EFFECT OF TANK MIXED ADJUVANTS ON THE DRIFT POTENTIAL OF PHENMEDIPHAM FORMULATIONS

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ABSTRACT

The aim of this paper is to analyse the effect of adjuvants and formulations on drift. The spray liquids consisted of four adjuvants (Actirob 0.4 %, Tensiofix 0.2 %, Break-thru 0.2 %, Silwet L-77 0.1%) with water and with two formulations of Phenmediphame ($C_{16}H_{16}N_2O_4$, 4.45 %): an emulsion-forming (EC) and a suspension concentrate (SC). A standard flat fan nozzle at a pressure of 3 bar was used.
The droplet size spectrum of each combination was determined using a Malvern granulometer. The droplet size was characterized by the volume median diameter (VMD) and the percentage of spray volume contained in droplets <100 µm (%<100). The relative drift potential was measured for each combination of formulation and adjuvant in a wind-tunnel. This latter has a working section 2.0 m wide by 2.0 m high by 6 .0 m long. The air-stream is drawn by a 1.2 m diameter axial flow fan, powered by a 22 kW electric motor. Wind speed was 5 m/s. Its uniformity was controlled by a three-dimensional sonic anemometer able to move on a linear translation beam placed in the tunnel cross section. The wind-tunnel was operated under ambient conditions and three repetitions were performed randomized in order to eliminate variations in temperature and humidity for each combination. The ground spray deposits were measured on glass fibber collectors using a fluorescent tracer dye (sodium fluorescein), at a concentration of 2.5 mg/l.
The statistical analysis of the droplet spectrum showed that the Phenmediphame SC formulation generated droplets of higher size than the EC. The mean VMD values were respectively equal to 228±11 µm and 185±11 µm for these formulations. For SC formulation, Break-thru decreased the VMD while Tensiofix increased the %<100. This confirmed that the degree to which an adjuvant influences spray characteristics is very variable. The drift profiles produced by the different combinations were similar, but the relative drift potential was significantly different comparing SC and EC formulations: it respectively reached 0.8±0,08% and 1.2±0,08%, whatever the adjuvant used in the liquid.
Clearly, when using a flat fan nozzle to spray Phenmediphame, the droplet size and the drift potential are mainly governed by the kind of formulation, even if an interaction between the formulation and the adjuvant exists.

Keywords: drift; formulation; droplet size; adjuvant

INTRODUCTION

Spray drift is now thoroughly considered because it can affect human health and the environment. It has become an important aspect in the registration process of pesticides.
Drift of sprayer has been studied over years by using different techniques. Field studies are designed mainly to measure actual drift as a function of meteorological variables (wind speed, temperature and relative humidity), of

application parameters (nozzles kind, boom height and speed) and of vegetation structure (Ganzelmeier *et al.*, 1995, Weisser *et al.*, 2002, Koch *et al.*, 2003). These studies involve a great amount of field trials and consequently are time-consuming and expensive, further more the number of variables involved makes interpretation difficult. Wind-tunnel techniques have been developed (Miller *et al.*, 1993, Parkin & Wheeler, 1996, Walklate *et al.*, 2000, Murphy *et al.*, 2000) and are being further used to characterize independently the effect of operating parameters on the drift risk in controlled conditions. Whatever the technique used, it appears that drift increases when a high proportion of the spray is produced in fine drops. Several parameters are used to characterise the droplet size spectrum, but the main basic parameter used to explain the drift potential of an application technique are the Volume Median Diameter (VMD) and the volume delivered in droplets smaller than 100 µm (Göbel & Pearson, 1993, Koch *et al.*, 2003). Nevertheless, according to Miller & Butler Ellis (2000), these measurements could lead to misleading information when comparing the risk of drift for different nozzles types.For a given pressure, the droplet size spectrum depends on the nozzle design, on the physical properties of the spray liquid and on the interaction between these two factors. From the Silsoe Research Institute studies on the effect of the physical properties of spray liquid on spray formation(Miller and Butler Ellis 2000, Butler Ellis *et al.* 2001), it appears that the main properties influencing the spray formation process are the dynamic surface tension and the viscosity, even if other factors have to be taken into account. It also appears from Miller and Butler Ellis results that the effect of emulsion based tank-mixed additive on the sprays is to increase the droplet size while surfactant based tank-mixed additive have the opposite effect. The interaction between nozzle and spray liquid was also investigated by Butler Ellis and Tuck (1999) with a study on the formation of sprays for five hydraulic nozzles with seven spray liquids. Even if spray formation mechanism are similar for a spray liquid through each nozzles, changes in droplet size were not the same for all nozzles. The consequence is that the development of a model predicting the droplet size of sprays as a function of the spray liquid remains difficult.

As it comes that the modelling of the spray drift including effect of properties of liquid is hazardous, direct measurements performed in wind tunnels with realistic sprays formulations and wind controlled conditions are the most appropriate solution to obtain accurate quantification of drift. Within this scope, the work reported in this paper analyses the potential drift of a phenylcarbamate herbicide, Phenmediphame ($C_{16}H_{16}N_2O_4$). Two formulations of this low toxicity herbicide are used: an emulsifiable concentrate (EC) and a suspension concentrate (SC), with four different additives. In general, EC formulations are lesser expensive, easier to formulate but more toxic regarding to the solvents needed to maintain emulsion than SC formulations. These latter contain more surfactant than can improve adhesion and coverage of the crop and are more stable in water than EC. The chosen tank-mix additives are not dedicated to one particular formulation but for several applications. In the study, a standart flat fan nozzle type is used to determine how the spray mixture effect on spray formation and on spray drift is influenced.

MATERIALS AND METHODS

Spray mixtures and nozzles

Two phenmedipham ($C_{16}H_{16}N_2O_4$) formulations were evaluated: Betanal (Bayer Crop Science), an emulsifiable concentrate (EC, 157 g/l), and Kemifam SC (Bayer Crop Science), a suspension concentrate (SC, 160 g/l). Each formulation of this sugar beet widely used phenylcarbamate herbicide was mixed at the rate 4.45 % of mass which is within the Belgian authorized concentration. Four additives belonging to different chemical families were selected: Actirob B (esterified crop oil, 0.40 %), Tensiofix D03 (non-ionic surfactant, 0.20 %), Break-thru S-240 (organo-silicone surfactant, trisiloxane, 0.15 %), Silwet L-77 (organosilicone surfactant, heptamethyltrisiloxane, 0.10 %). Fifteen combinations were tested, including the two phenmedipham formulations alone or mixed with the additives. (Table 1). Water alone and water mixed with the additives were used as reference.

A FF 110/0.8/3.0 flat fan nozzle was used to spray the mixtures at a constant 3 bars pressure using a centrifugal pump (0.80 l/min).

Table 1. Description and concentration of the 2 formulations and 4 tank-mix additives used to make the 15 spray mixtures combinations.

Name	Description	Concentration
Formulation		
KEMIFAM SC	Suspension Concentrate of Phenmedipham (160g/l)	4.45%
BETANAL	Emulsion Concentrate of Phenmedipham (154g/l)	4.45%
Tank mix additive		
Actirob B	Esterified crop oil	0.40%
Tensiofix D03	Non-ionic surfactant	0.20%
Break-thru S-240	Organo-silicones surfactant (Trisiloxane)	0.15%
Silwet L-77	Organosilicone surfactant (Heptamethyltrisiloxane)	0.10%
Spray mixtures		
Water	Kemifam SC	Betanal
Water + Actirob B	Kemifam SC + Actirob B	Betanal + Actirob B
Water + Tensiofix D03	Kemifam SC + Tensiofix D03	Betanal + Tensiofix D03
Water + Break-thru S-240	Kemifam SC + Break-thru S-240	Betanal + Break-thru S-240
Water + Silwet L-77	Kemifam SC + Silwet L-77	Betanal + Silwet L-77

Spray characteristics

The droplet size spectra were measured using a Malvern Particle Analyser (Mastersizer S) (University of Gent, Belgium). As the droplets diameter is known to be variable across the spray, three measurements were performed to sample the spray plume at 30 mm spacing, 150 mm down the nozzle tip, perpendicular to the main nozzle axis for the elliptical sprays of flat-fan nozzle. Measurements of spray droplets size distributions were analysed to determine the Volume Median Diameter (VMD) and the percentage of liquid volume contained in droplets less than 100 µm (%<100µm).

Spray drift trials

The drift of the 15 spray mixtures was determined in the aerodynamic wind tunnel facility at Gembloux Agricultural University, Belgium. This is a closed loop re-circulating wind tunnel designed around a 1200 mm diameter axial blower driven by a 22kW electric motor with variable speed controller. To minimise inherent turbulence intensity, the wind tunnel has a 1 m long honeycomb of 200*200 mm square tubes with a monoplane wind-break grid upstream and a porous textile sheet downstream to produce the desired turbulence intensity and uniform mean velocity profile. The test section of the wind tunnel is 2 m wide, 2 m high and 6 m long and located 1 meter downstream of the fabric. The blower located at the loop opposite to the test section drew air through the tunnel at the desired velocity within the range 0-6 m/s. The wind tunnel is mainly constructed of galvanised sheet metal and contains several clear plexiglass windows along the test section.
The nozzle under test was mounted in the wind tunnel on a computer controlled servo-motor traversing mechanism that move the nozzle horizontally at a 2 m/s speed, perpendicular to the air flow, 10 times across the working section of the wind tunnel (Figure 1).

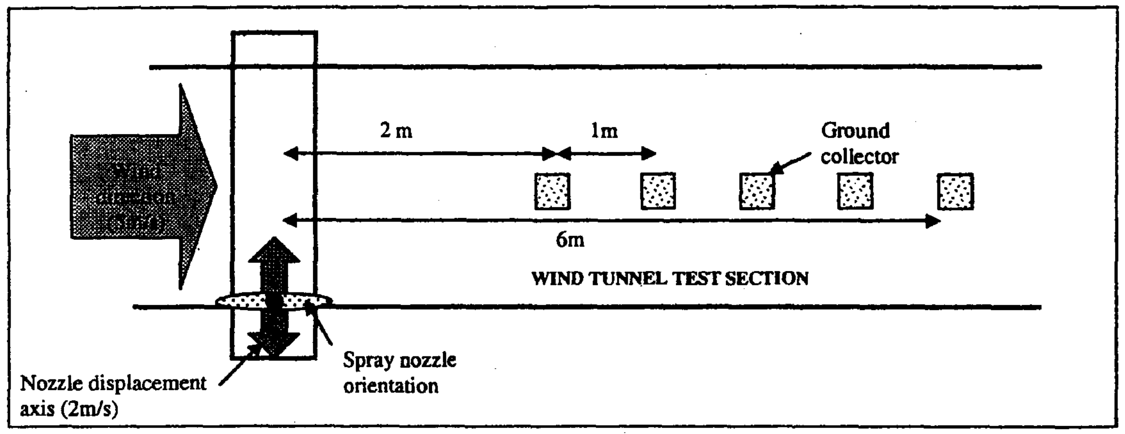

Figure 1. Wind tunnel trial setup for drift measurements

Three repetitions were made for each nozzle-mixture combination. The drift was evaluated by measuring the ground spray deposits on glass fibber collectors using a fluorescent tracer dye technique for 5 m/s wind to maximise drift. The deposits were measured every 1 meter from 2 to 6 m downwind the nozzle, for a total of 5 sampling points. Four 25*100 mm fibber glass collector were fixed to a clean tile with a rubber band for each sampling point to avoid unwanted contamination of the sampler with some residue on the tunnel floor. The rubber band was parallel to the air flow to limit the effect on the collector efficiency. The samplers were collected directly after the trial in 50 ml plastic tubes and stored in darkness. Fluorescein sodium salt (Sigma-Aldrich) was extracted by washing for 5 minutes in potassium phosphate buffer solution and quantified using a LS-50b Perkin-Elmer fluorometer using a combination of a primary and secondary filters of respectively 490 nm and 510 nm. From the reading of the fluorometer, the calibration line, the collector surface area, the dye concentration and the volume of solution, the amount of spray deposit per unit area was calculated. To allow statistical analysis of the wind tunnel trials, the curve obtained for spray deposits recovered on the sampler (Figure 2) has been reduced to one number. Herbst (2001) defined such a number for vertical drift profiles (DIX).

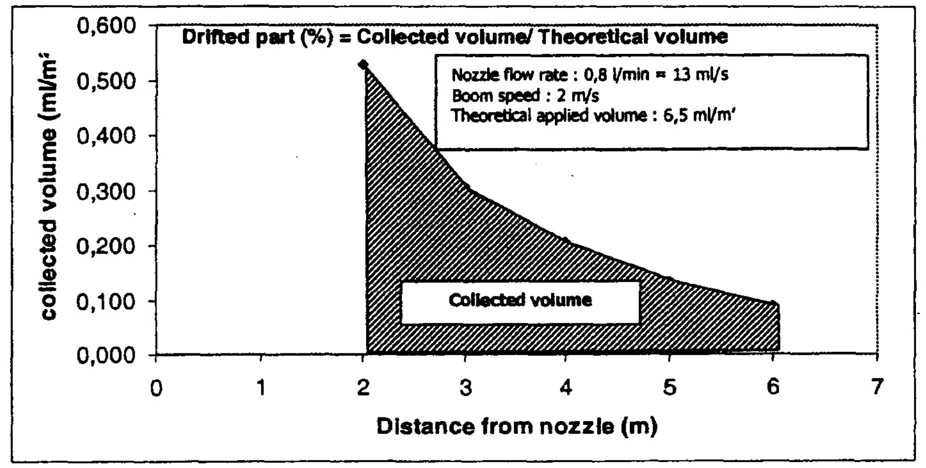

Figure 2. Horizontal drift curve and Drifted Part illustration, flat-fan nozzle, 3 bar pressure, 50 cm height, 2 m/s boom speed and 5 m/s wind speed.

For our horizontal drift measurements, a Drifted Part (DP) parameter was defined as the part of the sprayed volume drifted between 2 and 6 meters. DP was computed from the spray deposits as follow:

$$DP = \frac{100 \times v \times D \times (\frac{d_{2m}}{2} + d_{3m} + d_{4m} + d_{5m} + \frac{d_{6m}}{2})}{q}$$

With
DP : Drifted Part between 2 and 6 m (%)
d_{im} : Spray drift deposit on collector located i meters downwind from the nozzle (ml/m²)
v : nozzle speed across the tunnel (m/s)
D : distance between two collectors (m)
q : nozzle flow output (ml/s)

RESULTS AND DISCUSSION

Droplet size measurements

The statistical analysis is based on ANOVA to highlight interactions between parameters and Newman & Keuls multiple comparisons stepwise method to determine limits of groups of same behaviour. Table 2 first and second column are relative respectively to the VMD measurements and group classification while the third and fourth column shows values and groups for the % <100 μm measurements for all 15 mixtures these statistical tests gave two levels of interactions effects. The spray droplet spectra was mainly affected by the kind of formulation and to a lesser extend by the tank-mixed additive. Some differences appeared between both formulations with this nozzle whatever the adjuvant mixed. Regarding to water mixtures, EC formulation mixtures generated a mean VMD increase of 28 % while SC formulation VMD were similar to that of water with a 4% variation. These former results vary between tank mixed additives for each formulation. A statistical classification between additives for each formulation is given Table 2. The droplet distribution shows significant differences between additives while they are tested in water alone. However, when mixed with SC or EC formulation, the additive effects are hidden except for SC + Tensiofix spray mixture. Table 2 also show that VMD and %<100μm are highly related, what result in a similar classification.

Table 2. Measurements and statistical grouping results of the 15 spray mixtures for VMD (μm), %<100μm with a fiwed flat fan nozzle (3 bar pressure) and Drifted Part (%) for a moving flat fan nozzle (3 bar pressure, 50 cm height, 2 m/s boom speed and 5m/s wind speed) .

	Flat-fan					
	VMD		%<100μm		DP	
	Value	Group 1	Value	Group 1	Value	Group 1
water (w)	142	1a	32	1a	9.40	1a
w + actirob	293	1b	4	1b	6.47	1b
w + tensiofix	118	1a	40	1a	14.03	1c
w + break-thru	124	1a	38	1a	13.37	1c
w + silwetL-77	215	1c	10	1c	12.40	1c
	Value	Group 2	Value	Group 2	Value	Group 2
SC	253	2a	7	2a	7.20	2a
SC+ actirob	243	2a	8	2a	8.63	2a
SC + tensiofix	184	2b	16	2b	8.90	2a
SC + break-thru	220	2a	10	2a	7.53	2a
SC + silwetL-77	239	2a	9	2a	7.29	2a
	Value	Group 3	Value	Group 3	Value	Group 3
EC	195	3a	14	3a	14.47	3a
EC+ actirob	195	3a	14	3a	15.33	3a
EC + tensiofix	185	3a	16	3a	15.94	3a
EC + break-thru	175	3a	21	3a	15.06	3a
EC + silwetL-77	178	3a	18	3a	15.44	3a

Drift measurements

Figure 3 presents the flat fan nozzle horizontal drift profile measured for water, SC and EC formulation without additives. The low variability between repetitions confirms the good repeatability of the measurements. If we focus only on the formulation effect, the SC formulation increases significantly the drift level with regard to water while the EC formulation decreases drift level for the flat-fan nozzle. The Figure 4 shows the tank-mix additive effect on the drift curve with water alone (a), SC (b) and EC (c) formulation. Tested in water, Tensiofix, Break-thru and silwet L-77 give a higher drift curve than water while Actirob give a lower curve. The Neuman & Keuls test on the DP of those curves used to establish same behaviour groups, underlines three DP levels for group 1 (Table 2, 6th column): the 1a water level.

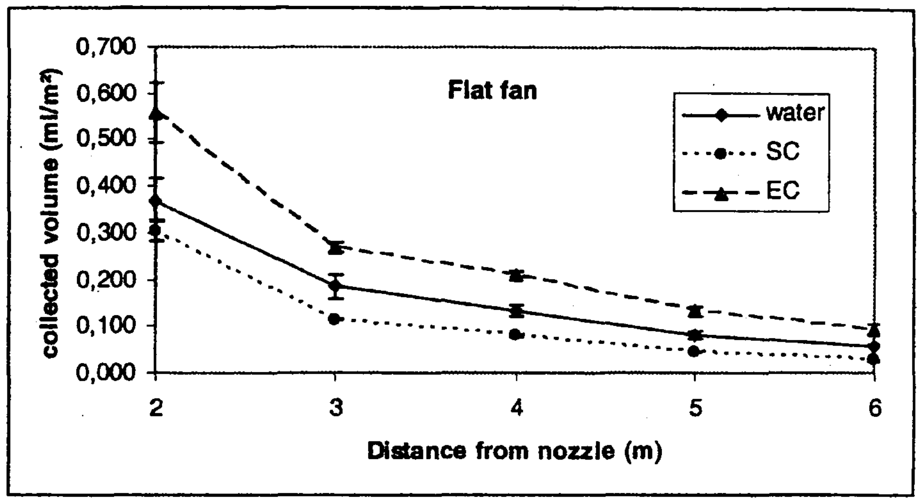

Figure 3. Mean drift curve of water, SC formulation and EC formulation for a flat-fan nozzle, 3 bar pressure, 50 cm height, 2 m/s boom speed and 5 m/s wind speed.

The 1b level having significantly smaller DP than water contains Actirob while tensiofix, break-thru and silwet L-77 are in 1c group than shows significantly higher drift potential than water. The effect of tank-mix additive is much smaller when SC formulation is present as shown in Figure 4b. The statistical test gives no significant differences between Drifted Part of the five different mixtures from the group 2. The same conclusion appears when additives are used with EC formulations where DP differences are further reduced (group 3). This main effect of formulation on mixture behaviour, whether tank-mix additives are present or not, could be explained by the high concentration of the phenmediphame formulations (manufacturer recommended 4.45 %) relatively to the range of the additive concentrations (between 0.1 and 0.5 %). Indeed EC and SC phenmedipham formulations also contain a large amount of co-formulates which concentrations can be higher than tank-mix additives, (a.e. Kemipham SC contains 40 % of vegetable oil than represent 1.78 % volume compared to the 0.4 % of the oil tank mix additive Actirob), leading to a moderate effect of the later ones on the droplet and drift behaviour.

Relations between droplet size distributions and drifted part

The correlation coefficient between VMD and drifted part is being quite poor (R^2 = 0.38), it appeared that there is no clear relations between droplet size and drift. As a matter of fact, even if it is widely known than VMD or %<100μm are good drift indicators, regarding to measurements made with the same liquid and similar spray nozzles of different flow rate, the present results confirm Butler Ellis and Bradley (2002) observations on the effect of formulations on spray drift. This poor correlation may result from the lower range of droplet size variation and influence of the formulation on other spray parameters as droplet initial velocity.

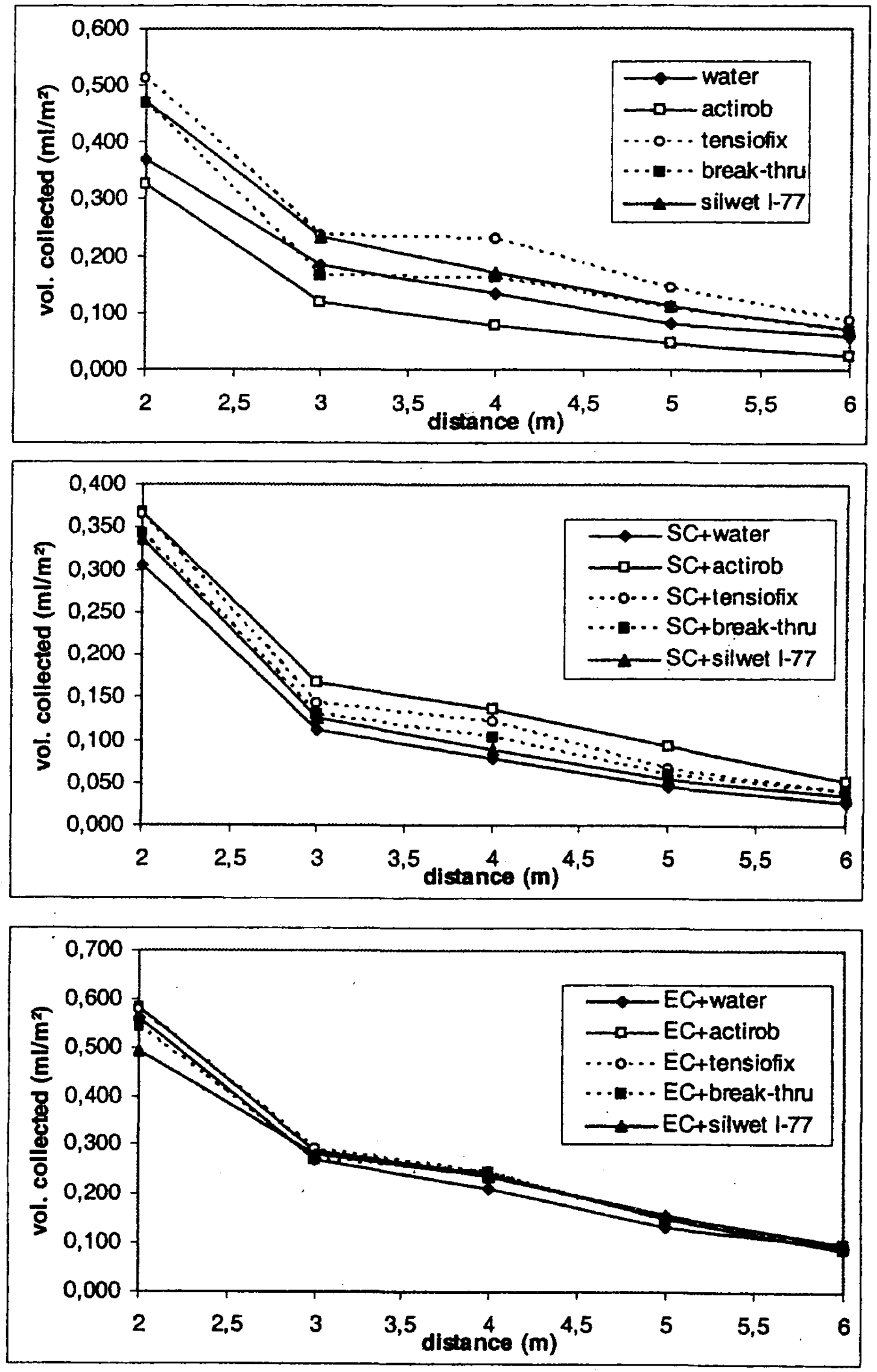

Figure 4. Drift curves of (a) water and additives , (b) SC formulation and additives, (c) EC formulation and additives sprayed with the flat-fan, 3 bar pressure, 50 cm height, 2 m/s boom speed and 5 m/s wind speed.

CONCLUSION

The effect of spray mixture on the droplet size spectra and drift was investigated for a flat-fan nozzle. The effect of the four tank-mix additives on whether the droplet size spectra or drift, was greater in pure water than in both formulations where their effect was damped. The mean effect of SC formulation was to decrease drift while it was increased for the EC formulation. The drift was not found highly correlated with the droplet size spectra parameters.

REFERENCES

BUTLER ELLIS M.C. & BRADELEY (2002). The influence of formulation on spray drift. Aspect of Applied Biology 66, International advances in pesticide application, 257-259.

BUTLER ELLIS M.C. & TUCK C.R. (1999). How adjuvants influence spray formation with different hydraulic nozzles. Crop Protection **18**:101-109.

BUTLER ELLIS M.C., TUCK C.R. & MILLER P.C.H. (2001). How surface tension of surfactant solutions influences the characteristics of sprays produced by hydraulic nozzles used for pesticides application. Colloids and Surfaces A: Physicochemical and Engineering Aspects **180**:267-276.

GANZELMEIER H., RAUTMANN D., SPANGENBERG R., STRELOKE M., HERRMANN M. WENZELSBURGER H.J. & WALTER H. (1995). Studies on the spray drift of plant protection products. Mitteilungen aus der Biologischen Bundesanstalt für Land- und Forstwirtschaft. Berlin-Dahlem. Heft 305. pp 51

GÖBEL & PEARSON (1993). Drift reduction by spray nozzle techniques. Second International Symposium on Pesticide Application Techniques, 219-226.

HERBST A. (2001) A method to determine Spray Drift Potential from nozzles and it link to buffer zone restriction, ASAE Paper 011047, ASAE international meeting, Sacramento, California, USA, July 30-August 1, 2001

HEWITT A.J. (2000). Spray drift: impact of requirements to protect the environment. Crop Protection **19**:623-627.

KOCH H., WEISSER P. & LANDFRIED M. (2003). Effect of drift potential on drift exposure in terrestrial habitats. Nachrichtenbl. Deut. Pflanzenschutzd. **55(9)**:181-188.

MILLER P.C.H. & BUTLER ELLIS M.C. (2000). Effects of formulation on spray nozzle performance for applications from ground-based sprayers. Crop Protection **19**:609-615.

MURPHY S.D., MILLER P.C.H. & PARKIN C.S. (2000). The effect of boom section and nozzle configuration on the risk of spray drift. Journal of Agricultural Engineering Research **75**:127-137.

PARKIN C.S. & WHEELER P.N. (1996). Influence of spray induced vortices on the movement of drops in wind tunnels. Journal of Agricultural Engineering Research **63**:35-44.

WALKATE P.J., MILLER P.C.H. & GILBERT A.J. (2000). Drift classification of boom sprayers based on single nozzle measurements in a wind tunnel. Aspects of Applied Biology 57, Pesticide Application, 49-56.

WEISSER P., LANDFRIED M. & KOCH H. (2002). Off-crop drift sediments on plant surfaces - exposure of non-target organisms. Aspects of Applied Biology **66**:225-230.