Aspects of Applied Biology 77, 2006
International Advances in Pesticide Application

Experimental study of factors influencing the risk of drift from field sprayers, Part 2: Spray application technique

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Summary

Recently, spray drift and its effects have become an important aspect of risk assessment in the registration process of pesticides in Belgium. In this regulation, drift reducing spray application techniques can be used to reduce buffer zones. The purpose of this research is to measure and compare the amount of drift sediment for different spray application techniques under field conditions. A drift prediction equation for the reference spraying was used to compare other spraying techniques with the reference spraying, under different weather conditions. Drift measurements were performed for several combinations of nozzle type (flat fan, low-drift, air injection) and size (ISO 02, 03, 04 and 06), spray pressure (2, 3 and 4 bar), driving speed (4, 6, 8 and 10 $km.h^{-1}$) and spray boom height (0.3, 0.5 and 0.75 m). Nozzle type as well as spray pressure, driving speed and spray boom height, have an important effect on the amount of spray drift. Larger nozzle sizes, lower spray pressures and driving speeds and lower spray boom heights generally reduce spray drift. Concerning nozzle types, air injection nozzles have the highest drift reduction potential followed by the low-drift nozzles and the standard flat fan nozzles

Key words: Spray drift, spray application technique, field experiments, spray pressure, boom height, nozzle type and size, driving speed

Introduction

Spray drift continues to be a major problem in applying agricultural pesticides. Factors that affect spray drift include the weather (Threadgill & Smith, 1975; Craig et al., 1998), the physical properties of the spray solution (Bode et al. 1976; Buttler & Bradley, 2002; Klein & Johnson, 2002) and the spray application itself. Different spray application factors have already been evaluated like spray boom height (De Jong et al., 2000), air support (Van De Zande et al., 2000), nozzle type and pressure (Heijne et al., 2002; Klein & Johnson, 2002) and driving speed (Miller & Smith, 1997; Ghosh and Hunt, 1998).

Recently, spray drift and drift reducing techniques have become an important aspect of risk assessment in the registration process of pesticides in Belgium. That is why there is still a need for field drift measurements with different techniques to enlarge the international drift database and to quantify the effect of spray application technique on the amount of spray drift.

In this paper, the amount of spray drift reduction for different spray application techniques is compared to the reference spraying. The effect of nozzle type and size, driving speed, boom height and spray pressure is investigated.

Materials and Methods

Most of the materials and methods used in this research are described in detail in part 1 of this paper: Experimental study of factors influencing the risk of drift from field sprayers, Part 1: Meteorological conditions, i.e. spray liquid, spray drift collectors, determination of drift deposits, experiment design and meteorological measurements. An overview of the experimental set-up for the field measurements is given in Figure 1.

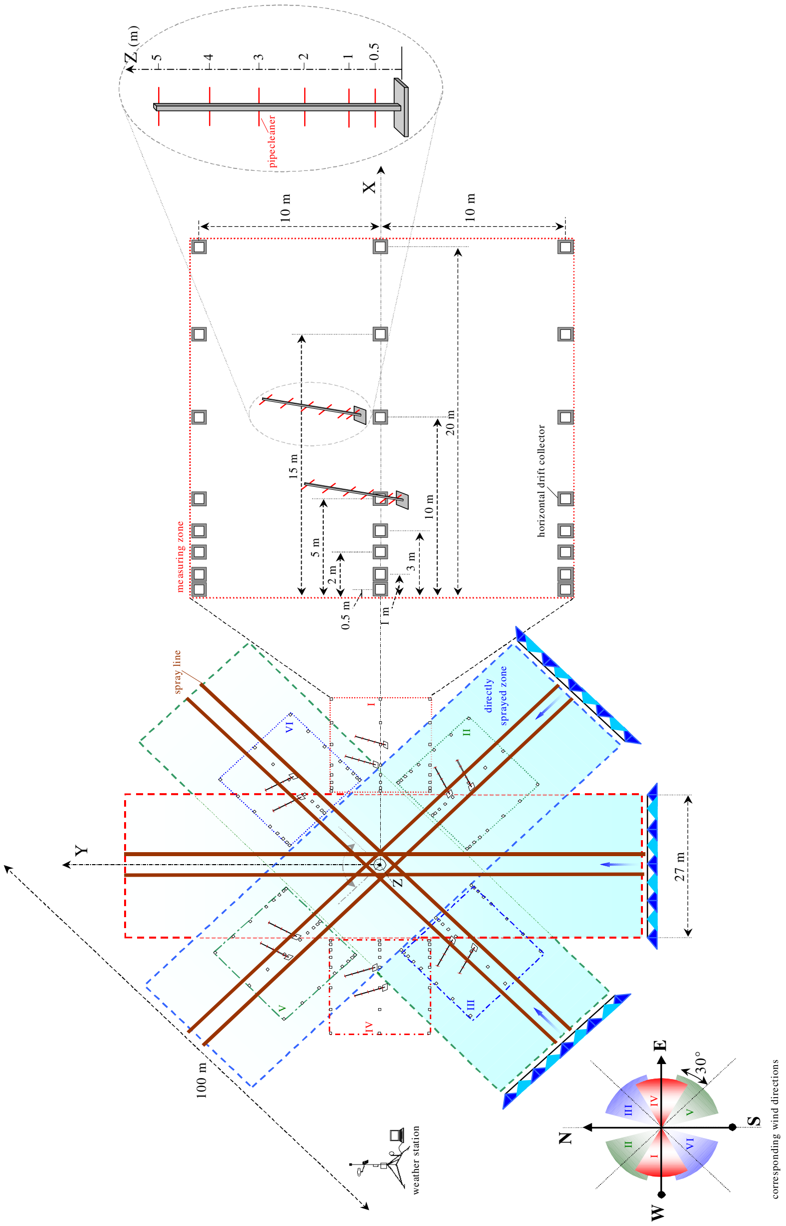

Fig. 1. Schematic overview of the experimental set-up for the field drift measurements.

Sprayer and sprayer settings

Besides the reference sprayings (RS), different other sprayings (OS) were performed for several combinations of nozzle type and size, spray pressure, driving speed and spray boom height with a Hardi Commander Twin Force trailed field sprayer with 27 m boom. Details about the spraying equipment settings for these other sprayings are given in Table 1. Because the conditions during a field measurement of spray drift are influenced by variables relating to the weather, the crop conditions and the spray boom movements that cannot be fully controlled, it is not possible to replicate a given measurement. Therefore, each experiment is replicated at least three times and the drift prediction equation is used as a reference. In total 61 other sprayings (1464 drift measurements) were carried out.

Table 1: *Spraying equipment settings for the different treatments*

Experiment	Nozzle Type	ISO nozzle size	Pressure (bar)	Speed ($km.h^{-1}$)	Flow rate ($l.min^{-1}$)	Application rate ($l.ha^{-1}$)	Boom height (m)	Number of repetitions
				VARIABLE: NOZZLE TYPE (ISO 03)				
A 1-4	**LD**	03	3	8	1.2	180	0.5	4
B 1-3	**Injet**	03	3	8	1.2	180	0.5	3
				VARIABLE: NOZZLE TYPE (ISO 02)				
C 1-3	**F**	**02**	3	8	0.8	120	0.5	3
D 1-3	**LD**	**02**	3	8	0.8	120	0.5	3
E 1-3	**Injet**	**02**	3	8	0.8	120	0.5	3
				VARIABLE: NOZZLE TYPE (ISO 04)				
F 1-4	**F**	**04**	3	8	1.6	240	0.5	4
G 1-3	**LD**	**04**	3	8	1.6	240	0.5	3
H 1-4	**Injet**	**04**	3	8	1.6	240	0.5	4
				VARIABLE: NOZZLE TYPE (ISO 06)				
I 1-3	**F**	**06**	3	8	2.4	360	0.5	3
				VARIABLE: SPRAY PRESSURE				
J 1-3	F	03	**2**	8	0.98	147	0.5	3
K 1-6	F	03	**4**	8	1.39	208.5	0.5	6
				VARIABLE: DRIVING SPEED				
L 1-6	F	03	3	**4**	1.2	360	0.5	6
M 1-5	F	03	3	**6**	1.2	240	0.5	5
N 1-3	F	03	3	**10**	1.2	144	0.5	4
				VARIABLE: SPRAY BOOM HEIGHT				
O 1-3	F	03	3	8	1.2	180	**0.3**	3
P 1-3	F	03	3	8	1.2	180	**0.75**	4
							Total	*61*
				REFERENCE SPRAYING				
Ref 1-27	**F**	**03**	**3**	**8**	**1.2**	**180**	**0.5**	**27**
F: Hardi ISO 110 Standard Flat Fan nozzles								
LD: Hardi ISO 110 Low-Drift nozzles								
Injet: Hardi ISO Injet Air Inclusion nozzles								

Drift results of these specific sprayings are compared with a reference spraying (boom height & nozzle distance: 0.50 m; ISO 110 03 flat fan nozzles at 3 bar; speed: 8 $km.h^{-1}$) by calculating their Drift Reduction Potential (DRP).

The DRP of these other sprayings (OS) is expressed as the percentage of drift reduction compared with the reference spraying (RS) at a certain drift distance. These percentages are calculated by comparing the measured OS drift values ($drift_{OS}$) with the RS drift values ($drift_{RS}$)

predicted by the drift equation (part 1 of this paper) for the same weather conditions using the following formula:

$$\text{DRP}\ (\%) = \left(\frac{drift_{RS} - drift_{OS}}{drift_{RS}}\right) \times 100$$

By means of numerical integration, the Total Drift Reduction Potential (DRP_t, %) of a specific spraying is calculated by comparing the surface under the measured drift curve of this spraying with the predicted surface under the drift curve of the reference spraying, again for the same weather conditions. This variable expresses the total amount of drift reduction of a specific spraying compared with the reference spraying. For the calculation of DRP and DRP_t, average values of the different repetitions are used.

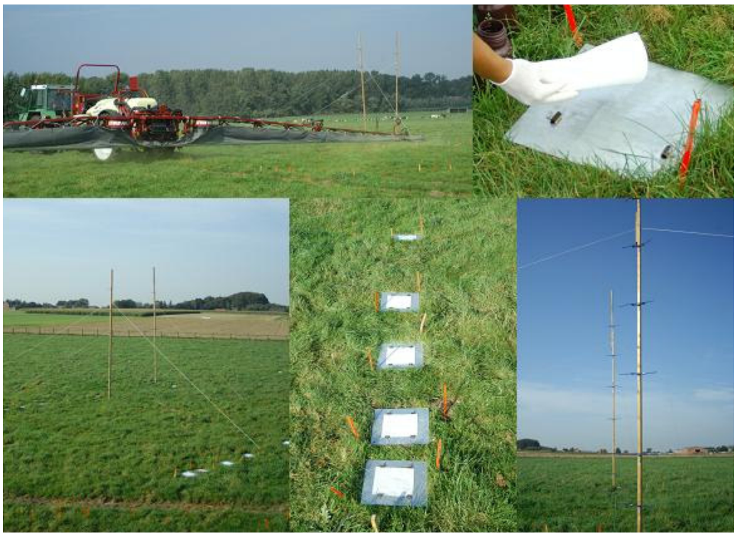

Fig. 2. Some pictures of the experimental set-up for the field drift measurements.

Results and discussion

Weather conditions

An overview of the spreading of the meteorological conditions influencing spray drift for the different measurements is given in Figure 3 i.e. relative humidity, wind speed and temperature. In 12 cases, the deviation of the ideal driving direction exceeded 40°. These experiments were not used in the further analysis. Mind that the spreading of the meteorological conditions for the reference sprayings are also presented and quite parallel. Hence, the drift equation presented in part 1 of this paper, is valid.

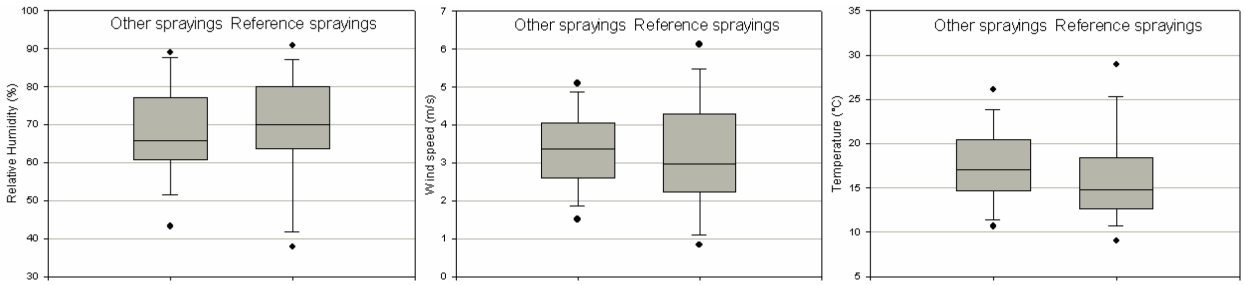

Fig. 3. Overview of the spreading of a. Relative humidity b. Wind speed and c. Temperature.

In Figure 4, Drift Reduction Potentials (DRP) for different nozzle types and sizes (at 3 bar) are presented for different collector distances as well as the total Drift Reduction Potential (DRP_t). These results are based on experiments A up to I (Table 1). Note that collector distances are an approach of the real drift distances because of variations in wind directions, which are different for each specific drift trial. Based on these DRP's and the drift equation of the reference spraying, expected sedimenting drift curves for these nozzle types can be determined for any weather conditions within the range of the drift equation. This is presented in Figure 5 for standard weather conditions (RH= 70 %, V= 3 $m.s^{-1}$, T= 15 °C).

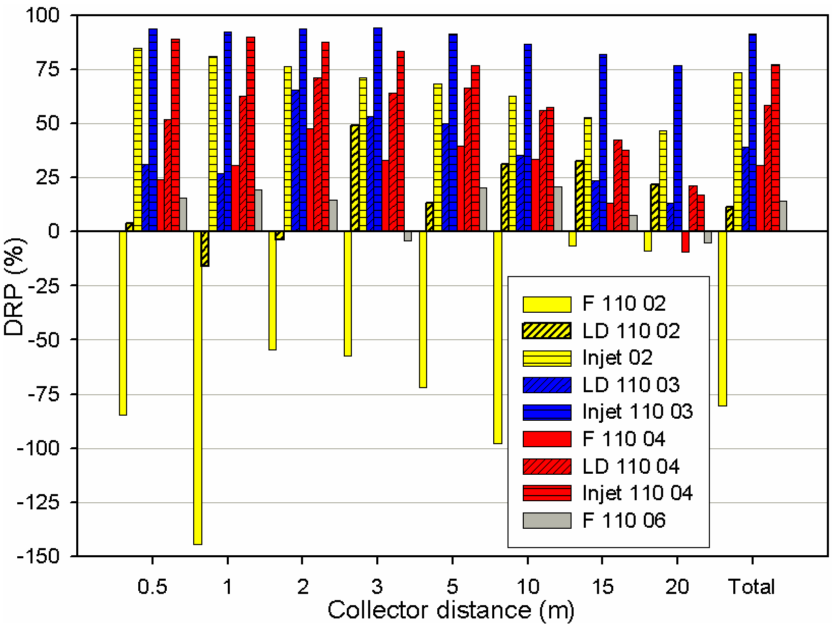

Fig. 4. DRP's for different nozzle types and sizes compared to the reference (F 110 03) at different distances + DRP_t for different nozzle types and sizes.

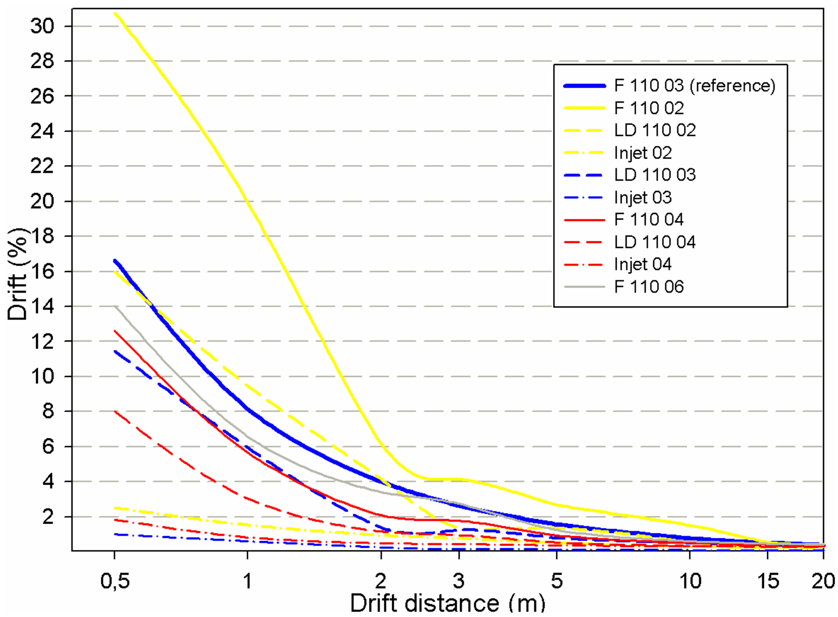

Fig. 5. Drift curves for different nozzle types and sizes at standard weather conditions (RH= 70 %, V= 3 $m.s^{-1}$, T= 15 °C).

It is clear that the nozzle type has an important influence on the amount of drift (Fig. 5). For example, for an ISO 02 nozzle size, DRP_t is –80 % for flat fan nozzles, 12 % for low-drift nozzles and 78 % for air injection nozzles. A similar tendency was found for 03 and 04 nozzle sizes.

Besides the nozzle type, the size of the nozzle is also related to the drift potential. In general, the bigger the nozzle size, the lower the amount of drift. For example, for flat fan nozzles, DRP_t's of –80, 0, 31 and 14 % were found for 02, 03, 04 and 06 nozzle sizes. The DRP_t of F 110 06 nozzles is smaller due to surprisingly high inexplicable drift results in one specific experiment (I 1). Without this outlier, a DRP_t of 47 % is found. This trend is less clear for air injection nozzles where DRP_t's are in each case very high (74 up to 91 %). It is clear that these results are strongly linked with the characteristics of droplet spectra produced by the different nozzles.

For some nozzles (F 110 02, LD 110 02), DRP's vary depending on the drift distances (Fig. 4). To quantify the overall amount of drift reduction, DRP_t values are calculated

Effect of spray pressure

In Figure 6a, DRP's for spray pressures of 2 and 4 bar with the F 110 03 reference nozzles are presented for different collector distances, as well as the DRP_t based on experiments J and K. In Figure 6b, drift curves for three different spray pressures are presented for standard weather conditions based on DRP's (2 and 4 bar) and the drift equation (3 bar).

These results indicate that lowering the pressure from 3 to 2 bar significantly decreases the amount of drift at all distances. A DRP_t of 35 % was found. The effect of raising the pressure from 3 to 4 bar is less clear. Higher drift values are found for small distances and vice versa. In total, the amount of spray drift increases slightly (DRP_t= -4 %).

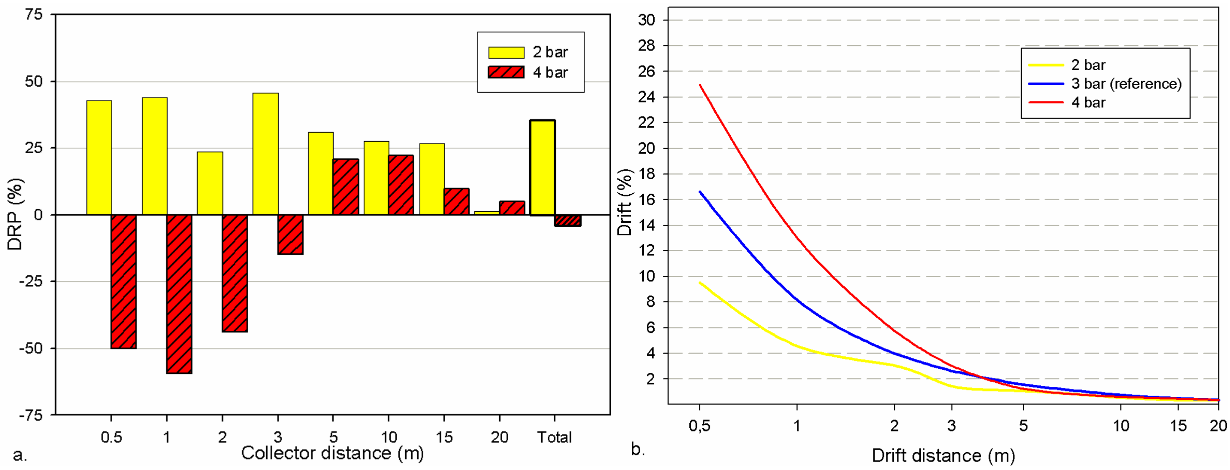

Fig. 6. a. DRP's for spray pressures of 2 and 4 bar compared to the reference pressure of 3 bar (F 110 03 nozzles) at different distances + DRP_t values. b. Drift curves for different spray pressures at standard weather conditions (RH= 70 %, V= 3 $m.s^{-1}$, T= 15 °C).

Effect of driving speed

Figure 7a presents DRP's for different driving speeds (4, 6 and 10 $km.h^{-1}$) and collector distances compared to a speed of 8 $km.h^{-1}$ as well as the DRP_t values based on experiments L, M and N. Figure 7b represents the corresponding drift curves for standard weather conditions based on DRP's and the drift equation.

By increasing the driving speed, the vertical air jet is bended over and distorted. This leads to the smallest droplets escaping from the spray into the atmosphere downwind of the spray resulting in a higher amount of spray drift (Ghosh and Hunt, 1998). This is confirmed by experiments with driving speeds of 4 (DRP_t= 39 %) and 6 $km.h^{-1}$ (DRP_t= 53 %). For a speed of

4 km.h^{-1}, DRP's are small for small distances compared to other distances and compared to DRP's at 6 km.h^{-1}. Probably, this can be attributed to spray boom movements or small deviations in spray line. The difference between a speed of 8 km.h^{-1} and 10 km.h^{-1} is statistically non-significant due to a large variation in DRP's (caused by one inexplicable outlier) between the different repetitions at a speed of 10 km.h^{-1}.

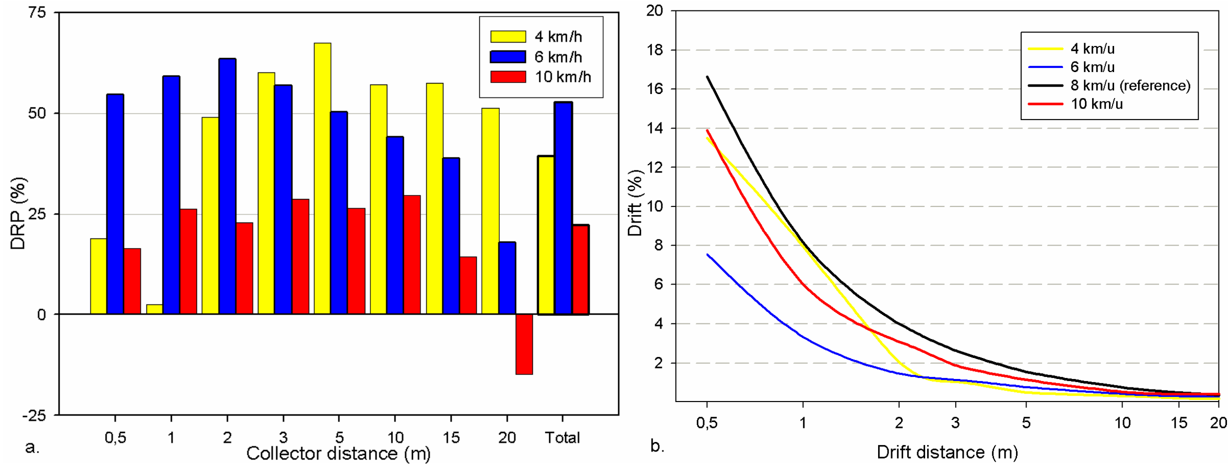

Fig. 7. a. DRP's for driving speeds of 4, 6 and 10 km.h^{-1} compared to the reference speed of 8 km.h^{-1} at different distances + DRP$_t$ values. b. Drift curves for different driving speeds at standard weather conditions (RH= 70 %, V= 3 m.s^{-1} , T= 15 °C).

Effect of spray boom height

Figure 8 a presents DRP's for different boom heights (0.30 and 0.75 m) and collector distances compared to a standard boom height of 0.50 m as well as the DRP$_t$ values based on experiments O and P. Figure 8 b represents the corresponding drift curves for standard weather conditions based on DRP's and the drift equation.

From these results, the effect of boom height is very clear. Lowering the spray boom height from 0.50 m to 0.35 m, decreases the amount of spray drift (DRP$_t$= 52 %) and the reduction is almost constant for all distances. Opposite results were found when raising the spray boom up to 0.75 m resulting in a DRP$_t$ of -22 %

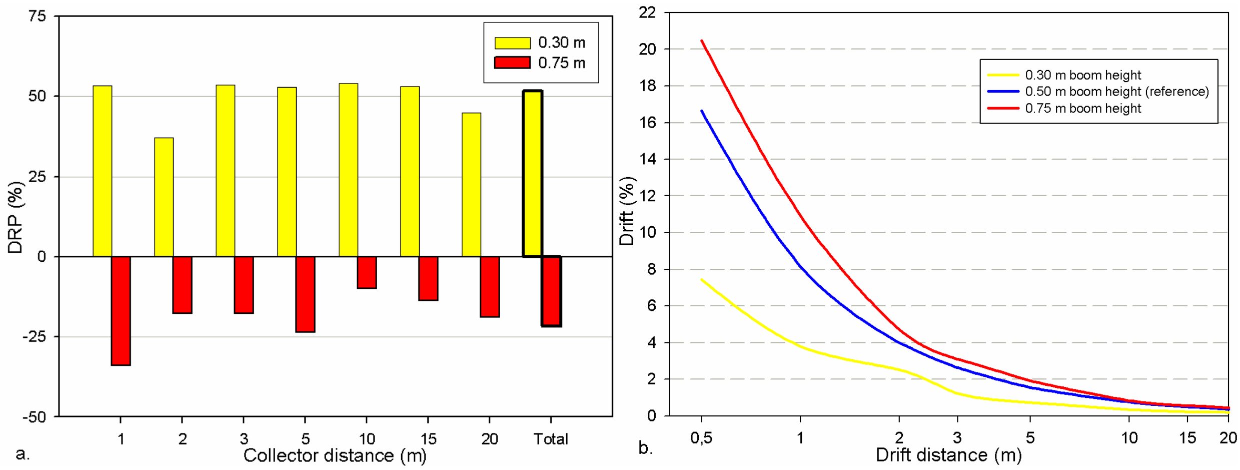

Fig. 8. a. DRP's for boom heights of 0.30 and 0.75 m compared to the reference boom height of 0.50 m at different distances + DRP$_t$ values. b. Drift curves for

different boom heights at standard weather conditions (RH= 70 %, V= 3 m.s^{-1} , T= 15 °C).

Conclusions

In this research, the drift potential of different spray application techniques is compared based on 61 drift experiments under field conditions. A drift prediction equation for the reference spraying was used to compare these techniques with the reference spraying, bringing into account the variation of weather conditions. Drift measurements were performed for several combinations of nozzle type (flat fan, low-drift, air injection) and size (ISO 02, 03, 04 and 06), spray pressure (2, 3 and 4 bar), driving speed (4, 6, 8 and 10 km.h^{-1}) and spray boom height (0.3, 0.5 and 0.75 m).

Nozzle type as well as spray pressure, driving speed and spray boom height, have an important effect on the amount of spray drift. Larger nozzle sizes, lower spray pressures, driving speeds and spray boom heights generally reduce spray drift. Concerning nozzle types, air injection nozzles have the highest drift reduction potential followed by the low-drift nozzles and the standard flat fan nozzles.

Acknowledgements

This research was funded by the Ministry of the Flemish Community IWT-Vlaanderen. The authors wish to thank the technical staff of CLO-DVL and the University Ghent for their assistance and Hardi International for the use of the sprayer.

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