AARHUS UNIVERSITY
SCIENCE AND TECHNOLOGY

Report
”Spray drift and deposition uniformity with conventional and Hardi Twin at two wind speeds”
2017-2018

Title page

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Numbers of pages	12
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SUMMARY

Spray deposition and spray drift from applications at two wind speeds were tested at 8 and 12 km/h with conventional technique and 8, 12 and 16 km/h with Twin air-assistance. Deposit values under the boom were generally larger at the lee side compared to the wind side. Deposit values were more even at both 8 and 12 km/h when Twin air-assistance was applied.
The spray drift measurements in the test overall showed a significant influence of spray technique. Conventional technique at 8 km/h and 12 km/h gave the highest spray drift values. Spray drift with Twin air-assistance at 16 km/h was significantly reduced compared to the two conventional applications. Twin air-assistance at 12 km/h and 8 km/h further reduced drift significantly.

INTRODUCTION

The purpose of the study was to measure deposition and deposition uniformity in the target area and sedimenting spray drift from a conventional sprayer and a Hardi Twin sprayer with air-assistance at different driving speeds. It was aimed at carrying the test out at two wind speeds, a normal low wind speed and a wind speed above the normal recommended for applications with conventional sprayers. The following five techniques were tested at both wind speeds.

Technique	Speed (km/h)	Volume rate (l/ha)
1. Conventional	8	150
2. Twin air-assisted	8	150
3. Conventional	12	100
4. Twin air-assisted	12	100
5. Twin air-assisted	16	75

MATERIALS AND METHODS

An LD-025 nozzle at 3 bar (1.0 l/min) was used in all settings to achieve the volume rates and a trailed Hardi Twin with a 24 meter boom width was used with and without air-assistance for all settings. Air-assistance in setting 2, 4 and 5 was decided by Hardi and varied between the test at low/normal wind speed and the test at high wind speed. Both test were carried out at Research Centre Flakkebjerg.
The test at low/normal wind speed was carried out in a short cut stubble field on 27th June 2017 according to the following protocol:

Technique	Speed (km/h)	Volume rate (l/ha)	Air-Assistance and angling
1. Conventional	8	150	-
2. Twin air-assisted	8	150	20 m/s at outlet 43^0-48^0
3. Conventional	12	100	-
4. Twin air-assisted	12	100	20 m/s at outlet 43^0-48^0
5. Twin air-assisted	16	75	20 m/s at outlet 43^0-48^0

Twin air was angled 48^0 when wind direction was perpendicular to driving direction and 43^0 when wind direction changed towards some degrees headwind.

The actual volume rates achieved during the test deviated a little from the plan as shown in table 1.

Table 1. Time and actual realized volume rates during the test at low wind speed in 2017. Data comes from sprayer log.

Technique	Replicate 1	Replicate 2	Replicate 3
Conv. 8 km/h 150 l/ha	10:00 3.0 bar 150 l/ha	10:30 2.8 bar 145 l/ha	12:04 3.0 bar 150 l/ha
TWIN 8 km/h 150 l/ha	10:15 3.0 bar 150 l/ha	11:54 2.8 bar 145 l/ha	12:15 3.0 bar 150 l/ha
Conv. 12 km/h 100 l/ha	10:42 2.8 bar 97 l/ha	11:40 speed 13.0 km/h 3 bar 93 l/ha	12:25 speed 12.0 km/h 2,6 bar 93 l/ha
TWIN 12 km/h 100 l/ha	10:56 2.8 bar 97 l/ha	11:30 speed 13.0 3 bar 93 l/ha	12:38 speed 12.0 km/h 2,6 bar 93 l/ha
TWIN 16 km/h 75 l/ha	11:09 2.8 bar 72 l/ha	11:20 2.8 bar 72 l/ha	12:55 2.8 bar 72 l/ha

The test at high wind speed was carried out in a newly ermerged/short cut cereal crop on 30th May 2018 with the following configuration:

Technique	Speed (km/h)	Volume rate (l/ha)	Air-Assistance* and angling
1. Conventional	8	150	-
2. Twin air-assisted	8	150	57 %, 5^0 backwards
3. Conventional	12	100	-
4. Twin air-assisted	12	100	57 %, 5^0 backwards
5. Twin air-assisted	16	75	57 %, 5^0 backwards

*Twin air setting see Table 2 below.

The actual volume rates achieved during the high wind speed test deviated a little from the plan as shown in table 2 below:

Table 2. Actual realized volume rates during the test at high wind speed in 2018 and TWIN air setting. Data comes from sprayer log.

Technique	Replicate 1	Replicate 2	Replicate 3
Conv. 8 km/h 150 l/ha	150 l/ha	150 l/ha	150 l/ha
TWIN 8 km/h 150 l/ha	150 l/ha, air 72% 2600 RPM	150 l/ha, air 62% 2050 RPM	150 l/ha, air 62% 2050 RPM
Conv. 12 km/h 100 l/ha	100 l/ha	100 l/ha	100 l/ha
TWIN 12 km/h 100 l/ha	100 l/ha, air 67 % 2350 RPM	100 l/ha, air 62 % 2150 RPM	100 l/ha, air 62 % 2150 RPM
TWIN 16 km/h 75 l/ha	77 l/ha, air 62 % 2400 RPM	77 l/ha, air 62 % 2400 RPM	75 l/ha, air 62 % 2400 RPM

Both tests follows the description in the document “Messung der direkten Abtrift beim Ausbringen von Flüssigen Pflanzenschutzmitteln im Freiland” September 1992 concerning conditions that are not described in this protocol. The number of measuring points is however less than described in the JKI protocol.

A tracer (brillantsulfoflavin) was added to the spray liquid corresponding to a dose of 200 g/ha at the low volume rate of 75 l/ha, 267 g/ha at 100 l/ha and 400 g/ha at 150 l/ha. All results are normalized to the same applied dose rate of BSF using the volume rates realized (Tables 1 & 2).
The area sprayed was 24 meters wide and 100 meters long, leaving a distance of more than 30 meters before respectively after the rows of drift collectors.
The sprayed area was placed next to a free area (short cut grass or crop with a height of less than 15 cm) in the wind direction.
The drift collectors were placed at distances of 3, 5, 10, 15 and 20 meters from the sprayed track on object carriers at soil level. Zero point is 25 cm outside the outermost nozzle. Five rows of objects carrier were included with a distance of three meters between the rows. In the sprayed area five rows of petri dishes were placed at four distances (1, 3, 21 and 23 meters) from the zero point to measure uniformity in the sprayed area. Petri dishes with an area of 149.6 cm^2 were used to collect deposits in the sprayed area and drift. The petri dishes were placed on the object carriers during the spraying to avoid contamination from previous passes. Additionally, one petri dish was placed upwind during each spraying to check methodology. After one pass of the sprayer the petri dishes were collected and stored for analysis. There was no measurement of airborne spray drift.
The plan included 3 replicates at each spray technique giving a total of 75 drift values, 60 deposition values and 3 methodology values at each setting. Climatic conditions were measured at an official meteorological station placed at Flakkebjerg. Additionally, wind speed, wind direction, temperature and humidity were measured continuously with mobile equipment during the experiment in the field where the drift test took place. These data are shown in Tables 3 & 4.

Table 3. Climatic conditions registered during the test at low/normal wind speed in 2017

Technique	Time	Wind (m/s) Handheld	Wind (m/s) weather station	Temperature (^{0}C)	Humidity (relative)
Rep: 1					
Conv 8 km/t	10:00	2,6-3,8	3,3-3,5	13	55-65
Twin 8 km/t	10:17	2,6-3,6	5,4-4,2		
Conv 12 km/t	10:45	2,8-3,8	3,3-3,3		
Twin 12 km/t	10:58	3,2-4,8	4,1-4,2		
Twin 16 km/t	11:09	2,5	2,3-2,3		
Rep: 2					
Conv 8 km/t	10:30	2,7-5,2	4,4-4,7	14	55-65
Twin 8 km/t	11:54	2,0-2,0	3,3-4,2		
Conv 12 km/t	11:48	4,3-4,8	2,8-2,8		
Twin 12 km/t	11:31	2,5-2,7	2,1-2,7		
Twin 16 km/t	11:20	3,1-2,8	2,8-3,9		
Rep: 3					
Conv 8 km/t	12:04	3,2-4,8	3,0-3,6	15	55-65
Twin 8 km/t	12:16	3,1-3,6	1,6-3,2		
Conv 12 km/t	12:26	2,1-2,0	1,1-1,8		
Twin 12 km/t	12:39	2,2-2,6	2,6-3,8		
Twin 16 km/t	12:55	3,1-3,9	4,3-4,7		

Table 4. Climatic conditions registered during the test at high wind speed in 2018.

Technique	Time	Wind (m/s) Handheld	Wind (m/s) weather station	Temperature (^{0}C)	Humidity (relative)
Rep: 1					
Conv 8 km/t	10:34	5,2	4,7	24	60
Twin 8 km/t	10:55	5,2	4,3		
Conv 12 km/t	11:21	5,1	4,5		
Twin 12 km/t	11:35	3,9	4,2		
Twin 16 km/t	11:46	4,6	5,7		
Rep: 2					
Conv 8 km/t	13:04	7,2	6,5	25	50
Twin 8 km/t	12:47	5,9	5,4		
Conv 12 km/t	12:30	5,8	6,1		
Twin 12 km/t	12:15	6,3	6,2		
Twin 16 km/t	12:01	6,3	6,5		
Rep: 3					
Conv 8 km/t	13:18	7,2	7,0	26	40
Twin 8 km/t	13:35	8,4	7,6		
Conv 12 km/t	13:48	6,0	7,0		
Twin 12 km/t	14:02	6,7	8,0		
Twin 16 km/t	14:14	7,5	7,8		

Following the field test the petri dishes were stored dark at 5^{0}C until the analysis. The BSF was solved with water and 0.1% non-ionic additive and the concentration of tracer was determined. The tracer content was determined using a Perkin Elmer model LS 50B luminescence spectrometer. The petri dishes were shaken and a sample of 6 µl was used in the fluorescence detector. The sample was excited at a wavelength of 410 nm and after excitation emission was measured at 518 nm. The content of the sample was quantified using a number of standard concentrations ranging from 2 to 192 µg l^{-1}. From the concentration of brillantsulfoflavin in the sample the total amount of tracer in the sample was calculated.
The results are presented as a percentage of the applied dose.

RESULTS AND DISCUSSION

The test at low/normal wind speed was carried out under conditions where the wind speed varied from 2-4 m/s and at a moderate temperature around 15 ^{0}C. During the test at high wind speed, the wind speed varied in the interval from 4 m/s during the first replicate to 8 m/s during the third replicate and with a high temperature around 25 ^{0}C during the entire test. The relative humidity varied in both tests around 50 %. In the following figures the results of the two tests are shown both separately and as an overall mean for both tests.

Deposition in the target area

Deposition values in the target area at four positions below the boom are shown in Figures 1-3. The deposit values found at the low/normal wind test are shown in Figure 1. Twin air-assistance had a limited influence on deposit values at 8 km/h. However at 12 km/h air-assistance significantly increased deposition compared to conventional application at both 8 and 12 km/h. Application with air-assistance at 16 km/h also gave larger deposits than conventional spraying but with larger differences between windside and leeside. The most uniform distribution at low/normal wind speed was achieved with Twin at 8 km/h.

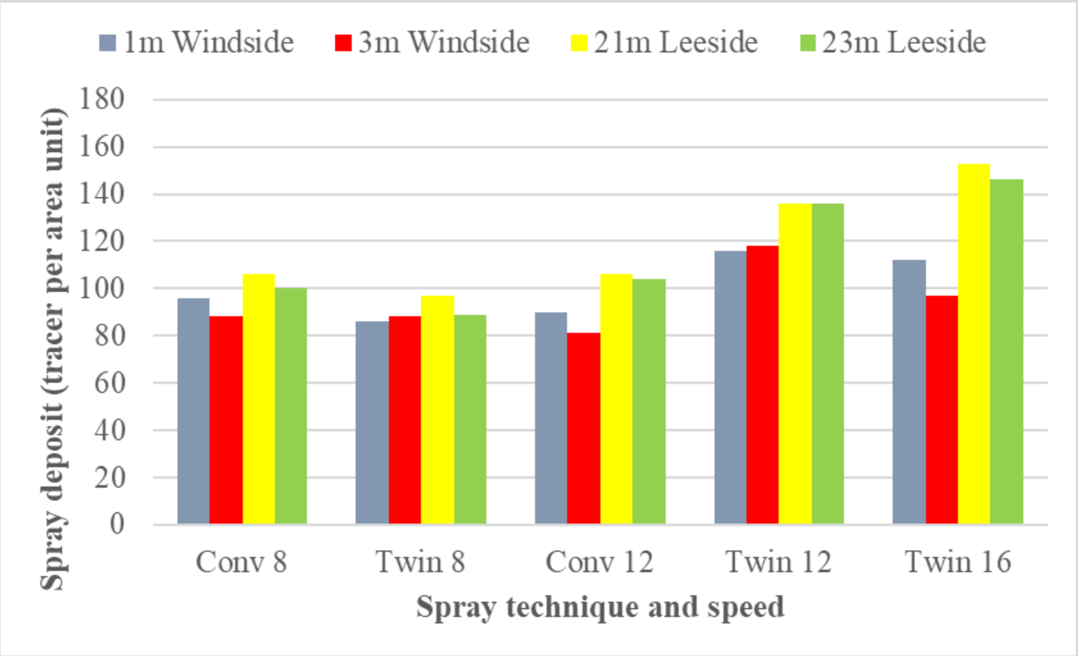

Figure 1. Deposition below the boom in different distances from the end of the boom. The wind direction was perpendicular to driving direction with petri dishes placed 1 and 3 m from the end of the boom in the wind side (1m W and 3m W) and placed 3 and 1 m from the end of the boom in the lee side (21m L and 23m L). Test at low/normal wind speed June 2017.

The corresponding results from the test at high wind speed are shown in Figure 2. There is a larger difference beween deposits in the windside and the leeside and especially with conventional technique at both 8 and 12 km/h. The most uniform application at high wind speed was found using Twin air-assistance at 12 km/h closely followed by air-assistance at 8 km/h. The values obtained using Twin at 16 km/h was almost the same as in the test with low/normal wind speed.

Deposition values as a mean from the two tests are summarized in Figure 3. Droplets are supposed to be transported from the windside towards the leeside as seen especially with the two conventional applications. The result is lower deposit values in the windside and maybe increased values in the leeside. There is however no explanation why the values in the windside with the Twin at 12 km/h is above 100 % of the theoretical applied at all positions. It is the same sprayer and exactly the same sampling positions under the boom used during all treatments. The overall conclusion concerning deposition in the target are is that Twin applications at 8 and 12 km/h gives a more uniform deposition below the boom than the corresponding conventional applications and especially at high wind speed.

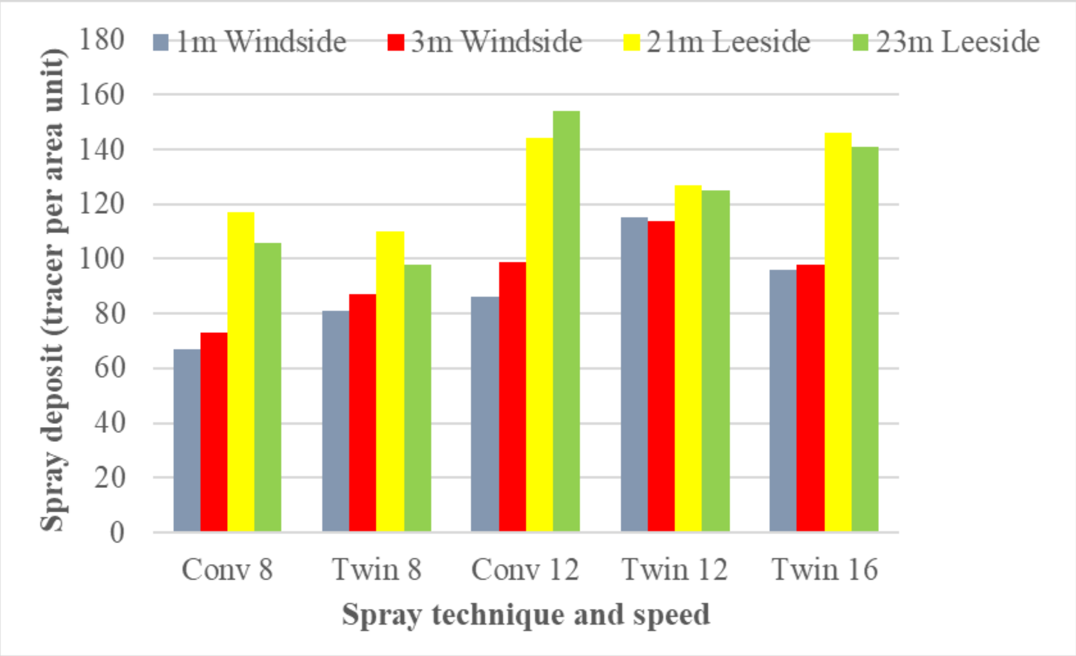

Figure 2. Deposition below the boom in different distances from the end of the boom. The wind direction was perpendicular to driving direction with petri dishes placed 1 and 3 m from the end of the boom in the wind side (1m W and 3m W) and placed 3 and 1 m from the end of the boom in the lee side (21m L and 23m L). Test at high wind speed May 2018

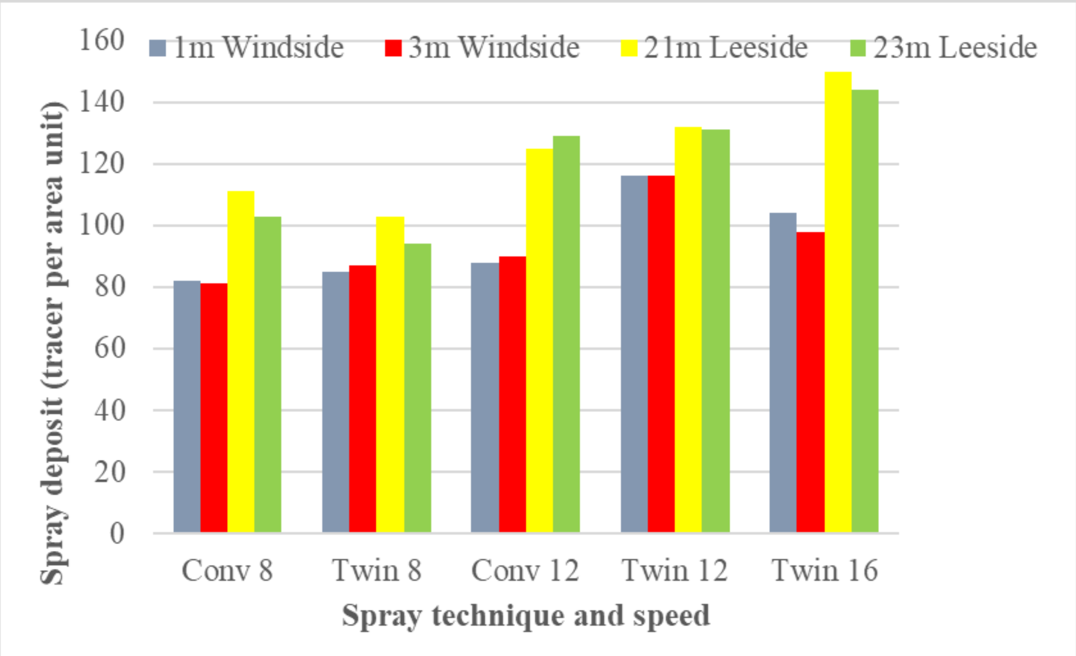

Figure 3. Deposition below the boom in different distances from the end of the boom. The wind direction was perpendicular to driving direction with petri dishes placed 1 and 3 m from the end of the boom in the wind side (1m W and 3m W) and placed 3 and 1 m from the end of the boom in the lee side (21m L and 23m L). Mean of tests at low/normal and high wind speed 2017 & 2018.

Sedimenting spray drift

Spray drift values from the two tests are shown in Figures 4-6. Although the wind speed varied much between the test at low/normal wind speed and the high wind speed test the absolute spray drift values in the two tests were at the same level. This could be due to the high temperature in the test at high wind speed and the low water pressure deficit. In the low/normal wind test (Figure 4) the conventional technique at 8 km/h had the largest drift and the Twin at 8 km/h the lowest values and the three other techniques were intermediate.

In the test at high wind speed (Figure 5) the two conventional applications at 8 and 12 km/h gave the largest spray drift values. Twin at 16 km/h reduced spray drift significantly compared to the two conventional treatments and the Twin application at 8 km/h had the lowest spray drift values although not significantly from Twin at 12 km/h. However drift values for Twin at 8 and 12 km/h was significantly below the Twin values at 16 km/h.

In Figure 6 mean values from the two tests are shown.

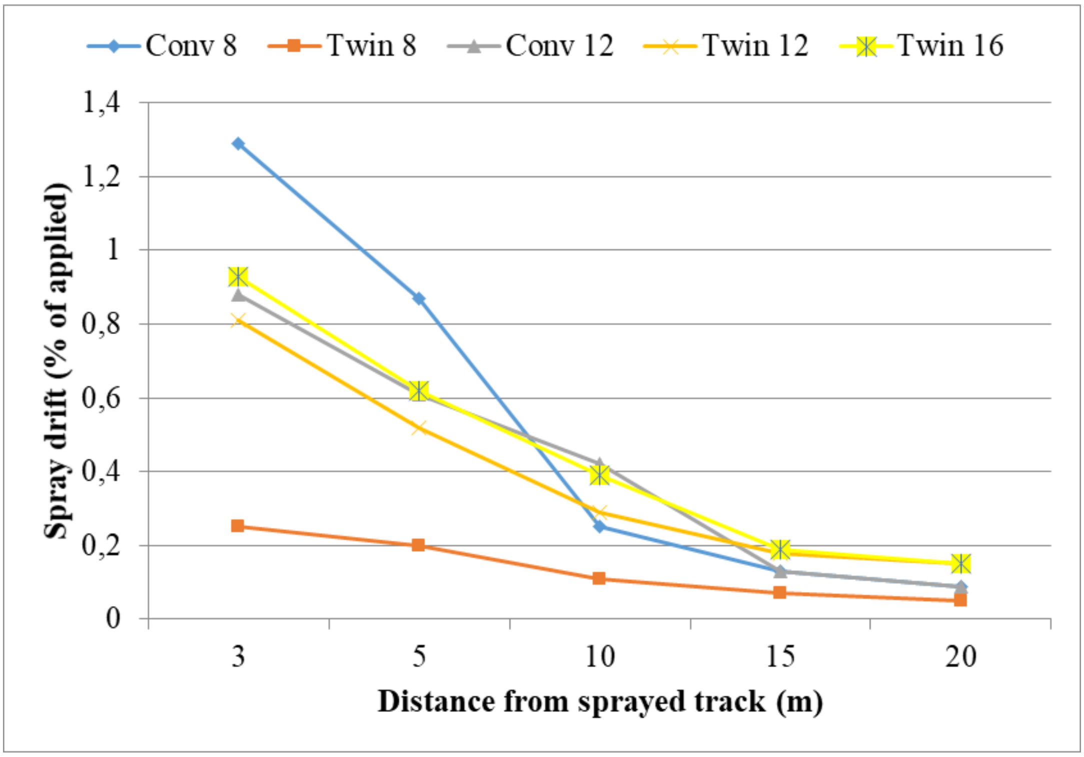

Figure 4. Spray drift at increasing distance from the sprayed area using conventional technique or Twin air-assistance at different driving speeds. Drift values are shown as a percentage of the applied dose. Results from test at low/normal wind speed June 2017.

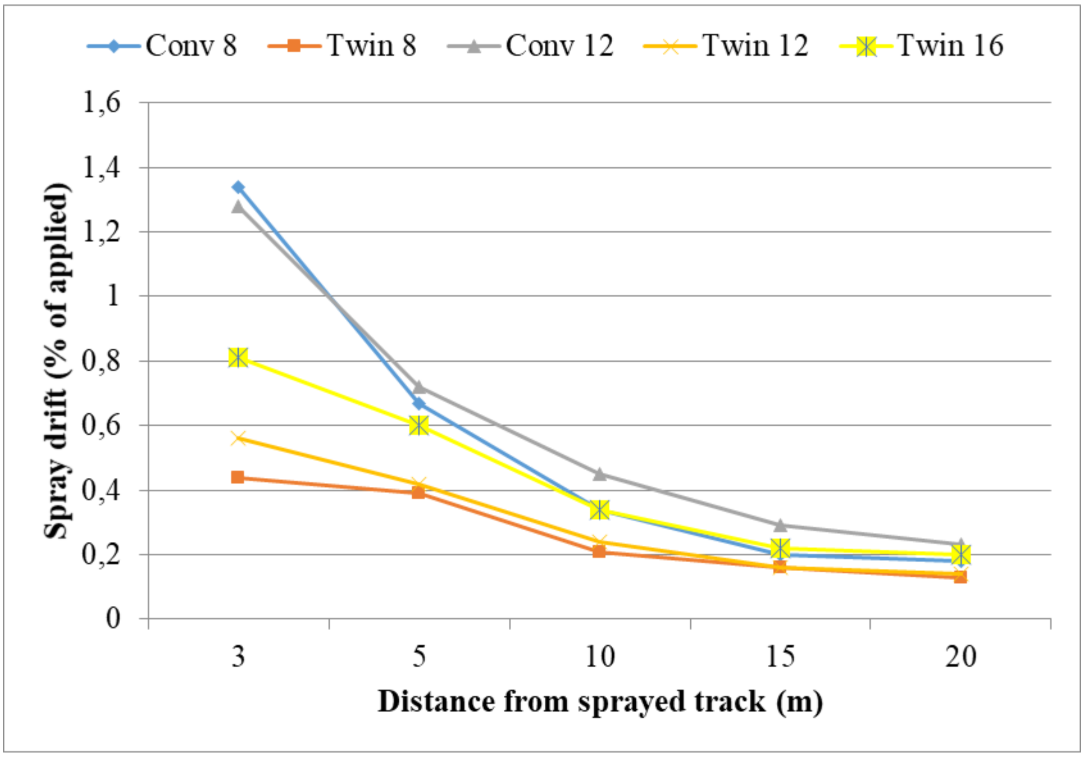

Figure 5. Spray drift at increasing distance from the sprayed area using conventional technique or Twin air-assistance at different driving speeds. Drift values are shown as a percentage of the applied dose. Results from test at high wind speed May 2018.

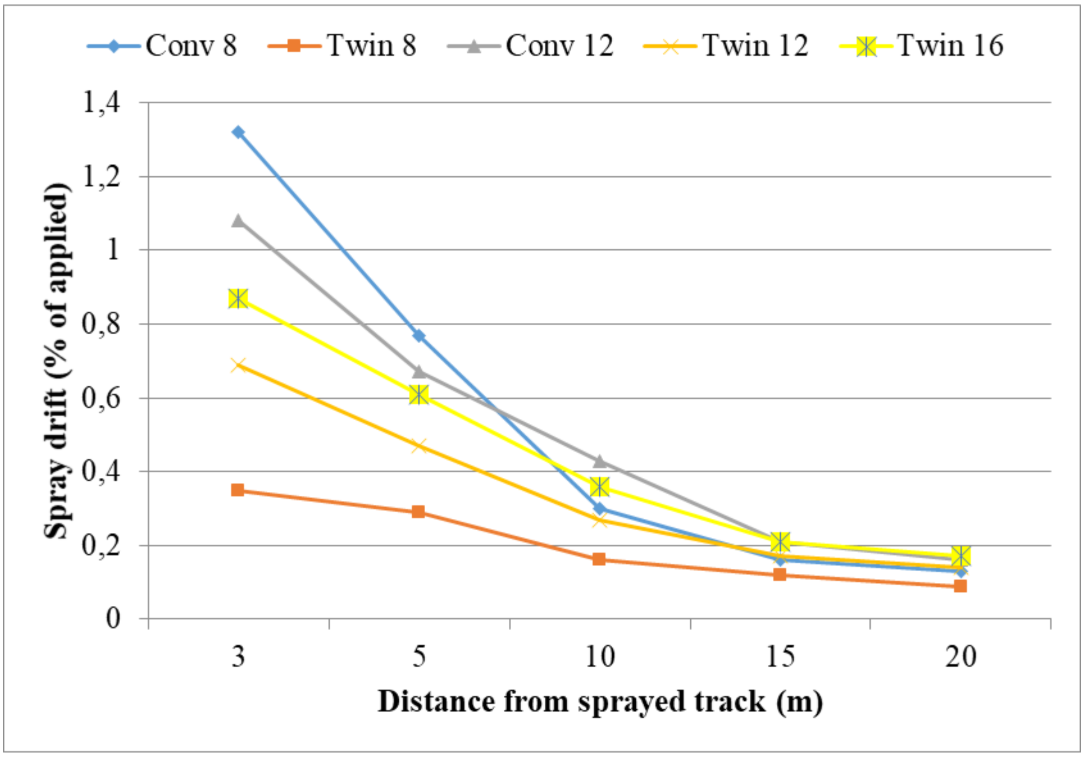

Figure 6. Spray drift at increasing distance from the sprayed area using conventional technique or Twin air-assistance at different driving speeds. Drift values are shown as a percentage of the applied dose. Mean of tests at low/normal and high wind speed 2017 & 2018.

CONCLUSION

Spray deposition and spray drift from applications at two wind speeds were tested at 8 and 12 km/h with conventional technique and at 8, 12 and 16 km/h with Twin air-assistance. A 24 meter trailed Hardi Twin sprayer equipped with LD-025 nozzles at 3 bar pressure was used in the test. Deposits values under the boom were generally larger at the lee side compared to the wind side. The differences was most pronounced in the test at high wind speed where the differences in deposition between windside and leeside was especially large with the two conventional techniques. The most even distribution was found with Twin air-assistance at 8 & 12 km/h.

The spray drift measurements in the test showed a significantly lower drift from Twin at 8 km/h compared to the other four techniques at both wind speeds. Conventional technique at 8 km/h and 12 km/h gave the highest spray drift. The two Twin applications at 12 and 16 km/h obtained significantly lower spray drift than the two conventional applications, but higher drift values than Twin at 8 km/h.

Enclosure

Deposition values

Deposition below the boom in different distances from the end of the boom (Tracer per area unit). The wind direction was perpendicular to driving direction with petri dishes placed 1 and 3 m from the end of the boom in the wind side (1m W and 3m W) and placed 3 and 1 m from the end of the boom in the lee side (21m L and 23m L). Test at low/normal wind speed June 2017.

Technique	Measuring point under boom			
	1m Windside	3m Windside	21m Leeside	23m Leeside
Conv 8	96	88	106	100
Twin 8	86	88	97	89
Conv 12	90	81	106	104
Twin 12	116	118	136	136
Twin 16	112	97	153	146

Deposition below the boom in different distances from the end of the boom (tracer per area unit). The wind direction was perpendicular to driving direction with petri dishes placed 1 and 3 m from the end of the boom in the wind side (1m W and 3m W) and placed 3 and 1 m from the end of the boom in the lee side (21m L and 23m L). Test at high wind speed May 2018.

Technique	Measuring point under boom			
	1m Windside	3m Windside	21m Leeside	23m Leeside
Conv 8	67	73	117	106
Twin 8	81	87	110	98
Conv 12	86	99	144	154
Twin 12	115	114	127	125
Twin 16	96	98	146	141

Deposition below the boom in different distances from the end of the boom (tracer per area unit). The wind direction was perpendicular to driving direction with petri dishes placed 1 and 3 m from the end of the boom in the wind side (1m W and 3m W) and placed 3 and 1 m from the end of the boom in the lee side (21m L and 23m L). Mean of tests at low/normal and high wind speed 2017 & 2018.

Technique	Measuring point under boom			
	1m Windside	3m Windside	21m Leeside	23m Leeside
Conv 8	82	81	111	103
Twin 8	85	87	103	94
Conv 12	88	90	125	129
Twin 12	116	116	132	131
Twin 16	104	98	150	144

Drift values

Spray drift at increasing distance from the sprayed area using conventional technique or Twin air-assistance at different driving speeds. Drift values are shown as a percentage of the applied dose. Results from test at low/normal wind speed June 2017.

Technique	Distance from sprayed track (m)				
	3	5	10	15	20
Conv 8	1,29	0,87	0,25	0,13	0,09
Twin 8	0,25	0,20	0,11	0,07	0,05
Conv 12	0,88	0,61	0,42	0,13	0,09
Twin 12	0,81	0,52	0,29	0,18	0,15
Twin 16	0,93	0,62	0,39	0,19	0,15

Spray drift at increasing distance from the sprayed area using conventional technique or Twin air-assistance at different driving speeds. Drift values are shown as a percentage of the applied dose. Results from test at high wind speed May 2018.

Technique	Distance from sprayed track (m)				
	3	5	10	15	20
Conv 8	1,34	0,67	0,34	0,2	0,18
Twin 8	0,44	0,39	0,21	0,16	0,13
Conv 12	1,28	0,72	0,45	0,29	0,23
Twin 12	0,56	0,42	0,24	0,16	0,14
Twin 16	0,81	0,60	0,34	0,22	0,2

Spray drift at increasing distance from the sprayed area using conventional technique or Twin air-assistance at different driving speeds. Drift values are shown as a percentage of the applied dose. Mean of tests at low/normal and high wind speed 2017 & 2018.

Technique	Distance from sprayed track (m)				
	3	5	10	15	20
Conv 8	1,32	0,77	0,3	0,16	0,13
Twin 8	0,35	0,29	0,16	0,12	0,09
Conv 12	1,08	0,67	0,43	0,21	0,16
Twin 12	0,69	0,47	0,27	0,17	0,14
Twin 16	0,87	0,61	0,36	0,21	0,17