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Evaluation of Pesticides Losses During Cereal Crop Spraying in Tunisian Conditions

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Abstract: In Tunisia, crop spraying is conducted under poorly controlled conditions. Important pesticide amounts are transferred in environment, with negative impacts in ecosystem, health and economy. An original method was developed to assess spray losses during cereal pesticide application, under field and laboratory conditions in Tunisian context. Some natural and artificial collectors were used to trap the droplets containing a fluorescent tracer dye (Brilliant SulphoFlavine: BSF). Four test series were carried out, in wind tunnel and field conditions, under two configurations, to assess spray drift and deposits under the sprayer boom, using a classic flat fan nozzle. The average captured on the ground was 30% to 65% of the sprayed tracer dose and 3% to 15,5% on plants. In the atmosphere, it varied between 8% and 16% of this same volume.
Key words: Pesticide, deposit, drift, emission, modelling.

INTRODUCTION

The use of pesticides in plant protection is a key factor to improve agricultural production. It has contributed considerably to increase yields and ensure regular production. Easy to apply and inexpensive to use, chemical treatments have proved to be extremely efficient and reliable, particularly on large surface areas.

However, the systematic use of pesticides is a source of environmental contamination. Some pesticides can travel long distances under certain conditions, and their deposition may have an impact on sensitive ecosystems, on non-targeted useful or domestic species and on human health, (Bidleman, 1999, Unsworth and al., 1999; Kumar, 2001). These contaminations are varying according to various parameters like meteorological conditions, equipment design, application parameters, spray physical properties and formulation.

Depending on the development stage of the vegetation, 10 to 70% of the application dose may be lost under the sprayer boom (Jensen, 2002), while 30 to 50% may be lost in the atmosphere (Van Den Berg and al., 1999). Thus, the assessment of pesticide losses is necessary to reduce the pollution risk, but it is particularly complex. In practice, it is very difficult to quantify the real losses under the field conditions, while it is possible to apply the modeling approach which permits to multiply test scenarios and to consider the atmospheric conditions (Sinfort and Vallet, 2003). Recently, scientists have developed several types of models to quantify pesticide dispersion in the environment, (Walklate, 1992, Reichard and al., 1992a and 1992b, Zhu and al., 1994 and 1995, Holterman and al., 1997, Teske and Thistle, 1999). In Tunisian context, crop spraying conditions are totally different from those in Europe and America, (atmospheric conditions, sprayer equipment, and treatment parameters). Thus, the obtained results in these regions are not necessarily available in Tunisia. This is why it has been judged important to develop a modeling platform that will allow analyzing different scenarios of environment contamination by spray drift, droplet evaporation and direct losses on the ground.

To quantify these losses and to provide necessary databases, many researchers, (Miller and Hadfield, 1989, Gil and al., 2005) used a simple method that is considered as a standard method, (Costa and al., 2006).

PVC lines (diameter 2 mm) are used to trap the droplets containing Brilliant Sulphoflavine, they are washed in neutral pH water and the BSF concentration is determined by spectrometry. Gil and al. (2005), studied this method in vineyard and showed that these collectors are sufficiently efficient to trap the lost droplets. However, in cereal applications, our tests have shown that nearby the boom, the retention capacity of the PVC lines is exceeded. In this context, an original methodology has been developed to assess ground spray losses, air emissions and quantities trapped by plants for low crops case.

This paper presents these tests and the results obtained under various configurations in Tunisian conditions.

MATERIALS and METHODS

The tests are based on measurements of tracer deposits on ground and emissions to atmosphere, during spraying. They were carried out under field conditions in Tunisian context and controlled conditions in wind tunnel were used to validate the results.

Two equipment configurations were tested with flat fan nozzles spraying 0.5m above the ground: the first one, called "drift configuration" (D+) was supposed favouring drift and emissions to atmosphere. It was characterized by a 02 size nozzle, a pressure of 4 bars giving a VMD of 127 µm. The second one was named "no-drift configuration" (D-) and represented some adjustments limiting drift. It was characterized by a 06 size nozzle and a pressure of 2 bars ensuring a VMD of 322 µm. The experimental method consisted on trapping an aqueous solution of 0.1% of BSF and 0.1% of a surfactant agent on artificial collectors set up in various positions. The tracer is recovered by washing each collector in a known volume of neutral pH water and the concentration was later determined by spectrometry.

The collectors selection

Three kinds of collectors were tested. First, we used PVC lines to trap losses to the air as described above. Secondly, for ground deposits, we used rubber carpets with dimension of 20cmx30cm. They are characterized by a great flexibility and a squared surface presenting some delimited cells, (fig.1) which allowed capturing important deposits. The carpet efficiency was tested in two steps: first, the test of the tracer recovery ratio and then the comparison to the PVC lines results. Finally, we also used wheat plants grown in wood boxes of the same size than the carpets (fig.1). The amount collected on them stand for the efficient amount of sprayed product.

Tests organization

Climatic variables were measured during spraying with an ultrasound anemometer and a humidity sensor installed near the boom. Laboratory tests were released in the Cemagref wind tunnel (a Prandtl tunnel-type with a section of 1.95m x 2.95m). It is equipped with 6 ventilators, an air conditioning system and a heating system. The sprayer boom can be either parallel or perpendicular to the wind direction. Two meteorological configurations have been implemented:

-“Drift configuration, D+”: wind speed: 6m/s, temperature: 30°C, hygrometry: 40%,

-“No drift configuration, “D-”: wind speed: 3m/s, temperature: 25°C, hygrometry: 80%

In field conditions, “D+” and “D-“, were characterized respectively by a wind speed of 4.14 and 2.1 m/s, a temperature of 32 and 30°C, an hygrometry of 54 and 55%.

The duration of each repetition was 20 minutes in the field, (one passage/2mn) and 10 seconds in the tunnel. All configurations were carried out with 3 replications of each one.

Field tests

In field conditions, as well as in the tunnel, experiments were conducted with the boom parallel to wind direction. The objective of these tests was to evaluate off-target deposition of spray, (drift, direct ground deposits and air emissions), depending on meteorological and equipment parameters.

Measure of deposits on ground

Direct ground deposits were measured with three carpets placed under the boom and plant deposits were measured with a wheat box placed in the middle of the sprayed band, (fig. 1). These measurements were not done in tunnel conditions.

To measure drift in field configurations, carpets were installed along an axis parallel to the wind direction, at distances of 1, 3, 6 and 10m downwind the boom extremity (fig. 1).

Air emissions measure

Concerning atmosphere emissions, three PVC 2.85m long PVC lines were placed horizontally across the wind direction, 5m downwind of the last nozzle axis, at three respective heights of 0.5, 1 and 1.5m, (fig. 1).

Wind tunnel tests

Distribution under the boom

The aim of these experiments was to test wind direction effect on nozzles and boom repartition.

The wind tunnel is equipped with a patternator which has a working section of 1.95x2.95 meter and 5cm wide gutters. The liquid repartition was measured for a mean wind velocity of 0 and 3m/s respectively, for a single and a three nozzles boom, located 5 meters downwind inside the tunnel at a 0,5m height from the floor. The tests were carried out with two boom configurations, parallel and perpendicular to the wind axis direction. The first and the last gutter measure were located respectively at 1m and 8m of the last downwind nozzle axis.

Drift and air emissions measure

The scope of these tests was to validate field results concerning drift and air emissions, under controlled meteorological parameters by trapping tracer on carpets placed at difference distances downwind the boom: every half meter from 1 to 3m, all meters between 3 and 6m and every 2m between 6 and 10m. To measure emissions to the air, we used exactly the same protocol as in field tests (fig. 1).

All tunnel experiments were conducted for two velocities: 0 and 3 m/s.

Measurement of tracer collections

The tracer is recovered by washing each PVC line in a volume of 200ml and every carpet in a volume of 500ml of neutral pH water. The loss calculation considers that each collector samples an area that is characterized by its length in the wind axis. The collected mass is extrapolated by the relation between collector width “Ie”, sampling the zone, and the width zone, “dz”. The lost mass in the sampled area is the estimated with the ratio dz/Ie. This amount is normalized by the sprayed volume during the test (10s for tunnel tests). This method will allow calculating the proportion of total losses, on the ground and in the air.

Drift carpet case:

The ground lost tracer proportion over the sampled area is:

$$Q_p = \frac{d}{b_t.n_b.q_b.t.C} \times M_t \qquad (1)$$

Where

d: sampled width of a carpet, [m]

Mt: measured tracer mass on the carpet, [g]

Qp: collected tracer proportion

bt: carpet width (in the boom sense), [m]

nb: boom nozzles number

qb: nozzle flow [l/s]

t: spraying duration [s]

C: tracer concentration [g/l].

PVC lines case:

Assuming that each PVC line samples a height "Hi", the lost tracer amount in the total sampled height is obtained by the expression:

$$Q_p = \frac{H_i}{D_f.n_b.q_b.t.C} \times \sum Mf_i \qquad (2)$$

where:

n: PVC lines number

Df: PVC lines diameter [m]

Mf_i: measured tracer mass on the PVC lines at the position "i" [g]

RESULTS

Collectors efficiency

Spraying a tracer solution with a concentration of 1g/l on the carpets, after washing these collectors, we recovered until 99% from applied dose. The PVC lines were tested in the same conditions and the coefficient carpet/PVC line was of 0.992. Realizing this same test with six wheat-leafs, it was showed that 96% of the applied dose was recoverable.

Distributions on the patternator

Figure 2 illustrates the results relative to the two configurations "D+" and "D-", with two boom situations: parallel and perpendicular to the wind direction. In both cases, the curve obtained with "drift" conditions is higher than that with "no drift" conditions. The curves show that the direction boom has a negligible influence in comparison with the conditions influence, (drift or not drift)

Table 1. Ground losses percentage. D+: drift configuration, D-: no drift configuration, H/ground: PVC line height from ground.

		D+	D-
Carpet distance to the axis of the last nozzle.	1m	3,67%	0,17%
	1.5m	0,72%	0,01%
	2m	0,47%	0,01%
	2.5m	0,44%	0,00%
	3m	0,36%	0,00%
	4m	0,31%	0,00%
	5m	0,19%	0,00%
	6m	0,11%	0,01%
	8m	0,07%	0,00%
	10m	0,04%	0,00%
PVC lines to 5m	H/ground =0.5m	1,67%	0,30%
	H/ground =1m	1,17%	0,17%
	H/ground =1.5m	0,86%	0,20%
Total losses	On ground	6,38%	0,22%
	In atmosphere	3,70%	0,67%
	Total	10,08%	0,89%

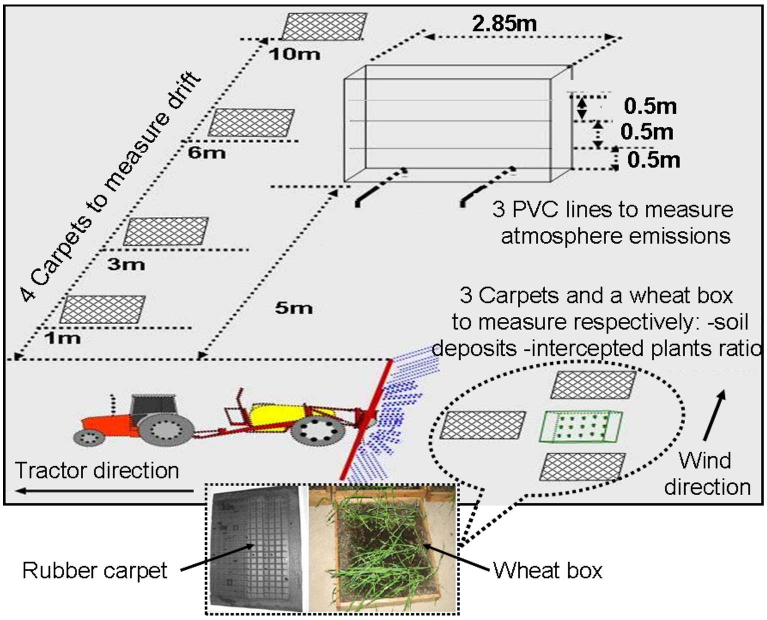

Figure 1. Field test configuration

Ground deposits

Percentages of soil deposition sampled by the carpets are shown in Table 1. A highly significant difference appears between the two tested configurations, "D+" and "D-". Evaluated losses are in the order of 10% with “drift” conditions and less than 1% in the opposite case.

Soil deposits are mainly high for the first collector, after that, they are decreasing very quickly (especially in the non-drift case). With “drift” conditions, atmosphere emissions are about two times greater than ground losses, while in “no drift” conditions, they are three times smaller.

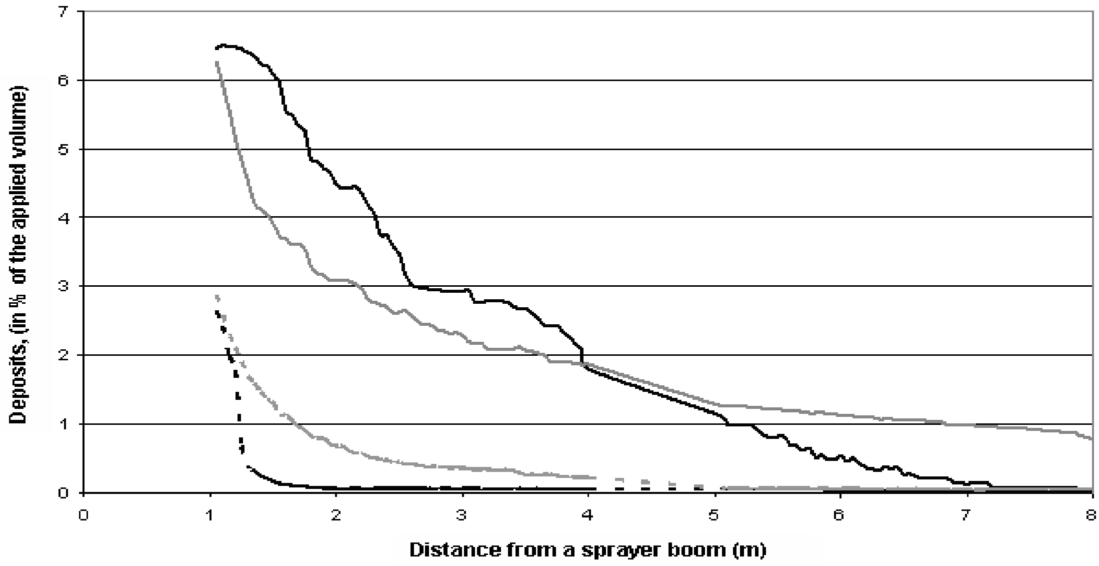

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Figure 2. Measuring deposits in wind tunnel for a three nozzles boom XR02; black mark: parallel boom; grey mark: perpendicular boom; continuous mark: drift configuration "D+"; dotted mark: no drift configuration "D-"

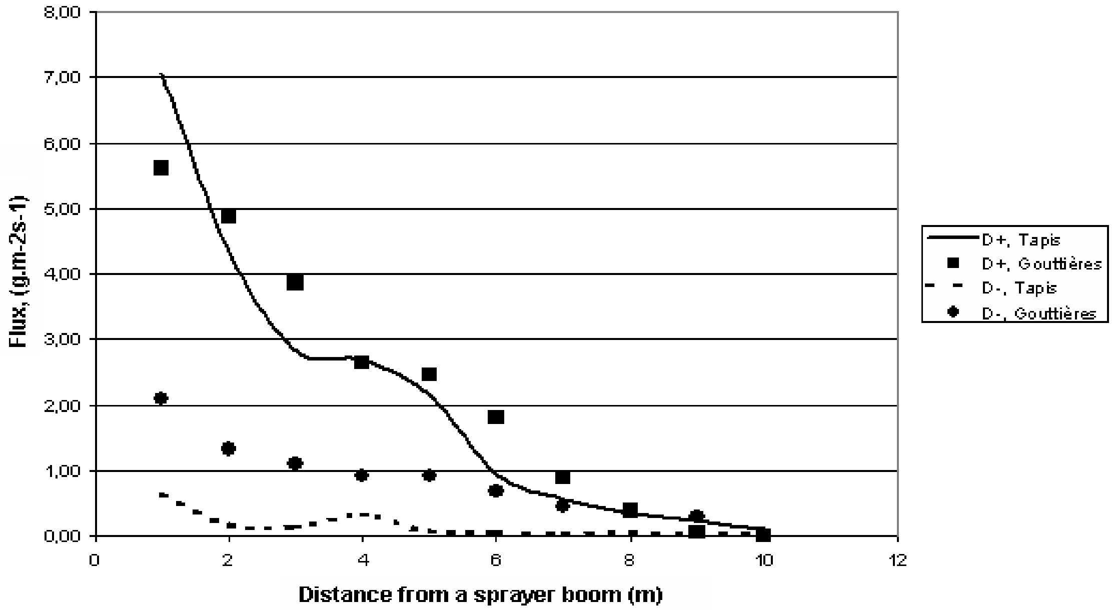

Figure 3. Flow solution trapped on the carpet and in the patternator

DISCUSSION

The two collectors tests show that the rubber carpets and the wheat plants may be used as collectors without significant effect on the results. They have a very good extraction ratio.

To validate these results, flow tracer solution captured by carpets and collected with the patternator has been calculated taking into account the sizes of carpet and gutters and the time of spraying.

Figure 3 shows the obtained flow in both cases. Under the conditions of drift, it can be noted that measures are acceptable, even if the first carpet overstates the lost amount. It may seem normal because, near the boom, carpets trap the tracer in the area where droplets cloud is highly dense, while gutters collect the liquid over the entire tunnel width.

Under no-drift conditions, the measured flow on both carpets and gutters have the same appearance, while the carpets values are lower than those obtained with the gutters.

CONCLUSION

The results presented in this paper provide experimental bases to set up a simulation platform to evaluate losses during pesticide spraying cereal in the Tunisian context.

The tests allowed selecting an adapted methodology to our work context. The adopted protocol provides consistent values, although measured deposits on the carpets are not always fully consistent with measured values on a patternator. It was showed that spraying conditions influence significantly pesticides losses: it reaches a value of 10% with drift conditions, and less than 1% in the opposite case.

Optimizing agricultural practices, particularly pesticides applications, can allow a significant losses reduction with economic and environmental benefits.

Comparison with "DriftSim" results

The obtained data were compared with simulations with the American software "DriftSim", (Zhu et al., 1994 and 1995). This software calculates distances based on drift trajectories of individual drops previously calculated depend on the diameter and external conditions. This software has been validated in wind tunnel with isolated drops. Under our conditions, (wind of 6 m / s, temperature of 30°C, humidity of 100%), it was observed that 1% of the spray was deported to a distance of 121.7m, 9% to 34 m and 20% remain to be 11.7 m.

These values are significantly higher than those measured in the wind tunnel. The assumptions of this model are not adapted to our tests conditions.

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