Tarım Makinaları Bilimi Dergisi (Journal of Agricultural Machinery Science)
2011, 7 (1), 61-65

Evaluation of Insecticides Losses from Dressed Seed from Conventional and Modified Pneumatic Drills for Maize

Daniele POCHI[1,*], Marcello BIOCCA[1], Roberto FANIGLIULO[1], Elisa CONTE[2], Patrizio PULCINI[2]
[1]CRA-ING, Agricultural Research Council, Agricultural Engineering Research Unit.
Via della Pascolare 16, 00016 Monterotondo, Roma-ITALY
[2]CRA-PAV, Agricultural Research Council, Plant Pathology Research Center
Via C.G. Bertero, 00156, Roma-ITALY
daniele.pochi@entecra.it

Received (Geliş Tarihi): 08.05.2011 Accepted (Kabul Tarihi): 09.07.2011

Abstract: The utilization of dressed seed for spring sowing is a widespread practice to control some pests with reduced doses of chemical products. Pneumatic drills used in maize (*Zea mays* L.) sowing are charged of contributing to the dispersion of the abrasion dust produced by dressed seeds, favoring the contamination of the environment. Moreover in the last years, some active ingredients (a.i.), namely insecticides belonging to the neonicotinoid family and fipronil, have been claimed to play a role in honeybees (*Apis mellifera* L.) decline. In order to reduce the a.i. drift different devices similar to air deflectors have been introduced on pneumatic drills. This paper refers about a two-year research activity aimed at the following purposes: (1) investigate the critical points of the machines related to seed dressing particle losses during tests carried out at fixed point; (2) design a test methodology in order to determine the a.i. losses; (3) evaluate the a.i. drift in both small and large (about 3 ha) field plots as a consequence of the use of conventional and modified (with air deflectors) pneumatic drills. The adoption of the air deflectors determined a reduction of dust drift at least around 50% of the a.i. amounts observed without deflectors at soil level. Since it is not capable to completely avoid the drift, further studies are needed, aimed at providing engineering solutions on the machineries to obtain a full control of a.i. losses.
Key words: Pesticides, neonicotinoids, honey bee, dust drift, seed coating.

INTRODUCTION

The seed dressing (or coating) with neonicotinoids insecticides (Elbert et al., 2008) and fipronil is a pest control technique against a broad range of species harmful to maize (*Zea mays* L.) and it allows pest control with a reduced amount of insecticide in comparison with other methods. The seed dressing may lead to honey bee (*Apis mellifera* L.) exposure because these active ingredients (a.i.) are highly systemic (except for fipronil), and, during sowing operations, in case of losses of a. i. from the outflow air fan of pneumatic drills, they can reach green and flowering parts of the vegetation in nearby fields (Greatti et al., 2003; Greatti et al., 2006). This may cause direct poisoning (Pistorius et al., 2008) or sub-lethal effects (Bortolotti et al., 2003; Bonmatin et al., 2005) and in the last years, the pesticides employed in maize seed dressing have been claimed to play a role in honeybee decline (Maini et al., 2010; Bortolotti et al., 2009).

As a consequence of dressing process, storage conditions, handling and movements before the drilling, the dressed seeds produce different amounts of abraded dressing particles. The pneumatic drills (largely the most common machines) have a seed distribution system based on vacuum effect created by a centrifugal fan. In these machines the sucked air is expelled through the fan opening, dragging with it powder and seed particles containing dressing substances. Part of these particles will be localized in the ground, near the sowing area; the remaining fraction will be subjected to drift. To reduce this inconvenient and the consequent risk for the bees, drill manufacturers have proposed specific equipments capable to limit dust emission during sowing operations. Outflow fans may, for example, be oriented towards the soil so that dust drift is reduced. In addition, innovative deflecting devices may redirect the air and the dust it contains towards the soil avoiding turbulences and further drift. An effective assessment of these devices compared to conventional equipments is a preliminary requirement to their generalized implementation on seed drills.

The paper refers about a two-year research activity aimed at the following purposes: (1) to investigate the critical points of the machines related to seed dressing particle losses during tests carried out at fixed point; (2) to design a test methodology in order to determine the a.i. losses; (3) to evaluate the a.i. drift in both small (first year of activity) and large (about 3 ha) field plots as a consequence of the use of conventional and modified (with air deflectors) pneumatic drills.

MATERIALS and METHOD

Tests at fixed point

The tests were carried out in the workshop's porch of CRA-ING, in order to obtain a site protected by external influences and enough large to contain the machines. The open side of the porch was closed by means of tarpaulin sheets settled as curtains. In the test site artificial wind conditions have been produced by means of an electric fan rotating at a speed of 1,358 r.p.m. In the "gallery" the average wind speeds were 1.4 m/s at 0.5 m from the soil (min 0.0, max 2.6 m/s) and 1.8 m/s at 2.0 m from the soil (min 1.6, max 2.5 m/s). The test site permitted to maintain a rather constant and uniform air flow both in terms of velocity and direction (perpendicular to the simulated sowing direction).

The drill, suitably placed in the test area, operated the seed distribution "*sur place*" by means of a system allowing to adjust the peripheral speed of the drill's driving wheel. Such a system consisted of an electric engine connected to the driving wheel through a gear-reducer (transmission ratio: 40/1). An inverter (OMRON Varispeed V7) was installed to set the speed of the driving wheel, on the desired value of 1.67 m/s.

With the aim of capturing the depositing dust and providing the concentration of the a.i. at ground level, a 22.5 m long sampling area, leeward with respect to the drill position, has been identified. Along the sampling area, five series of Petri dishes, spaced 4.5 m, have been placed; each series consisted of three Petri dishes spaced 1.5 m; therefore a grid of 15 sampling points was arranged. The Petri dishes were filled with a acetonitrile-water solution, before each test.

Each trial was replicated three times.

Seeds

The trials were carried out using four lots of commercial maize seed (Pioneer Hybreed PR32G44) dressed with four insecticides (Gaucho™, a.i.: imidacloprid; Poncho™, a.i.: clothianidin; Cruiser™, a.i.: thiametoxam, Regent™, a.i.: fipronil) and a fungicide (Celest™, a.i.: fludioxonil and metalaxyl). According to the manufacturers, the quantities of a.i. were respectively equal to 1.000 mg/seed for imidacloprid, 1.250 mg/seed for clothianidin, 0.600 mg/seed for thiametoxam and 0.500 mg/seed for fipronil. The seed was packed in sacks (25,000 seeds/sack).

Pneumatic drills

A six-row precision pneumatic drill "Gaspardo Magica" has been employed (Pochi and Fanigliulo, 2010), with and without an air deflector system applied at the fan opening with the aim of directing the expelled air in the furrows opened for the seed distribution. The deflector system consists of a steel frame, applied at the fan opening, from which the air is directed into the furrows opened by the two central sowing units by means of four flexible plastic pipes. This device can be removed, restoring the "conventional drill" conditions and allowing the comparison between conventional and modified machine. Before each test, the machine underwent accurate cleaning.

The drill was regulated as follows: simulated forward speed of 1.67 m/s; row distance of 0.75 m; seed distance on the row of 0.18 m; sowing density of 75,000 seeds/ha; vacuum pressure of 45 mbar.

During each test, a seed amount of 25,000 seeds was distributed, corresponding to 3,333 m^2.

Field tests

The trials have been carried out in the experimental farms of CRA-ING and CRA-PCM (around 42°5'51.26"; N 12°37'3.52"E; 24 m a.s.l.) from April to July, 2009 and from April to June, 2010.

The drill employed was always set as in the tests at fixed point, with and without the deflecting devices previously described. During the trials, the main micrometeorological parameters were monitored.

The same kind of samplers of the tests at fixed point were employed to evaluate drifted dust at ground level (i.e. Petri dishes containing a solution of acetonitrile and water).

Small plots

During the year 2009, the field tests were carried out in plots of 0.16 ha (40 x 40 m). A sampling zone made of a series of five lines placed at 5, 10, 20, 30, 50 m from the field edge, with three Petri dishes for each distance, was arranged in the leeward side of the plot. For each a. i., the sowing test was replicated three times.

Large plots

During the year 2010 the tests were carried out sowing 3 ha rectangular plots (150 x 200 m). The sampling zone corresponded to a 20 m large belt along the field perimeter. The dust deposition has been monitored on each side of the plot by means of a series of Petri dishes (North, South, East and West), with the aim of capturing the settling dust at ground level independently from the possible changes in wind directions and speed during the trials. Therefore, on each side, a series of three Petri dishes spaced 1.5 m were placed at 5, 10 and 20 m from the field edge; hence a total of 36 sampling points were obtained.

Active ingredients determination

After the trials the liquid was removed and stored in laboratory at temperature of -20°C until the analyses were carried out. The solutions from the plates were sonicated in an ultrasonic bath for 10 min, then filtered with HPLC 0.45 µm filters. The analytical determinations were carried out by means of HPLC - ESI - MS – MS and the relative methods were validated in compliance with GLP procedures.

RESULTS and DISCUSSION

The results of the analyses of residues collected in the samplers (Petri dishes) at the soil level in the three experiments are reported in Tables 1 to 3. The tables show the mean values of the residues (µg/m^2) obtained multiplying the values of residue concentrations of a.i. in the Petri dishes by 105.23 (virtual number of Petri dishes/m^2).

In general, the results showed a regular decreasing of the concentrations for distance increase. Moreover, the difference determined by the adoption of the drift reducing device (air deflectors) resulted clear and it can be quantified at least around 50% of the a.i. amounts observed without deflectors at the soil level (Table 4).

Table 1. Average concentration of a. i. collected in Petri dishes (µg/m^2 ± s.e.) in the tests at fixed point

Drill	Distance [m]	Clothiadinin	Fipronil	Imidacloprid	Thiametoxan
With deflector	4.5	287.97 ± 65.85	161.93 ± 33.72	104.41 ± 15.26	204.84 ± 58.33
	9.0	117.09 ± 15.05	104.29 ± 12.77	36.36 ± 4.89	134.69 ± 12.64
	13.5	101.02 ± 16.95	70.38 ± 4.89	26.66 ± 6.58	55.89 ± 10.52
	18.0	90.26 ± 8.35	27.94 ± 3.79	32.85 ± 7.42	55.07 ± 4.44
	22.5	84.88 ± 5.84	14.77 ± 2.39	9.65 ± 1.13	24.79 ± 3.31
Average		**136.24 ± 22.41**	**75.86 ± 11.51**	**41.99 ± 7.06**	**95.05 ± 17.85**
Without deflector	4.5	603.88 ± 105.20	480.77 ± 72.47	296.86 ± 59.30	308.08 ± 58.91
	9.0	336.49 ± 31.98	269.15 ± 26.17	197.36 ± 35.76	238.98 ± 27.36
	13.5	230.56 ± 23.24	134.57 ± 11.11	112.01 ± 13.29	113.53 ± 28.51
	18.0	152.70 ± 7.15	50.16 ± 3.51	89.33 ± 15.87	164.27 ± 14.51
	22.5	105.69 ± 7.19	29.70 ± 3.28	75.30 ± 13.13	42.32 ± 6.03
Average		**285.87 ± 34.96**	**192.87±23.31**	**154.17 ± 27.47**	**173.44 ± 27.06**

Table 2. Residues collected at ground level for the four a.i. in the trials in small plots [µg/m^2 ± st.dev.]

Drill	Distance [m]	Clothiadinin	Fipronil	Imidacloprid	Thiametoxan
With deflector	5	2.24 ± 1.14	0.90 ± 0.31	3.63 ± 1.586	2.52 ± 1.01
	10	1.46 ± 0.74	0.73 ± 0.20	2.48 ± 0.755	1.41 ± 0.33
	20	1.18 ± 1.00	0.88 ± 0.42	2.16 ± 0.752	1.40 ± 0.29
	30	0.60 ± 0.32	0.59 ± 0.12	1.88 ± 0.481	1.35 ± 0.35
	50	0.57 ± 0.32	0.46 ± 0.21	1.63 ± 0.477	1.08 ± 0.60
Average		**1.21 ± 0.71**	**0.72 ± 0.25**	**2.36 ± 0.81**	**1.56 ± 0.52**
Without deflector	5	4.44 ± 3.43	*	4.19 ± 1.773	4.85 ± 1.804
	10	1.66 ± 0.86	*	2.59 ± 0.968	3.28 ± 0.827
	20	1.73 ± 1.63	*	2.80 ± 1.695	2.84 ± 0.862
	30	1.36 ± 0.69	*	2.77 ± 2.712	2.33 ± 0.682
	50	1.39 ± 0.62	*	1.45 ± 0.386	1.71 ± 0.341
Average		**2.12 ± 1.45**	*	**2.76 ± 1.51**	**3.01 ± 0.90**

* the trials with fipronil with no modified drill showed always recorded values under the strumental detectable limit.

Table 3. Residues collected at ground level for the four a.i. in the trials in large plots [µg/m^2]

Drill	Distance [m]*	Clothiadinin	Fipronil	Imidacloprid	Thiametoxan
With deflector	5	6.25	0.27	3.65	3.16
	10	5.88	0.27	2.74	1.92
	20	4.71	0.11	1.43	2.15
Average		**5.61**	**0.22**	**2.61**	**2.41**
Without deflector	5	11.57	1.15	16.01	6.88
	10	8.13	0.47	7.60	2.84
	20	6.31	0.10	4.07	2.31
Average		**8.67**	**0.57**	**9.23**	**4.01**

* each values is the mean of the four side of the field – explanation in the text.

Table 4. Average percentage reduction of the a.i. detected at soil level in the different experiments caused by the employ of the modified drill with a deflector

Experiment	*year*	imidacloprid	clothianidin	thiametoxan	fipronil
SMALL PLOTS	*2009*	14.6%	42.8%	48.2%	-
LARGE PLOTS	*2010*	71.7%	35.2%	39.8%	61.9%
FIXED POINT	*2010*	72.8%	53.4%	53.5%	60.7%

The observed differences among different a.i. in terms of collected amount of residue may be attributed both to the difference in initial concentrations of a.i. on the seeds and to the chemical characteristics of the dressing components.

In the tests at fixed point the collected large amounts depend on the fact that the sampling area received the same quantity of the a.i. expelled during the sowing of a 0.33 ha field. After the analysis of the obtained data at fixed point (according to the method described in Biocca et al., in press) it was showed that the dust drift amount increased as the dimensions of the sowed field increases. Consequently, it was decided to carry out field studies also in large plots in the second year of the project (2010), comparable to a real maize field in order to validate the findings of fixed point tests and to obtain an evaluation of the amount of drifted dust under such conditions.

CONCLUSIONS

The studies carried out at fixed point to compare modified (with deflector) and conventional pneumatic drills in a controlled system have been useful to calculate the percentage of dust drift reduction after the adoption of the deflecting device (air deflectors).

The comparison of these results with the field test data shows that the curves obtained using the prevision model have similar behaviors to the experimental curves, ranging into intervals of values of the same order of magnitude and confirming the 50% average reduction determined by the application of the air deflector on the drill.

The estimation of the quantity of a.i. expelled by the drills during the sowing, represents the starting point for further studies in which it, conveniently expressed, should be put in relation with the a.i. quantity present on the soil and vegetation surface and considered dangerous to the honey bees. The determination of a threshold value for the drills could allow the development of a drill evaluation system.

Some other practices related to the practical use of the machineries can contribute to reduce field losses (i.e. avoiding an excessive vacuum level that can lead major dust losses) but in general it appears crucial to adopt (also in the case of the seeding operation) the principles of IPM (integrated pest management), addressing the use of dressed seeds only in the contaminated areas.

In conclusion, the use of the deflectors seems to determine significant reduction of the losses of dust and particles from dressed seeds during the sowing, but it is not capable to completely avoid the drift of a.i. in the environment. Consequently, further studies are needed, aimed at providing engineering solutions on the machineries to obtain a full control of a.i. losses.

ACKNOWLEDGEMENTS

The study is a part of the APENET project, a national research activity funded by the Italian Ministry of Agriculture.

REFERENCES

Biocca M., Conte E., Pulcini P., Marinelli E., Pochi D. (in press) Sowing simulation tests of a pneumatic drill equipped with systems aimed at reducing the emission of abrasion dust from maize dressed seed. Journal of Environmental Science and Health. Part B.

Bonmatin J. M., I. Moineau, R. Charvet, M.E. Colin, C. Fleche, E.R. Bengsch, 2005. Behaviour of Imidacloprid in Fields. Toxicity for Honey Bees. In: *Environmental Chemistry. Green Chemistry and Pollutants in Ecosystems*, Chapter 44 Part V; Lichtfouse, Schwarzbauer, Robert, Eds., 483-494.

Bortolotti L., R. Montanari, J. Marcelino, P. Medrzycki, S. Maini, C. Porrini, 2003. Effects of sub-lethal imidacloprid doses on the homing rate and foraging activity of honey bees. Bulletin of Insectology. 56 (1), 63-67.

Bortolotti L., A.G. Sabatini, F. Mutinelli, M. Astuti, A. Lavazza, R. Piro, D. Tesoriero, P. Medrzycki, F. Sgolastra, C. Porrini, 2009. Spring honeybee losses in Italy. Julius-Kühn Archiv. Proceedings *"Hazards of pesticides to bees – 10th International Symposium of the ICP-Bee Protection Group"*. Julius-Kühn-Archiv 423, 148-152.

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

Greatti M., A.G. Sabatini, R. Barbattini, S. Rossi, A. Stravisi, 2003. Risk of environmental contamination by the active ingredient imidacloprid used for corn seed dressing. Preliminary results. Bulletin of Insectology. 56 (1), 69-72.

Greatti M., R. Barbattini, A. Stravisi, A.G. Sabatini, S. Rossi, 2006. Presence of the a.i. imidacloprid on vegetation near corn fields sown with Gaucho® dressed seeds. Bulletin of Insectology. ,59 (2), 99-103.

Maini S., P. Medrzycki, C. Porrini. 2010. The puzzle of honey bee losses: a brief review. Bulletin of Insectology 63 (1) 153-160.

Pistorius J., G. Bischoff, U. Heimbach, M. Stähler, 2009. Bee poisoning incidents in Germany in spring 2008 caused by abrasion of active substance from treated seeds during sowing of maize. Proceedings *"Hazards of pesticides to bees – 10th International Symposium of the ICP-Bee Protection Group"*. Julius-Kühn-Archiv 423, 118-126.

Pochi D, R. Fanigliulo, Seminatrici: innovazioni e tendenze del settore. 2010, Mondo Macchina, 19(3/4), 22-28.