Reduction of Spray Pressure Leads to Less Emission and Better Deposition of Spray Liquid at High-Volume Spraying in Greenhouse Tomato

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Abstract

In an experimental greenhouse, growing a tomato crop, it was investigated if a reduction in spray pressure could improve the spray result, while, simultaneously, emission to the ground could be reduced. Spray deposition on the leaves and the emission to the ground was evaluated at different spray pressures (2.5, 5, 10 and 15 bar). An Empas vertical spray mast with 6x2 Teejet XR8002VK flat fan nozzles was used to spray the tomato crop in three stages of crop growth, respectively 0.75, 2.25 and 2.80 m height, spraying 500-1500 l ha^{-1} (stage 1) and 1000-3000 l ha^{-1} (stage 2 and 3) depending on the spray pressure. Flow rate ranged from 0.74 to 1.80 l min^{-1} at an increasing spray pressure from 2.5 to 15 bar. The VMD (Volume Median Diameter) decreased in the same pressure range from 207 to 124 μm. The emission of spray liquid to the ground was measured in the spraying path and beneath the plants between the rows closest to the spray mast. The highest emission to the ground appeared closest to the spray mast, and increased at higher spray pressures. In crop growth stage 1 and 2 about 35% of the spray volume emitted to the ground, in stage 3 only 15%. The direction of the nozzles (upwards directed with an angle of at least 40^0) appeared to be of great importance. The deposition of spray liquid on the leaves was measured at two rows (A: closest to the sprayer, B: the next row behind it) at one, two or three heights depending the stage of the crop. Highest spray deposition could be found in row A, at the upper side of the leaf and at a higher working pressure. Differences were smaller in the next row and at greater height in the plant. Finally it could be concluded that a decrease in spray pressure to 5 bar gave an adequate deposition on the leaves in μl cm^{-2}, and a decrease in emission to the ground.

INTRODUCTION

In Dutch greenhouse horticulture chemical pesticide application takes place with spray pressures of 5 to 15 bar, spraying up to 3000 l ha^{-1} (Van der Knaap and Koning, 1991; Van der Staaij and Douwes, 1996a). Chemicals are applied as a concentration (grams per litre) of applied volume rate and not as a certain amount per ha. Consequently, there is runoff from the leaves of the surplus of spray solution to the ground. This runoff is a big potential emission to the environment (Meerjarenplan Gewasbescherming, 1991), resulting in a higher risk of the pests and diseases for resistance to chemicals. High pressures result in a faster wearing of the nozzles and therefore in a more heterogeneous release, more chemical residuals on fruits and flowers and, not unimportant, higher labour input and costs. The Multi Year Crop Protection Plan (Ministry of Agriculture, 1991) demanded the greenhouse sector to reduce the use of chemical crop protection products with 65% by the year 2000. Present methods of application techniques in fruit vegetables (75% of greenhouse vegetable production) show a switch from crop directed spraying to space treatments. In 2001 (LTO, Milieujaarverslag Glastuinbouw) 72% of the chemicals were applied with space treatment, mainly Low Volume Mister (LVM). This method requires little labour but its effectiveness is limited and its potential emission to the environment is much higher than of crop directed spraying; reason for the Ministry of Agriculture to focus on crop directed spraying of chemicals. Commercial growers use a spray mast with spray pressures ranging from 10-15 bar, spraying a volume of 1500 (tomato) to 2500 l ha^{-1} (sweet pepper) (Van der Knaap and Koning, 1991; Van der Staaij and Douwes, 1996b).

The aim of the described experiment was to investigate if spraying with reduced spray pressures (2.5, 5, 10 and 15 bar) could improve the deposition of spray liquid on the leaves and could decrease the emission to the ground.

MATERIAL AND METHODS

In a 300 m^2 greenhouse (2 spans of 6.4m x 24m) a tomato crop (2.7 plants per m^2) was grown in a high wire system, planted at January 10. Spraying was done at three crop growth stages (February, 75cm high; March, 225cm high and May, 280cm high) with an Empas spray mast at spray pressures of 2.5, 5, 10 and 15 bar, measured at 0.5m before the nozzles in four repetitions. The spray mast moves over the pipe-rail system and is pulled backward, while spraying, by an automatic reel with a speed of 40m min^{-1}. Two Teejet XR8002VK flat fan nozzles were placed at the mast at each height of 25, 60, 95, 130, 165 and 200 cm above the ground; one spraying to the left, the other to the right. In crop growth stage 1 only the three lowest nozzles were opened, realizing a total dosage in stage 1 of 496, 813, 1235 and 1534 l/ha at respectively 2.5, 5, 10 and 15 bar spray pressure. In stage 2 and 3 (all 6 nozzles opened) respectively 992, 1626, 2496, 3068 l/ha was sprayed at 2.5, 5, 10 and 15 bar. Lowest set of nozzles was spraying with an angle of 30^0 upward, second set sprayed horizontally and third set of nozzles sprayed 15^0 downward. In crop growth stage 2 all nozzles were opened, with the lowest set spraying 30^0 upward, and the highest set 30^0 downward, while the others sprayed horizontally. In crop growth stage 3 the direction of all nozzles was 45^0 upward. From three Teejet XR8002VK flat fan nozzles the droplet size spectrum was measured (Phase-Doppler Particle Analyser; Aerometrics-PDPA) at the four spray pressures of 2.5, 5, 10 and 15 bar.

Spray deposition on the leaves was measured on collectors (chromatography paper, Whatman no. 1, 2x20 cm) placed at one, two or three heights in the crop depending on the stage of crop growth (Fig. 1). Collectors were folded around the leaf to measure amounts at the top and at the bottom side of the leaf and at two rows, one close to the path (A) and one in the following row (B). For measuring emission to the ground collectors made of filter tissue (Technofil TM290, 8x100 cm) were placed in one path and between two rows below the plants, while spraying took place in three additional nearest paths (Fig. 1). The fluorescent tracer Brilliant Sulfo Flavine (BSF; 0.28 g/l) was added to the tank mix to quantify spray deposition. After spraying chromatography paper and filter tissue collectors were collected and analysed in the laboratory using a Perkin-Elmer fluorimeter (LS2B), following a standard protocol (Michielsen and Porskamp, 1993). The data were statistically analysed for each crop growing stage and for spray deposition and emission separately with the programme GenStat Release 7.

RESULTS AND DISCUSSION

Droplet Size

Decreasing the spray pressure from 15 to 2.5 bar decreases the flow rate from 1.80 to 0.74 l.min^{-1} (Table 1), while the VMD changes from 124 to 207 µm and the V_{100} from 36.8 to 11.8 %. It means that at high pressures the finer spray spectrum increases the risk for spreading of droplets outside the target area (the crop canopy) dramatically, consequently, the risk for dispersal to the environment increases. Besides, nozzles were designed for spray pressures below 5 bar; higher pressures increase the wear and the heterogeneity in distribution. The total amount of released spray volume is higher at high pressures when spraying at the same driving speed. It can be concluded that lower pressures have technically a better performance and can decrease the risk for emission to the ground and the environment.

Emission to the Ground

The statistical analyses of the data for the emission of spray liquid to the ground (Table 2) showed an interaction between spray pressure and place in the row for all stages. At 10 and 15 bar there was more spray penetration through the canopy of two rows resulting in deposition on the following path. At 2.5 and 5 bar droplets move less far and, consequently, deposition underneath the plants is higher. Emission to the ground amounts to about 35% in crop growth stages 1 and 2 (Table 2) and about 15% in crop growth stage 3. The direction of the lowest nozzle in stage 1 and 2 was 30^{o} upward, but the next one is horizontally oriented. In stage 3 all nozzles spray 45^{o} upward, while the top angle of the spray is 80^{o}. Tak & van der Knaap (1997) found about 33% emission to the ground in a similar experiment. In their experiments, nozzles were oriented only 15^{o} upwards. It can be concluded that lower pressures (2.5, 5 bar) decrease the amount of emission to the ground and that the direction of the nozzles should be oriented upwards with more than 40^{o} to minimize emission to the ground.

Deposition on the Leaves

In table 3 the figures of the deposition of spray liquid on the leaves are presented. The statistical analyses performed with the GenStat package (2004) show interactions between spray pressure, leaf side and row. Decreasing the spray pressure decreases the deposition on the leaves, especially at the row closest to the path (A). At the low level in the plant canopy those differences are bigger than at greater height in the plant. Spray deposition in row B (between the plants) at the highest level in plant canopy is decreasing at lower pressure. In this situation, the spray mast appeared to be too short. Deposition on the top side of the leaves is in most cases higher than at the underside of the leaves, but differences are getting smaller at higher plant level, mainly caused by lower depositions on the topside. Differences between either 5 bar and 10 or 15 bar are rather small, while deposition at 2.5 bar is much lower. Higher spray pressures deliver a higher part of the total spray volume at the underside of the leaves, which can be seen in crop growth stage 1 and 2. In crop growth stage 3 this relationship is highly influenced by the lower deposition on plant level 3. Another aspect that could be seen during the spraying at 15 bar was the strong shadow effect realised by the high pressure. Leaves come very close to the nozzles and are sprayed in a vertical position. The backside of the leaf cannot be reached anymore, but also for other leaves further in the canopy spray deposition may become less because of this shadowing effect.

Spray Volume

In commercial practice growers often use a spray mast at 12 bar pressure with an adaptation of the speed of the reel to get an adequate spray volume of 1500 – 2500 l ha^{-1} (Van der Staaij and Douwes, 1996a, 1996b; Tak and Van der Knaap, 1997) with a fixed concentration of the tank mix in grams per litre. In these experiments we kept the speed the same and changed the spray pressure. It appeared that with a spray pressure between 5 and 10 bar the deposition of spray liquid on the leaves is the same, while the emission to the ground decreases. Van der Staaij and Douwes (1996a, 1996b) concluded that there is no difference between spray volumes of 1500 or 3000 l ha^{-1} on efficacy against mildew and larva of white fly. Besides, half of the dosing normally used in 1500 l was still adequate to give the same biological efficacy for mildew and white fly larva control. Consequently, the concentration used for 750-1000 l ha^{-1} should be the guideline for the amount of spraying per ha, if the spray pressure decreases to 5 bar or increases to 12-15 bar. The high volumes will also quickly result in runoff of spray liquid and of chemicals from the leaves to the ground.

CONCLUSIONS

The aim of the experiments was to investigate if a reduction in spray pressure could give a comparable or better deposition on the leaves and a reduction in emission of spray liquid to the ground. It appeared that a reduction in spray pressure from 15 to 5 bar reduced the emission to the ground, while deposition on the leaves remained adequate. A spray pressure of 2.5 bar gave an insufficient spray deposition, especially farther in the canopy. Spray pressures of 10 or 15 bar gave too much emission to the ground and too much deposition on the leaves resulting in runoff of spray liquid (dripping). Special attention has to be made to the direction of the nozzles (>40^o upward), as it might decrease the emission to the ground substantially. Further the length of the spray mast should be better adapted to the height of the crop.

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Literature Cited

Genstat 5 Comittee, 2004. GenStat Release 7.2. Rothamsted, Harpenden, UK; Lawes Agricultural Trust.

Knaap, R. van der and Koning, F. 1991. Emissie en toedieningstechnieken van bestrijdingsmiddelen in de glastuinbouw. Rapport 19, Proefstation Naaldwijk.

Meerjarenplan Gewasbescherming, 1991. Ministerie van Landbouw, Natuurbeheer en Visserij. (Multi Year Crop Protection Plan, Min. of Agriculture, English summary) Den Haag.

Milieujaarverslag Glastuinbouw, 2001. LTO. Den Haag.

Michielsen, J.M.G.P. and Porskamp, H.A.J. 1993. Meetmethodiek voor depositie en emissie bij de toediening van gewasbeschermingsmiddelen, IMAG-DLO nota P 93-75.

Staaij, M. van der and Douwes, M.S. 1996a. Optimalisering van de toepassing van gewasbeschermingsmiddelen in de glastuinbouw (bestrijding echte meeldauw in tomaat). Intern verslag 71, Naaldwijk.

Staaij, M. van der and Douwes, M.S. 1996b. Optimalisering van de toepassing van gewasbeschermingsmiddelen in de glastuinbouw (bestrijding wittevlieglarven in tomaat). Intern verslag 72, Naaldwijk.

Tak, F. and van der Knaap, R. 1997. Emissie-beperkend spuiten in de glastuinbouw. Rapport 51, deel 1; Research station Naaldwijk.

<u>Tables</u>

Table 1. Droplet size spectra of Teejet XR8002VK at different spray pressures (PDPA; Aerometrics).

Pressure [bar]	Volume [l/min]	D_{10}[!] [µm]	VMD[2] [µm]	D_{90}[3] [µm]	V_{100}[4] [%]
2.5	0.74	92	207	334	11.8
5	1.04	73	177	297	18.2
10	1.47	56	145	251	28.1
15	1.80	49	124	227	36.8

[1] 10% of the volume of the droplets have a diameter smaller than the value

[2] VMD = Volume Median Diameter, 50% of the volume of the droplets have a diameter smaller than the value

[3] 90% of the volume of the droplets have a diameter smaller than the value

[4] Percentage of the spray volume having a drop size smaller than 100 µm

Table 2. Emission of spray liquid to the ground at different spray pressures and in different growth stages of a tomato crop.

Pressure	Place in the row	Stage 1		Stage 2		Stage 3	
		Deposition		Deposition		Deposition	
bar		$\mu l\ cm^{-2}$ [1]	% of released volume	$\mu l\ cm^{-2}$ [2]	% of released volume	$\mu l\ cm^{-2}$ [3]	% of released volume
2,5	Below plants	1.11	22.3	2.90	29.3	1.17	11.8
	In path	0.46	9.2	0.66	6.6	1.25	12.6
5	Below plants	1.25	15.3	4.06	25.0	1.28	7.9
	In path	1.70	20.9	1.54	9.5	1.29	8.0
10	Below plants	1.76	14.3	3.26	13.2	1.23	5.0
	In path	3.65	29.6	5.46	22.1	1.35	5.5
15	Below plants	1.80	11.9	4.20	13.7	1.09	3.6
	In path	2.56	17.8	5.98	19.5	2.83	9.2

[1] average standard deviation is 0.2
[2] average standard deviation is 0.3
[3] average standard deviation is 0.2

Table 3. Average deposition of spray liquid on the tomato leaves per stage of growth and per spray pressure.

Leaf side	Row	Plant level	Deposition per crop growth stage and spray pressure ($\mu l.cm^{-2}$)											
			Stage 1 [1]				Stage 2 [2]				Stage 3 [3]			
			2,5	5	10	15	2,5	5	10	15	2,5	5	10	15
Up	A	1	3.30	8.67	8.63	8.54	2.39	5.26	5.22	5.44	1.81	2.44	3.68	4.29
		2					3.09	5.95	4.12	5.00	1.68	2.45	2.65	2.63
		3									0.55	0.64	1.36	2.81
	B	1	1.89	3.26	4.05	6.80	2.11	3.13	3.59	3.78	1.53	1.90	1.83	1.60
		2					1.91	2.21	3.04	3.02	1.45	2.73	2.77	2.66
		3									0.27	0.95	1.84	2.78
Down	A	1	0.65	0.90	2.52	3.36	0.09	0.25	0.29	1.45	0.59	0.43	2.07	2.36
		2					0.03	0.03	0.38	0.67	1.02	3.16	3.24	5.08
		3									0.66	0.46	1.71	3.35
	B	1	1.09	1.53	2.12	3.57	0.39	0.75	2.47	1.58	0.20	0.23	0.38	0.82
		2					0.16	0.53	1.25	0.86	0.16	0.34	1.52	1.48
		3									0.12	0.44	1.10	1.80

[1] average standard deviation is 0.75
[2] average standard deviation is 0.5
[3] average standard deviation is 0.25

Figures

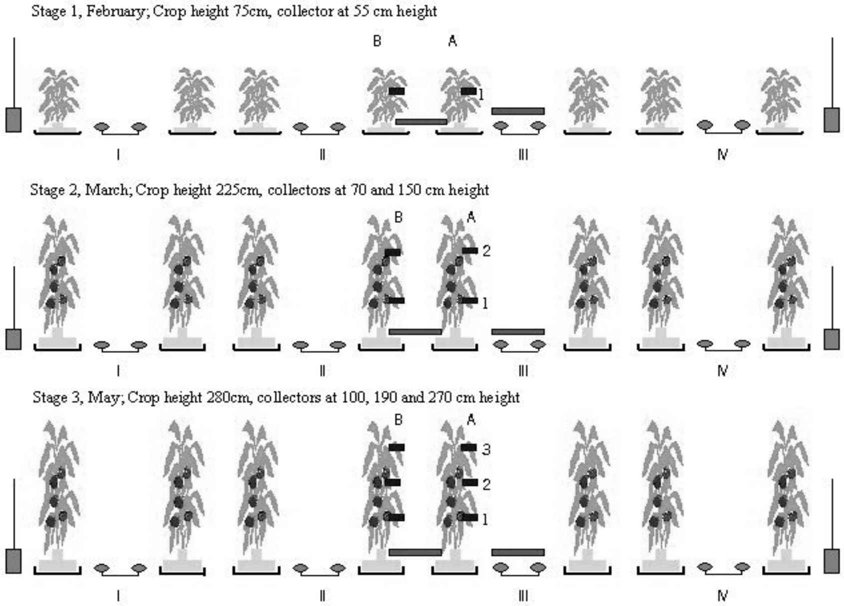

Fig. 1. Schematic overview per crop growing stage of experimental design and situation of collectors.

Fig. 2. Spray mast and automatic reel; in crop growing stage 2.

Fig. 3. Collectors below the plants and in the path for measuring emission to the ground; in crop growing stage 3.

Fig. 4. Collector for deposition on the leaves; in crop growing stage 1.