding elements. Tests 3 and 4 were performed with and without the kit on the sowing  
105 machine.

106 Tests were performed without dressed maize seeds but using a defined tracer amount to  
107 simulate the seed dressing dust. This choice allowed elimination of the variability in the  
108 amount of dust abraded from the coated seeds during each test and to have reproducible  
109 test conditions for all the trials.

110

### 111 *3.1. Cyclone dust separation efficiency*

112

113

114 The cyclone dust separation efficiency was evaluated using a mass balance method. The  
115 difference between the mass of tracer inserted into the kit and the amount intercepted by  
116 the cyclone system was measured. Because an inert material was used, the tests could be  
117 conducted without specific operator safety precautions.

118 Wheat flour “00”, was used as proposed by Balsari et al. (2013) because this material has  
119 particle sizes similar to seed dressing material in the exit from the drill’s fan (Table 2)  
120 (Balsari et al., 2013).

121

122 This result had been obtained by analysing the particle sizes of the dust material expelled  
123 from the air outlets of the drills when using dressed maize seeds (KWS® and Pioneer®)  
124 and of wheat flour “00”. To collect the dust material expelled from seed drills a “cyclone  
125 vacuum cleaner” (characterized by vacuum air flow rate of  $260 \text{ m}^3 \text{ h}^{-1}$  and 97% efficiency  
126 separation) was used and the particles size analysis was made through an image analysis  
127 system (Image Pro Plus®). In order to select the inert material for simulating the dressed

128 maize powder, tests were made using wheat flour “00” (a cheap and widely available  
129 material) and considering the Volumetric Median Diameter (VMD) value. For each material  
130 (maize seed dressing and wheat flour “00”), the diameters of the granules were  
131 determined using the specific software Image Pro Plus<sup>®</sup> on five samples of at least 2000  
132 particles obtained from 50 images acquired by a Epix Sv 5 C10 5 Mpixel camera with a 1.4  
133  $\mu\text{m pixel}^{-1}$  resolution equipped with a Nikon<sup>®</sup> AF Micro Nikkor 60 mm lens.

134 Statistical analysis (ANOVA) showed that the wheat flour “00” had physical characteristics  
135 very similar to the maize seed dressing material and therefore it was used to assess the  
136 dust dispersion from the sowing machines (Table 2).

137

138 During the tests, a partial vacuum of 42 mbar was maintained inside the seeding element,  
139 which Bragatto (2008) considers optimal for correct maize sowing. One hundred grams of  
140 wheat flour “00” (3 g per min) was introduced into the inlet air stream of the cyclone. This  
141 is approximately 100 times higher than the potential, worst-case amount of abraded dust  
142 (3 g per 100 kg of treated seeds) (Heimbach, 2012). The efficiency of the cyclone was  
143 determined with a higher dust rate because during normal sowing activities the drill can  
144 also ingest soil dust.

145 All wheat flour “00” amounts were measured with an accuracy of 0.1 g. Tests were  
146 conducted with and without seeds in the hopper. Note that without seeds on the disc of the  
147 seeding elements, the airflow rate exiting the drill’s fan is increased by approximately  
148 130% (Balsari et al., 2013). For this reason, during sowing activities, if the seeds are not  
149 present in the seeding elements, the cyclone must be able to effectively clean a larger  
150 airflow. Therefore, tests were conducted using airflow rates of 210 and 480  $\text{m}^3 \text{h}^{-1}$ . The  
151 system was run for 5 min both before and after insertion of the wheat flour “00” to ensure  
152 that the cyclone was fully operational.

153 A specially designed, electrically driven piston-cylinder test system with a 40-mm internal  
154 diameter was used to introduce the tracer into the primary pipe that feeds the cyclone.  
155 This system inserted the wheat flour “00” at a rate of 3 g per min. To reduce the risk that  
156 the dust would deposit inside the primary pipe, the wheat flour “00” insertion device was  
157 placed 60 mm from the cyclone inlet (Fig. 2).  
158 The tests were conducted ten times and the data were processed using SSPS 2014.

159

### 160 3.2. *Vacuum rotary valve life*

161

162

163 The vacuum rotary valve life was tested. The efficiency of this component is extremely  
164 important because if the valve does not keep a hermetic seal, pesticide particles may leak.  
165 The valve tightness was evaluated with compressed air in accordance with UNI 7129/08  
166 (2008), a standard used for methane civil plant testing. In particular, the standard specifies  
167 that the inlet side of a valve connected to an air compressor is able to maintain a pressure  
168 of 500 mbar. After a stabilization time of 15 min, the air leakage was determined using a  
169 water manometer connected to the valve outlet (Fig. 3).

170 A series of tests were conducted to verify the rotary valve life. For these tests, a test  
171 apparatus that simulated sowing operations was used. Schematically, the device was  
172 made of a frame able to support a hopper containing soil dust, a support for the test rotary  
173 valve, a volumetric dispenser and an electric gear-motor. The gear-motor powered the  
174 dispenser and the rotary valve using a chain transmission system. The exhaust dust was  
175 conveyed into a container to recover and recycle it (Fig. 4).

176 To simulate a sowing operation, 1 kg of soil dust was introduced into the hopper. Glass  
177 microspheres with a diameter of 90-120  $\mu\text{m}$  were added to the dust (10% microspheres by  
178 weight), to increase the dust’s abrasive action in order to accelerate the wear of the valve.

179 The valve operated at nine revolutions per minute, which corresponded to emptying the  
180 cyclone every 16 m assuming a forward speed of the seed drill of 9 km h<sup>-1</sup>. The test had  
181 a time duration of 210 h; this value exceeded the annual usage time normally operated in  
182 Italy (150-200 h) (Bertocco et al., 2008; Basso et al., 2011). Leak testing was performed  
183 every 30 hours.

184

### 185 3.3. Furrow system efficiency

186

187

188 The efficiency of the furrow system was evaluated in the field by simulating sowing  
189 operations using maize seeds without dressing (Fig. 5). Trials were carried out in absence  
190 of environmental wind. For these tests, a special test apparatus consisting of two parts (A  
191 and B) was used. Part A was comprised of an electrical fan connected to two fan exhaust  
192 pipes that flowed air past the furrow system. The electrical fan could produce an air speed  
193 of 3 m s<sup>-1</sup> at the exit of the two pipes. Each pipe had a 100 mm internal diameter. The  
194 pipes were placed immediately behind the furrow system and oriented horizontally, 30 mm  
195 above the soil surface and separated from one another by 0.50 m. Part B was comprised  
196 of two Camfil dust collectors (100 x 200 mm) and support brackets. The Camfil collectors  
197 were placed 0.35 m in front of the fan exhaust pipes. The distance between the two  
198 collectors was 0.40 m. The forced air entrained the dust particles from the furrow and  
199 transported the dust to the Camfil collectors.

200 For these tests, 30 g of tracer were introduced into the fan of the drill for 10 min (3 g per  
201 min) using a volumetric powder feeder (BHT® BD20). Unlike the cyclone dust separation  
202 efficiency evaluations, a yellow inert material (Tartrazine E102) was used. Tartrazine E102  
203 has physical characteristics (e.g. particle size, density) similar to the abraded dust from  
204 dressed seed (Table 2) (Manzone et al., 2014). Physical characteristics of the Tartrazine

205 E102 were determined with the same method used for to wheat flour “00”.  
206 The use of two different inert materials was related to the resolution needed in each  
207 specific trial. Wheat flour “00” was employed when relatively high amounts of dust were  
208 expected in the samplers/collectors (e.g., the Cyclone dust separation efficiency test) and  
209 a gravimetric method was used. Alternatively, Tartrazine E102 was used when it was  
210 necessary to detect very low amounts of dust in the samplers/collectors (e.g., the furrow  
211 efficiency test), where spectrophotometric analysis was used. The contaminated Camfil  
212 collectors were washed with 50 ml of deionized water. The washing was analysed with a  
213 spectrophotometer (Biochrom Lybra S11) at a wavelength of 434 nm, corresponding to the  
214 peak absorption of the dye. The amount of Tartrazine E102 was calculated from the  
215 absorbance measured by the spectrophotometer. Each test was made without  
216 environmental wind and driving with a forward speed of 6 km h<sup>-1</sup>. Tests were repeated  
217 three times. Between repetitions test collectors were changed without switching the drill’s  
218 fan.

#### 219 220 *3.4. Fan airflow rate and vacuum level inside the seeding element*

221

222

223 Tests were conducted with the seed drills in a static position (Balsari et al., 2013). The fan  
224 airflow rate was measured at the fan outlet using a 110-mm diameter, 1 m long conveyor  
225 where a propeller anemometer (Allemano Testo 400) with 0.1 m s<sup>-1</sup> precision was  
226 positioned.

227 The vacuum level in the seeding element was measured with a water manometer placed  
228 in the hose connecting the seeding element and the fan. The water manometer was made  
229 with two vertical tubes each with a 16 mm internal diameter and 2 m tall. The difference in  
230 the water level in each tube was determined using a ruler with 1 mm accuracy.

231 Tests were made using the drill with four and six seeding elements, with and without the kit  
232 installed. All measurements were performed adopting a PTO revolution speed of 540 rev  
233 min<sup>-1</sup> and using no dressed seeds. All tests were conducted in similar environmental  
234 conditions: 20-25 C° air temperature and 65-70% relative humidity. Each test was  
235 repeated three times, and the data were processed using SSPS 2014. The statistical  
236 significance of differences between treatments was tested with the Ryan–Einot–Gabriel–  
237 Welsch (REGW) test.

238

## 239 **4. RESULTS**

240

### 241 *4.1. Cyclone dust separation efficiency*

242

243

244 The data were processed to calculate the cyclone's net dust separation efficiency. When  
245 there were no seeds in the hopper, the cyclone removed 99.4% (by mass) of the wheat  
246 flour "00". When there were seeds in the hopper, the cyclone removed 99.6% (by mass) of  
247 the wheat flour "00" (Table 4). The presence of a value higher than 100 g (the amount  
248 introduced in each test) highlights a potential dust deposit inside the cyclone that at the  
249 same time falls from the cyclone.

250

### 251 *4.2. Vacuum ball rotary valve life*

252

253

254 The trials showed that the valve maintained a hermetic seal until 120 h of operation; in fact  
255 no pressure losses were registered for the whole period. In contrast, after 120 hours the  
256 valve did not guarantee a total hermetic seal: between 150 and 210 h (the assumed

257 annual operational time for maize drills), the valve lost less than 5 mbar of pressure. In  
258 detail, the pressure losses showed an increment never lower than 50% per each  
259 successive step of measurement (30 hours). Nevertheless, the maximum pressure loss  
260 was only 1% of the input pressure (500 mbar) (Table 5).

261

#### 262 *4.3. Furrow system efficiency*

263

264

265 Spectrophotometric analysis showed no value difference between the deionised water  
266 used for device calibration and the deionised water used to Camfil collectors cleaning. This  
267 showed that there was no Tartrazine E102 present on the different collectors used in each  
268 test. On the basis of this, it is possible to assert that there was no drift effect during the  
269 dust insertion into the soil.

270

#### 271 *4.4. Fan airflow rate and vacuum level in the seeding element*

272

273

274 Adding the kit to the standard seed drill configuration did not change the airflow rate exiting  
275 from the fan because no statistic significant difference was found between the value  
276 recorded before and after kit installation. The airflow rate value depended only on the  
277 number of seeding elements present on the seed drill (Fig. 6).

278 The vacuum levels measured in the seeding element and at the manufacturer's  
279 recommended PTO revolution speed (540 rev min<sup>-1</sup>) were between 62 and 58 mbar. Also  
280 in this case, the value show no significant difference. The measured vacuum levels were  
281 approximately 30% greater than the optimal value (42 mbar) recommended for maize  
282 seeding (Bragatto, 2008) (Fig. 7).

283

## 284 5. DISCUSSION

285

286 The tests show that the cyclone system effectively separated 99.4% of the wheat flour  
287 “00”, even when larger than normal amounts of dust were present. These results agree  
288 with previous tests of different cyclone systems (Chapple et al., 2014). Additionally, good  
289 results were obtained also by the furrow system which has been able to guarantee the  
290 dust insertion into the soil without particles emission in atmosphere.

291

292 The valve system tests showed that the valve maintained an essentially hermetic seal. The  
293 registered pressure loss (2 mbar) after 150 h of work is acceptable. In normal sowing  
294 operation (pneumatic drill with six seeding elements and a forward speed of 9 km h<sup>-1</sup>), 600  
295 hectares would be seeded in 150 h. The vacuum valve system should be changed every  
296 550 ha, which is equivalent to about three years of farm operation (Bertocco et al., 2008;  
297 Basso et al., 2011). Additionally, the valve test was made in severe conditions because  
298 abrasive glass spheres were added to the soil dust.

299

300 The kit did not negatively impact drill performance. The minimal vacuum losses registered  
301 inside of the seeding element (2 mbar) would not impact sowing activities because the  
302 resulting pressure still exceeded the value considered sufficient for a correct seeding (42  
303 mbar) (Bragatto et al., 2008).

304

305 The kit reduced the contaminated soil area by half and eliminated dust drift because the  
306 abraded seed dust was effectively inserted into the soil and it performed better than  
307 previously developed and tested systems to reduce dust emission from pneumatic drills. In  
308 fact, comparing the results obtained in this study with those achieved in previous

309 experiments carried out using wheat flour “00” and Tartrazine E 102 and applying the  
310 same tests methods on the devices which only convey the air toward the soil (Balsari et  
311 al., 2013; Manzone et al., 2014), it was noticed that the tested kit was able to reduce the  
312 contaminated area and the dust drift by nearly 100%.

313

314 Unlike previous devices, the tested kit could eliminate pesticide contamination on the  
315 external surface of the drill. This could eliminate a potential pollution point source and  
316 improve operator safety (operators can be contaminated while filling the hoppers and  
317 when the drill is being connected to a tractor). The operator health risk may be even higher  
318 during maintenance operations (Manzone et al., 2014).

319

320 A complete evaluation of the performance of the tested device could be conducted using  
321 treated seed (Giffard and Dupont, 2009; Biocca et al., 2011; Tapparo et al., 2012) and  
322 under field conditions (Harrington et al., 2004; Friessleben et al., 2010).

323

324 Finally, the integrity of drill seals must be determined and appropriate seals used to  
325 prevent dust dispersion from the drill’s parts. Dust dispersion can be localized on pipe  
326 connections or at the junctions of parts where the air stream is conveyed.

327

328 In conclusion, cyclone systems could be a valid solution to clean the exhaust air of maize  
329 pneumatic drills. In fact, the tested kit, under conditions used in this experimentation, was  
330 able to remove almost 100% of the dust dispersed from the fan of pneumatic drill during  
331 sowing activities without affecting the drill’s performance. In contrast to previous devices,  
332 this system is also able to insert the particles of dust from dressed seed in the soil avoiding  
333 soil surface contamination with pesticides.

334 On the basis of results obtained in this work, by adopting the tested system it is possible to  
335 use dressed seeds and avoid environmental pollution. Furthermore, the kit can be used  
336 with all types of maize pneumatic drills (new and already in use) because it is only  
337 necessary to direct the air stream from the drill fan into the primary pipe of the kit. In  
338 addition, the tested kit could improve operator and environmental safety because the  
339 external surface of drill is not contaminated by pesticides. These results apply only to the  
340 wheat flour “00” and Tartrazine E 102 used in the tests and will be confirmed in the field  
341 using dressed seeds.

342

343

344

345

## 346 **References**

347 Altmann, R., 2003. Poncho: a new insecticidal seed treatment for the control of the major  
348 maize pests in Europe. Pflanzenschutz-Nachrichten Bayer (English edition) 56, 102-  
349 110.

350 Baldessari, M., Trona, F., Leonardelli, E., Angeli, G., 2008. Efficacia di acetamiprid e di  
351 azadiractina nel contenimento di *Dysaphys plantaginea*. Proceedine of national  
352 conference “Giornate Fitopatologiche 2008”.

353 Balsari, P., Manzone, M., Marucco, P., Tamagnone, M., 2013. Evaluation of seeds  
354 dressing dust dispersion from maize sowing machines. Crop Protection 51, 19-23.

355 Basso, B., Sartori, L., Bertocco, M., Cammarano, D., Martin, C.E., Grace, P.R., 2011.  
356 Economic and environmental evaluation of site –specific tillage in a maize crop in NE  
357 Italy. European Journal of Agronomy 35, 83-92.

358 Bertocco, M., Basso, B., Sartori, L., Martin, E.C., 2008. Evaluating energy efficiency of  
359 site-specific tillage in maize in NE Italy. *Bioresource technology* 99, 6957-6965.

360 Biocca, M., Conte, E., Pulcini, P., Marinelli, E., Pochi, D., 2011. Sowing simulation tests of  
361 a pneumatic drill equipped with systems aimed at reducing the emission of abrasion  
362 dust from maize dressed seed. *J Environ Sci Hlth Part B* 46, 438–448.

363 Blengini, G.A., Busto, M., 2009. The life cycle of rice: LCA of alternative agri-food chain  
364 management systems in Vercelli (Italy). *Journal of Environmental Management* 90,  
365 1512-1522.

366 Bragatto, G., 2008. Responsible for the engineering sector of the Maschio-Gaspardo  
367 manufacturer. Personal Communication.

368 Chapple, A.C., Vrbka, L., Friessleben, R., Schnier, H.F., Cantoni, A., Arnold, A.C., 2014. A  
369 novel technical solution to minimize seed dust during the sowing process of maize  
370 using vacuum based equipment: principals and an estimate of efficiency. *Aspect of*  
371 *applied Biology* 122, International Advances in Pesticide Application, 119-124.

372 Elbert, A., Haas, M., Springer, B., Thielert, W., Nauen, R., 2008. Applied aspects of  
373 neonicotinoid uses in crop protection. *Pest management Science* 64(11), 1099-1105.

374 Friessleben, R., Schad, T., Schmuck, R., Schnier, H., Schoning, R., Nikolakis, A., 2010.  
375 An effective risk management approach to prevent bee damage due to the emission of  
376 abraded seed treatment particles during sowing of neonicotinoid treated maize seeds.  
377 *Aspects Appl Biol* 99, 277–282.

378 Giffard, H., Dupont, T., 2009. A methodology to assess the impact on bees of dust from  
379 coated seeds. *Julius-Kühn-Arch* 423, 73–75.

380 Girolami, V., Mazzon, L., Squartini, A., Mori, N., Marzaro, M., Di Bernardo, A., Greatti, M.,  
381 Giorio, C., Tappararo, A., 2009. Translocation of neonicotinoid Insecticides From Coated

382 Seeds to Seedling Guttation Drop: A Novel Way Intoxication for Bees. *Journal Econ.*  
383 *Entomol.* 102, 1808-1815.

384 Greatti, M., Sabatini, A.G., Barbatini, R., Rossi, S., Stravisi, A., 2003. Risk of  
385 environmental contamination by the active ingredient imidacloprid used for corn seed  
386 dressing. Preliminary results. *Bulletin of Insectology* 56, 69-72.

387 Greatti, M., Barbatini, R., Stravisi, A., Sabatini, A.G., Rossi, S., 2006. Presence of the a.i.  
388 imidacloprid on vegetation near corn fields sown with Gaucho dressed seeds. *Bulletin*  
389 *of Insectology* 59, 99-103.

390 Harrington, P., Mathers, J.J., Smith, S., Glass, C.R., 2004. Methods for the evaluation of  
391 granular drift. *Aspects Appl Biol* 71, 197–200.

392 Heimbach U, Mit Beizen geizen. *Wochenblatt-Mag* 1, 14-18 (2012).

393 Herbst, A., Rautmann, D., Osteroth, H.J., Wehmann, H.J., Ganzelmeier, H., 2010. Drift of  
394 seed dressing chemicals during the sowing of maize. *Aspects of Applied Biology* 99  
395 (2010). *International Advances in Pesticide Application*.

396 Lichiheb, N., Personne, E., Bedos, C., Barriuso, E., 2014. Adaptation of a resistive model  
397 to pesticide volatilization from plants at the field scale: comparison with a dataset.  
398 *Atmos. Environ*, 260-268.

399 Manzone, M., Balsari, P., Marucco, P., Tamagnone, M., 2014. Indoor assessment of dust  
400 drift effect from different types of pneumatic seed drills. *Crop Protection* 57,15-19.

401 Nuyttens, D., Devarrewaere, W., Verboven, P., Foquè, D., 2013. Pesticide-laden dust  
402 emission and drift from treated seeds during seed drilling: a review. *Pesticide*  
403 *management Science* 69, 564-575.

404 Rautmann, D., Osteroth, H.J., Herbst, A., Wehmann, H.J., Ganzelmeier, H., 2009. Prüfung  
405 abdriftmindernder Maissägeräte. *Journal für Kulturpflanzen*, 61(5), 153-160.

406 Safa, M., Samarasinghe, S., 2012. CO<sub>2</sub> emissions from farm input “case study of wheat  
 407 production in Caterbury, New Zeland”. *Environmental Pollution* 171,126-132.

408 Schnier, H.F., Wenig, G., Laubert, F., Volker, S., Schmuck, R., 2003. Hey bee safety of  
 409 imidacloprid corn seed treatment. *Bulletin of insectology* 56(1), 73-75.

410 Snyder, C.S., Bruulsema, T.W., Jensen, T.L., Fixen, P.E., 2009. Review of greenhouse  
 411 gas emission from crop production system systems and fertilizer management affects.  
 412 *Agriculture, Ecosystems & Environment* 133, 247-266.

413 Tapparo, A., Marton, D., Giorio, C., Zanella, A., Solda, L., Marzaro, M., et al., 2012.  
 414 Assessment of the environmental exposure of honeybees to particulate matter  
 415 containing neonicotinoid insecticides coming from corn coated seeds. *Environ Sci*  
 416 *Technol* 46, 2592–2599.

417 UNI 7129/08, 2008. Gas systems for domestic use and similar fed by the distribution.

418 Vrbka, L., Friessleben, R., Neubauer, K., Cantoni, A., Chapple, A.C., 2014. Bayer Air  
 419 Washer® and SweepAir®: technological options for mitigation of dust emission from  
 420 vacuum based maize sowing equipment. *Aspect of applied Biology* 122, International  
 421 *Advances in Pesticide Application*, 113-118.

422

## Figures' captions

Fig. 1 - SweepAir® system schematic.

Fig. 2 - Drill used in the trials with the SweepAir® mounted.

Fig. 2 - Devices used to introduce the tracer into the airflow.

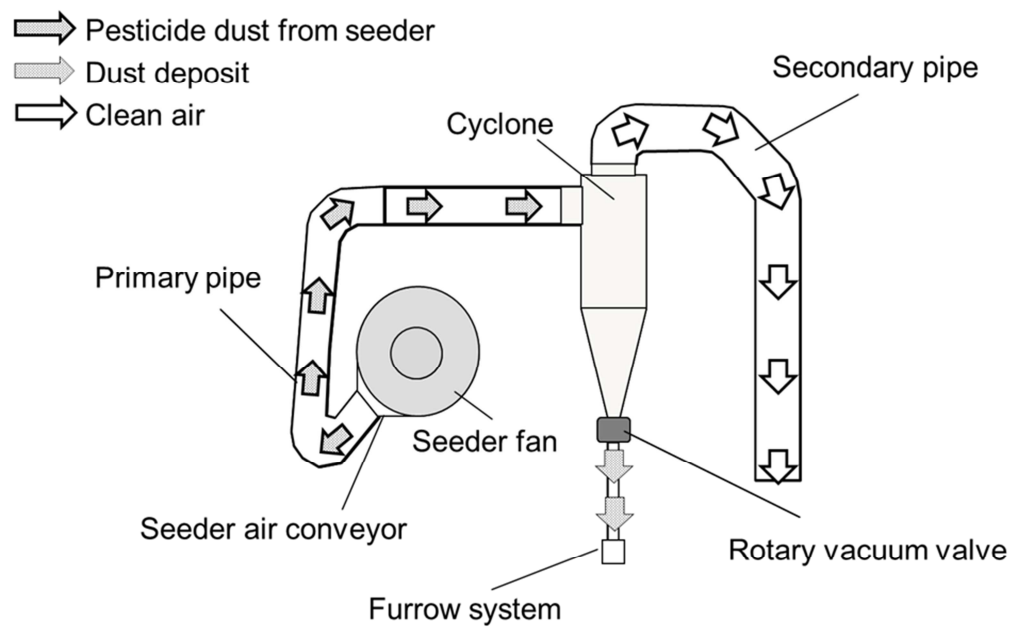
Fig. 3 - System used for the hermetic valve tests.

Fig. 4 - Device used for the rotary valve tests.

Fig. 5 - Furrow efficiency test apparatus.

Fig. 6 - Airflow rate measured at fan output with the sowing machine in the standard set up and equipped with the tested kit, using 4 and 6 rows configurations.

Fig. 7 - Vacuum level measured inside the seeding element with the machine in standard configuration and equipped with the tested kit.



443

444 Figure 1

445 Note for the editor: to be rendered in Black and White

446



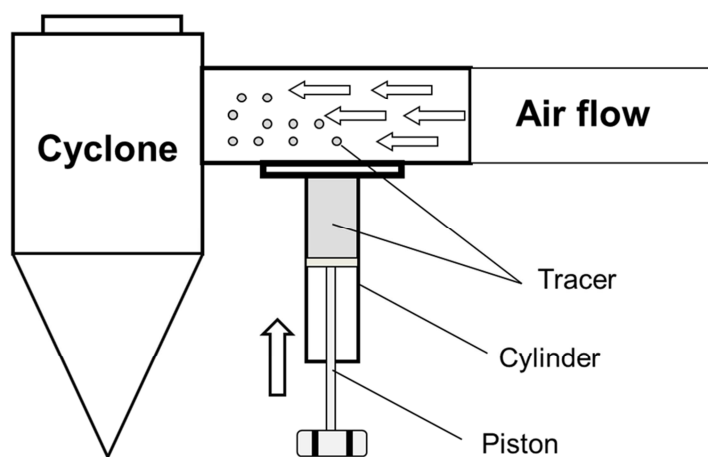
447

448 Figure 2

449 Note for the editor: to be rendered in Black and White

450

451

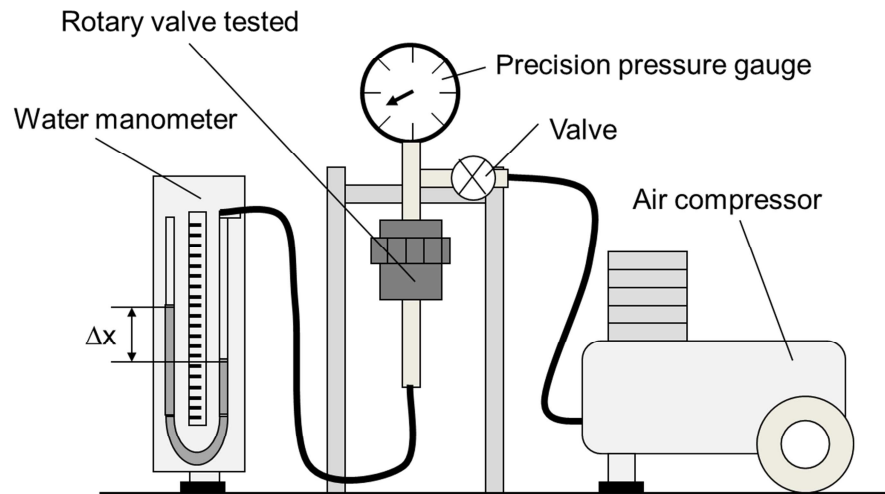


452

453 Figure 2

454 Note for the editor: to be rendered in Black and White

455

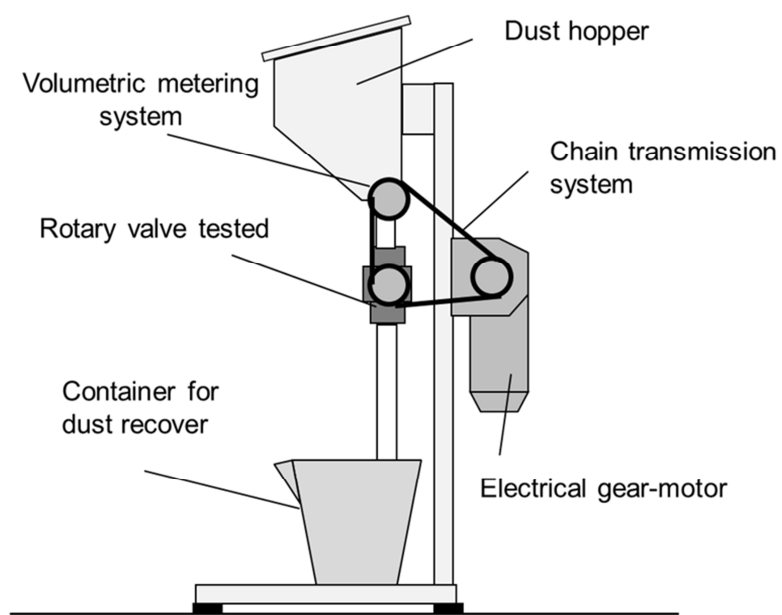


456

457 Figure 3

458 Note for the editor: to be rendered in Black and White

459

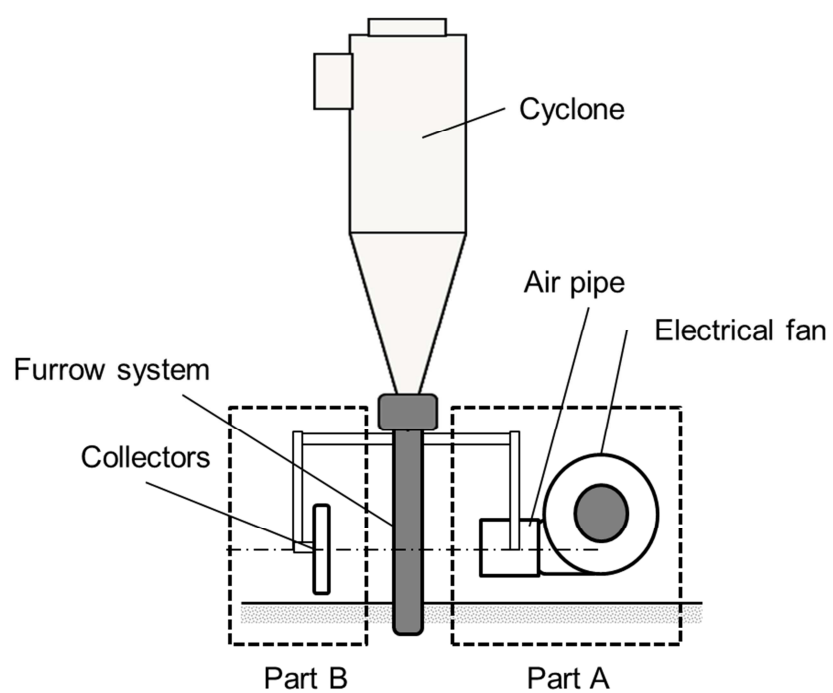


460

461 Figure 4

462 Note for the editor: to be rendered in Black and White

463

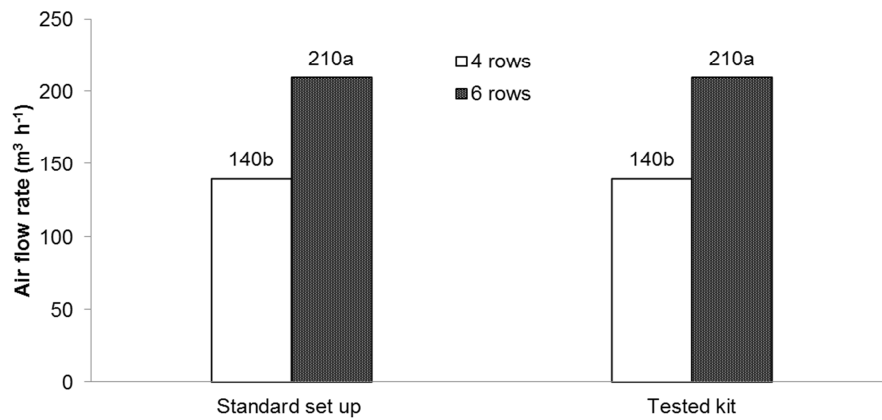


464

465 Figure 5

466 Note for the editor: to be rendered in Black and White

467



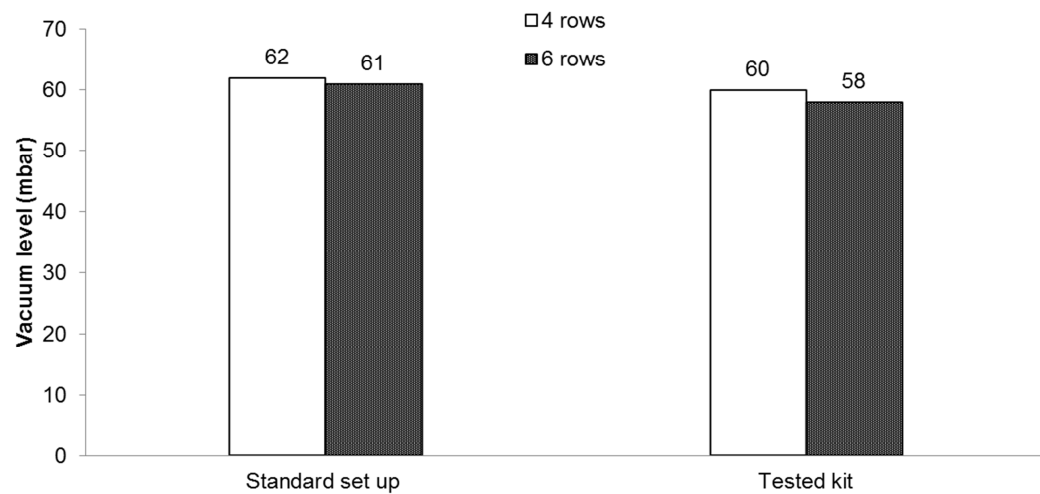
468

469 Note: different superscript letters indicate significant differences between treatments for  $\alpha = 0.05$

470 Figure 6

471 Note for the editor: to be rendered in Black and White

472



473

474 Note: statistical analysis could not detect any significant difference on vacuum level equipping the seed drill  
 475 with the tested kit

476 Figure 7

477 Note for the editor: to be rendered in Black and White

478

479    Tables

480    Table 1 - Pneumatic drill test configuration.

Manufacturer	Gaspardo®MARTA
Seeding elements (n°)	4-6
Fertilizer hoppers (n°)	2
Fan diameter (mm)	410
Fan width (mm)	60
Blades (n°)	10
Blade inclination (°)	31
Blade width (mm)	30
Air outlet size (mm)	230 x 60
Air direction	downwards
Fan rotation speed (rev min <sup>-1</sup> )	5400

481

482

483 Table 2 – Particle sizes of the dust dressed seed, wheat flour “00” and tracer Tartrazine  
 484 E104.

Size particles	Dust of dressed seed	Wheat flour “00”	Tartrazine E102
D <sub>10</sub> (µm)	34.1	35.4	42.6
D <sub>50</sub> (µm)	84.1	74.1	80.1
D <sub>90</sub> (µm)	180.9	163.5	172.3
Density (g cm <sup>-3</sup> )	0.41	0.45	0.44

485 Note: No significant difference - Statistical analysis ANOVA unvaried, p > 0.05.

486

487

488    Table 3 – ANOVA table

	DF	SS	%	F-Value	P-Value
Diameter	2	85959.42	97.8	639.584	0.001
Dust	2	382.91	0.4	2.849	0.084
Interaction	4	320.28	0.4	1.192	0.348
Residual	18	1209.59	1.4		

489    Notes:  $R^2=0.986$

490

491 Table 4 - Wheat flour “00” collected by cyclone.

Test	mean (g)	min (g)	max (g)	DS	IQR	Efficiency (%)
with seeds	99.6	99.2	100.0	0.4	0.7	99.6
without seeds	99.4	98.8	100.1	0.7	1.1	99.4

Note: SD = Standard Deviation; IQR = Interquartile range  
Statistical analysis could not detect any significant difference between test with and without seeds in the hopper

492

493

494    Table 5 - Vacuum ball rotary valve pressure losses.

Hours worked	Pressure losses (mbar)	Increment (%)
0 (new)	0	-
30	0	-
60	0	-
90	0	-
120	0	-
150	2	-
180	3	0.50
210	5	0.67

495