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Effect of canopy density on spray coverage of kiwifruit pergola canopies

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EXECUTIVE SUMMARY

This study was undertaken to evaluate the effect of canopy density on efficiency of spray coverage on pergola canopies. It was carried out in autumn 2012, on a Hort 16A pergola orchard in the Bay of Plenty. A dense canopy was pruned to also provide medium and lighter density canopy treatment plots. Airblast sprays were applied to each of the three canopies in typical dilute (run-off) application volumes. Deposits were measured at four different height positions through the canopy in both the centre-of-row and leader zones. The effect of canopy density on the spray coverage of foliage was compared.

In summary:

- The dense, unmanaged canopy received lower spray deposits in all zones than managed (pruned) canopies.

- Mean deposits on the dense canopy (2000 L/ha spray volume) were approximately 40% less than for the medium (1500 L/ha) and light (1000 L/ha) canopies despite receiving the highest volume spray (deposit measurements are based on equivalent chemical application rates per ha in different spray volumes).

- Spray deposits on all foliage in the dense unmanaged canopy were unacceptable, apart from on leaves directly exposed to the sprayer.

- **Even using the current best type of airblast sprayer and setup available, dense unmanaged canopies cannot be adequately covered with protectant sprays applied in the typical dilute spray volumes used by the kiwifruit industry.**

- Spray deposits on all foliage in the managed canopies were acceptable, with the proviso that the lower canopy, directly exposed to the sprayer, received excessively high deposits.

- In a pergola structure, airblast sprayers will always overdose the lower exposed foliage.

- **All foliage can be covered with protectant sprays, using a well set-up airblast sprayer, if canopies are managed to reduce their density.**

- The bottom surfaces of kiwifruit leaves have the capacity to retain more spray deposits than the top surface due to their hairy character, but those deposits may not always contact the leaf surface and thus, may not protect it adequately.

- Concentrated, reduced-volume airblast sprays will be more efficient in managed canopies compared to dilute, high volume sprays, and their retention and coverage on foliage will benefit from the addition of a superspreader-type adjuvant.

INTRODUCTION

Recent research studies to improve the performance of spray applications on kiwifruit have demonstrated the impact of canopy density on potential spray deposits and coverage (Manktelow *et al.* 2012). Canopy density was confirmed to be a bigger factor than sprayer type and setup (nozzling, calibration, application volume, etc) in determining the efficiency of spray applications applied to a range of Hayward and Hort 16A canopies. While that study was not set up to examine canopy effects, the results suggested that effective control of Psa using protectant chemicals will require canopy management to reduce vine density.

The study reported here was undertaken to evaluate the effect of canopy density on efficiency of spray coverage on pergola canopies.

METHODS AND MATERIALS

The deposit studies were undertaken between 7-14th March 2012, on DL & KN Walker's Orchard on Wilson Road South, Paengaroa in the Bay of Plenty (Appendix 1). The pergola orchard contained pre-harvest, Psa-V infected, Hort 16A vines, planted on 3.3 m row spacing with alternate row strip males. Bays were 6.0 m long. The orchard was scheduled for destruction post-harvest. The study was carried out over three separate blocks, each 15 rows wide and separated by shelterbelts. Psa symptoms were evident in all blocks and some gaps existed in the canopy due to vine dieback, but many bays contained regular, dense canopy (Photo 1).

Photo 1: Un-pruned 'dense' canopies

Canopy density
Three canopy densities were evaluated in the study, with two replicates of each sprayed, in separate blocks (Appendix 1). The 'dense' canopy was used as it existed (Photo 1), with a mean overall cane density of 24 per bay and a leaf layer density of >6.5 (Table 1). The 'medium' and 'light' densities (Photo 2) were achieved by Mike Muller strategically pruning treatment and adjacent bays to provide potential cane and

leaf densities for managed canopies (Table 1). In the two managed canopies, all canes were removed from male leaders. Measurements were made of standard parameters such as cane density per bay and leaf layer numbers (Table 1) and also of canopy gaps. To determine the latter, photos were taken directly beneath three random sites in each canopy zone in all treatment bays (3 photos per zone per replicate) and the percentage of planar area (blue sky) not covered by leaves was determined by image processing of each photo (Appendix 2).

Table 1: Canopy characterisation

Tmt/rep	canopy	Cane density per bay	Mean cane spacing (mm)	Canopy zone	Canopy depth (mm)	Mean # of leaf layers	Canopy gaps (%)
1/1	dense	24	245	leader	548	6.6	5.9
				centre	499	7.1	3.0
				male ldr	510	7.2	4.0
1/2	dense	24	238	leader	514	5.2	2.9
				centre	447	6.3	4.0
				male ldr	508	6.8	4.7
'dense' mean		24	242		504	6.5	4.1
2/1	medium	26	222	leader	450	4.8	10.8
				centre	256	3.8	13.1
				-	-	-	31.0
2/2	medium	23	260	leader	258	3.6	6.8
				centre	222	4.1	8.4
				-	-	-	21.1
'medium' mean		25	241		297	4.1	15.2
3/1	light	22	274	leader	378	3.6	9.2
				centre	241	2.6	12.2
				-	-	-	>50[1]
3/2	light	22	273	leader	436	4.2	7.7
				centre	162	2.3	16.2
				-	-	-	30.7
'light' mean		22	274		304	3.2	>21

(-) male leader canopy pruned; [1]male leader not recorded as it was dead.

Spray application

All treatments were applied between midday and 4.00 pm in light easterly winds (mean 0 – 0.6 m/s) blowing consistently across rows, in warm temperatures of 22-26ºC (Appendix 3).

The sprayer was a trailed Eco 2000 sprayer with an Arivac front entry 36 inch fan and three spray rings consisting of eight nozzles per side. All three spray volume treatments were achieved using Article 58 pink ceramic tips and stainless steel cores (Appendix 4). Travel speed was 6.1 km/h in all applications. Each treatment was replicated on two plots, consisting of three bays. Sprays were applied to the centre row of each plot with all nozzles operating and to the adjacent rows either side, in the opposite direction of travel, with nozzles operating only on the treatment plot side. The sprayer was operated using the low fan gear with a PTO speed of 440 rpm.

Sprays were applied to the ‘dense’ canopy (Tmt 1) at 2000 L/ha. This canopy was estimated to require at least 3000 L/ha as a ‘true’ dilute spray (ie application to run-off). However, the 2000 L/ha volume was used as this better reflected typical industry application practices on this type of canopy. The ‘medium’ density (Tmt 2) received 1500 L/ha and the ‘light’ density (Tmt 3) received 1000 L/ha dilute sprays, based on their proportional leaf layers relative to the dense canopy (Table 1). The application volumes used for the medium and light density canopies were considered true dilute spray volumes. No pesticide was included in sprays, but all contained the non-hazardous fluorescent dye, Pyranin 120% (ca 10 g/ha; Lanxess, ex Bayer NZ), as a tracer to measure deposits, and also the adjuvant Latron B, at 25 ml/100 L.

Treatments were applied sequentially in order, and each treatment was harvested as soon as spray had dried and prior to the next treatment being applied, to avoid any cross-contamination of treatments.

Water sensitive papers (WSP) were positioned in the row centre and in female leader zones, in both the lower and upper canopy positions, in a single replicate of each treatment. WSP were attached to both upper and lower leaf surfaces of five random leaves in each zone x position (Appendix 5)

Photo 2: ‘Medium’ (LHS) and ‘light’ (RHS) density canopy bays (in foreground only)

Spray deposit assessment

After spray treatments had dried, leaf samples were collected from up to 10 different canopy zones: upper (leaves in top of canopy shielded from sprayer), mid (leaves shielded by upper and lower canopy) and lower (exposed to sprayer) positions at the row centre, female leader zone (within one wire either side of the vine), male leader zone (ditto, in Tmt 1 only), and randomly from the canopy tops (leaves growing at >1 m above pergola wires). In treatments 2 & 3, where the male leader canes had been completely removed, a random sample was collected of leaves growing on female canes at the leader vine (Photo 3). Two replicate samples of six random leaves each were collected in each zone from each replicate block, placed in resealable plastic bags and kept out of direct sunlight. They were washed (with 400 ml water containing 0.025% Du-Wett) within 20 minutes of harvest to recover dye. Prior audits confirmed >90% dye recovery from leaves within this time period. Spray deposits were quantified using a fluorimeter, and leaf areas were determined with a Leaf Area Meter. Deposits were calculated as dose (μg/cm^2) and were normalised to an equivalent spray application rate of 1 kg a.i. per ha in each treatment (to allow meaningful direct comparisons of deposits between treatments). The deposit data are presented as micrograms of tracer per square centimetre of projected (one-sided) leaf area. True average deposit per square centimetre of top and bottom leaf surface is theoretically half of this figure, but deposits on top and bottom leaf surfaces may vary widely (Gaskin et al. 2011). Results were statistically analysed using ANOVA to determine the significance of treatment on spray deposits retained on leaves in different zones.

In addition to standard leaf deposits estimated from bulked leaves, individual leaves (x5) were randomly sampled from the upper and lower canopy at the row centre and female leader positions in all replicated treatments. Individual sides of each leaf were washed separately (in 50 ml water as described above) to accurately determine deposits retained on adaxial (top) and abaxial (bottom) leaf surfaces in the different canopy zones. Deposits were calculated as dose (μg/cm^2) normalised to an equivalent spray application rate of 1 kg a.i. per ha in each treatment as described for bulk leaf samples. The deposit data on separate leaf surfaces are presented as micrograms of tracer per square centimetre of projected (one-sided) leaf area. When deposits on both leaf surfaces are combined for comparison with bulk leaf deposits, they are also presented as micrograms of tracer per square centimetre of projected (one-sided) leaf area. Thus, adding together deposits from both leaf surfaces should approximate the bulked leaf deposit.

Photo 3: Typical foliage density at male leader zones in (LHS) 'dense' canopy and (RHS) pruned 'light' canopy

RESULTS and DISCUSSION

Deposits on canopy

Average treatment deposits provide limited information on spray distribution within canopies, but they are useful to show gross trends. As was as expected (from our previous study; Gaskin *et al.* 2011), dense canopies received lowest deposits consistently across all canopy zones (Table 2).

In the dense canopy, the centre row and female leader foliage deposits were similar, while the male leader zone received up to 35% lower deposits. The reason for this was not immediately apparent; although more leaf layers were present in the male leader zone than in other zones, the female leader was the deepest canopy and the centre row generally had less gaps (Table 1).

The medium and light density canopies retained similar deposits in the centre and (female) leader zones and these were approximately 60% higher than for the dense canopy (Table 2). The very high deposits recorded on male leader zones in these two managed canopies were a result of male cane pruning (Photo 3), so the (limited) foliage remaining was fully exposed to sprays. Because of this, deposits on all male leader zones were excluded from analysis in the main data set (Table 3).

Table 2: Mean deposits (µg/cm^2, normalised to a 1 kg/ha application of dye) on leaves in all canopy zones

Canopy density	Spray volume (L/ha)	Canopy zone		
		Centre row	Female leader	Male leader
dense	2000	1.31 c	1.21 c	0.85 d
medium	1500	2.15 b	1.95 b	3.82 a
light	1000	2.13 b	2.15 b	3.98 a

Means sharing common postscripts are not significantly different (LSD, P=0.05).

The dense canopy mean deposit was approximately 40% less than for medium and light canopies despite the former receiving the highest spray volume (Table 3). Spray deposits were distributed similarly between the centre row and leader zones in all three canopies (Table 3, Fig. 1), which indicated that the sprayer output distribution was well matched to the canopy. This was also confirmed by examination of the WSPs (Appendix 5).

Table 3: Mean deposits (µg/cm^2, normalised to a 1 kg/ha application of dye) on leaves in all zones and canopy positions, excluding male leader zones

Canopy density	Spray vol. (L/ha)	Canopy zone		Position in canopy				**Tmt mean**
		centre row	female leader	lower	mid	upper	tops	
dense	2000	1.31 b	1.21 b	2.43 b	0.91 de	1.05 d	0.64 e	**1.26 B**
medium	1500	2.15 a	1.95 a	3.15 a	1.72 c	1.71 c	1.62 c	**2.05 A**
light	1000	2.13 a	2.15 a	3.36 a	1.81 c	1.82 c	1.58 c	**2.14 A**
mean		**1.87 A**	**1.77 A**	**2.98 A**	**1.48 BC**	**1.53 B**	**1.28 C**	

Means within each coloured table sharing common postscripts are not significantly different (LSD, P=0.05).

Within each canopy, leaves in the lower position always received highest deposits (Table 3). In the dense canopy, the mid and upper positions were similar with top foliage receiving the lowest deposits (Fig. 2), but coverage of all foliage in the dense canopy, apart from that directly exposed to the sprayer, was unacceptable (Fig. 3). Deposits on the medium and light canopies were similar; while the lower leaves directly exposed to the sprayer received excessively high deposits (Fig. 2), coverage of all other foliage was similar and adequate (Fig. 3). Differences in the densities of the medium and light canopies were not substantial (Table 1), but they were sprayed with different application volumes; 1500 and 1000 L/ha, respectively. The results confirm that lower volume sprays applied with a well setup sprayer can cover a managed pergola canopy equally as well as higher volume sprays, and provide adequate distribution of protectant sprays throughout the canopy. In contrast, foliage in dense pergola canopies cannot be adequately covered by protectant sprays applied in the typical dilute volumes used by the kiwifruit industry, even with a good sprayer setup.

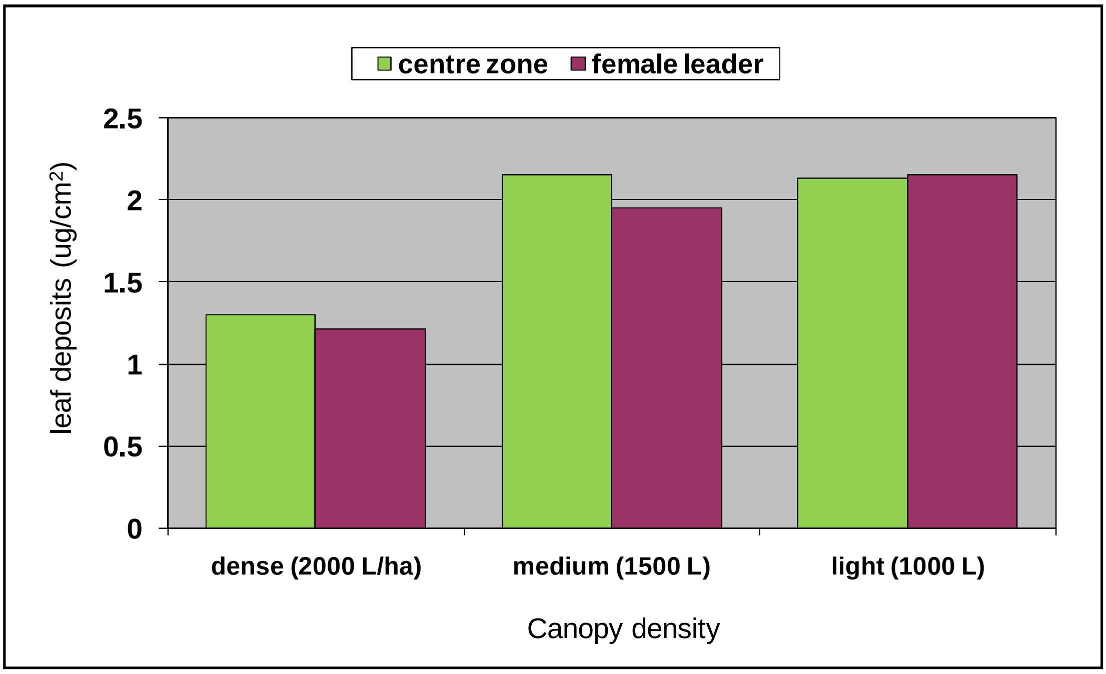

Figure 1: Mean deposits on foliage in centre row and leader zones in three canopy densities.

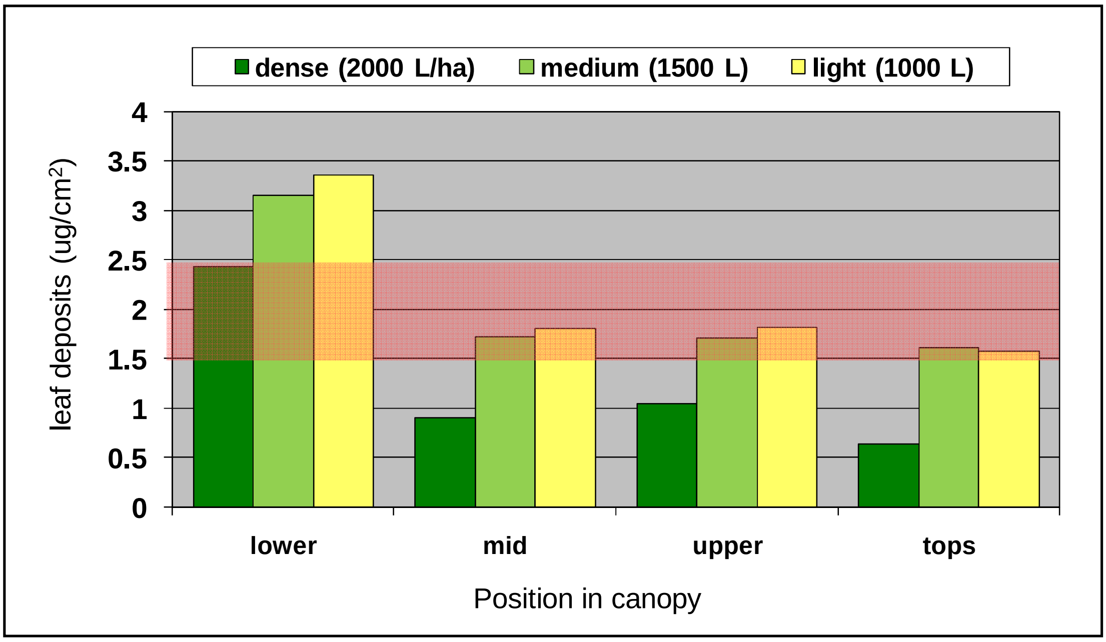

Figure 2: Mean deposits on foliage in four positions within canopies. *The red shaded band (between 1.5-2.5 µg/cm² deposits) indicates typical normalised deposit levels expected on a kiwifruit pergola canopy from spray applications providing "acceptable" coverage of leaf surfaces. Note that individual deposits within treatments may vary widely and fall outside of this range.*

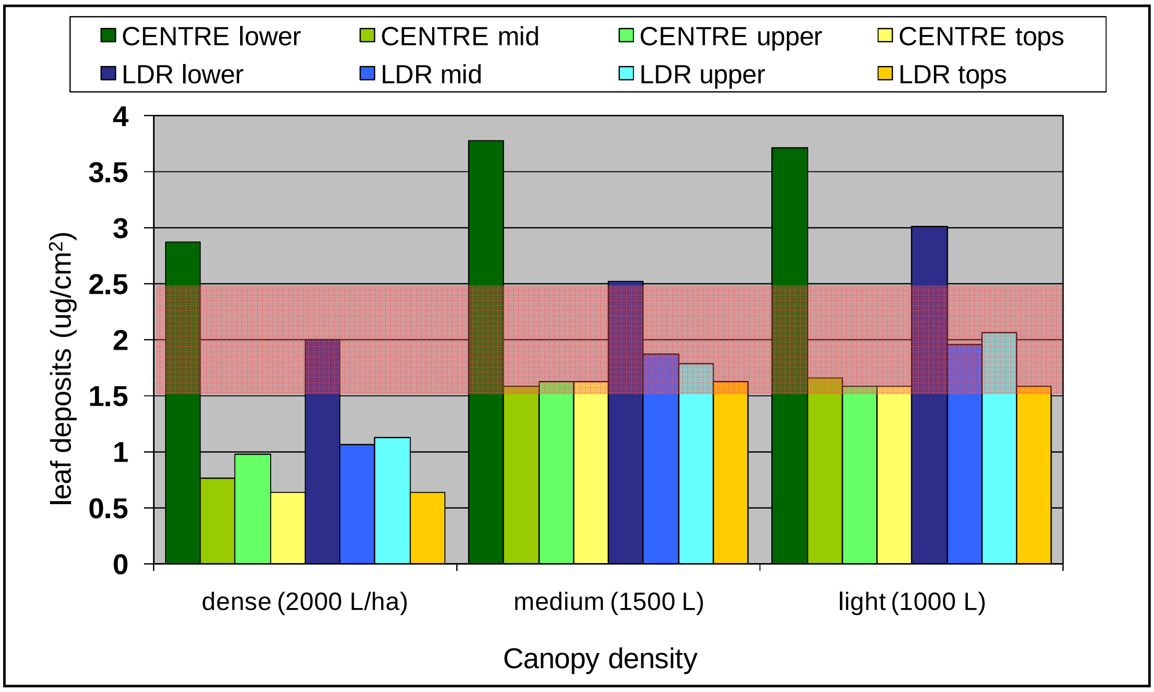

Figure 3: Mean deposits on foliage in all positions within centre row and leader canopy zones (LSD $P_{0.05}$=0.58)

Deposits on top and bottom surfaces of single leaves

Determining deposits on separate leaf surfaces is difficult and time-consuming, but the significance of where sprays are deposited has become very important with the arrival of Psa. As seen in our previous study (Gaskin *et al*. 2011), mean deposits on the bottom surfaces of leaves were substantially higher than on top surfaces (P<0.001; Table 4). These differences were maximised on leaves directly exposed to the sprayer (lower canopy) and minimised in the upper canopy where all deposits were generally very low (Table 4).

Table 4: Deposits (µg/cm^2, normalised to a 1 kg/ha application of dye) on top and bottom surfaces of leaves in four canopy zones within three canopy densities.

Canopy density	Spray volume (L/ha)	**Leaf surface**	Centre row		Leader (female)		**Mean**
			upper canopy	lower canopy	upper canopy	lower canopy	
Dense	2000	**top**	0.25	0.26	0.21	0.23	**0.24 d**
		bottom	0.25	2.44	0.50	1.18	**1.09 b**
medium	1500	**top**	0.59	0.43	0.44	0.30	**0.44 cd**
		bottom	0.70	2.26	0.73	1.11	**1.20 b**
Light	1000	**top**	0.67	0.51	0.70	0.66	**0.63 c**
		bottom	0.87	2.11	1.20	2.17	**1.57 a**
Mean			**0.55 C**	**1.33 A**	**0.63 C**	**0.93 B**	

Means sharing common postscripts are not significantly different (LSD, P=0.05). LSD (P=0.05) for data in shaded table = 0.36.

The top surface of kiwifruit leaves is very easy-to-wet. Deposits on upper surfaces of leaves are quite consistent within canopies and show much less variation across all zones than on the difficult-to-wet lower surfaces (Table 4). Similar deposits and trends to those measured here were recorded on top surfaces of leaves after application of 1000 L/ha sprays containing Du-Wett superspreader (Gaskin *et al*. 2011). The trend on top surfaces of leaves is for deposits to increase as sprays become more concentrated, i.e. as spray volume is reduced, and also as canopy density decreases (Fig. 4).

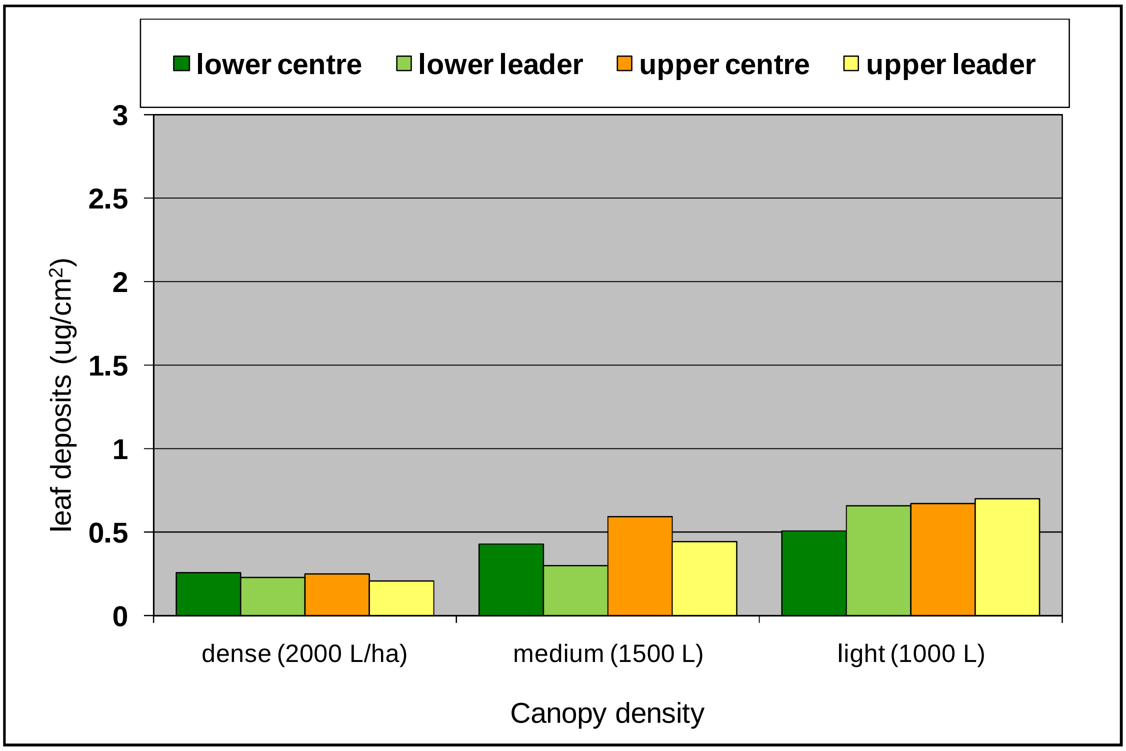

Figure 4: Mean deposits on TOP surfaces of leaves in four positions within different density canopies.

Mean deposits on the bottom surfaces of leaves could be similar to those on top surfaces when overall deposits were low, as in the dense upper canopy (Table 4), reflecting the limited spray which reached both surfaces. Where bottom surfaces of leaves were directly exposed to sprays, then deposits could be as much as nine-fold higher than on top surfaces of leaves (Table 4) due to the large surface area of hairs present on this surface. Deposits on the bottom surfaces of leaves in the lower canopy (directly exposed to sprays) were quite similar for all canopy densities, particularly in the centre row (Fig. 5). At the lower leader position, most spray was retained on the light canopy, reflecting the bulk leaf deposits (Fig. 3) and lowest deposits were measured on the upper leaves in the centre row (Fig. 5). The centre canopy zone had more leaf layers than the leader zone in the dense canopy but not in the light canopy (Table 1), confirming that while canopy density determines overall spray coverage, sprayer setup is important for distributing sprays evenly to all zones.

The 1000 L/ha spray on the light canopy resulted in higher bottom leaf deposits than the 1500 L/ha spray on the medium canopy, which were similar to the 2000 L/ha spray on the dense canopy (Table 4 & Fig. 5).

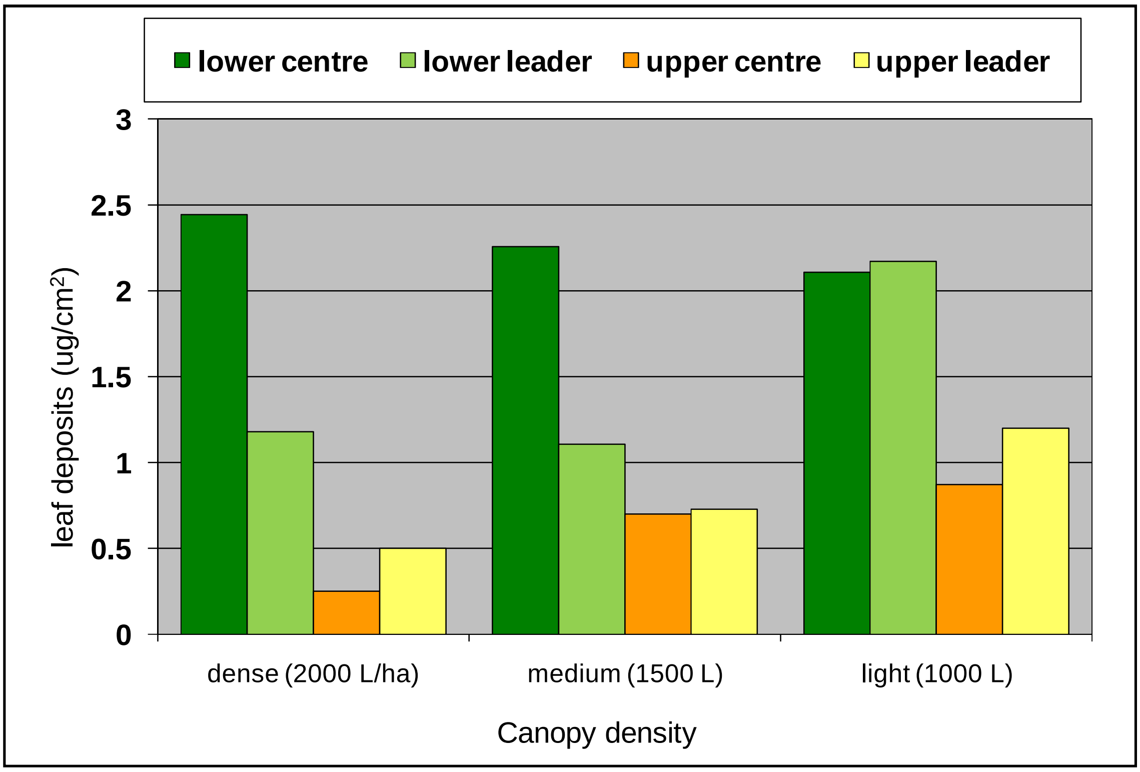

Figure 5: Mean deposits on BOTTOM surfaces of leaves in four positions within different density canopies.

No superspreader adjuvant was used in the study reported here; sprays were applied at dilute volumes to run-off (except that the application volume to the dense canopy was less than the true estimated run-off volume) and contained the conventional adjuvant Latron B. Despite this, the deposits retained on top surfaces of leaves were very similar to those measured from dilute and 2.5x concentrate sprays containing 400 ml/ha Du-Wett superspreader, applied to late autumn Hort 16A canopies (Gaskin *et al.* 2011). Adjuvants have little effect on spray retention on easy-to-wet leaf surfaces except to increase run-off and thus, will often reduce retention of dilute sprays. Concentrating sprays, allied with reducing spray volumes, is a useful method to increase chemical deposits on the topside of leaves. The inclusion of a superspreader adjuvant to such low volume, concentrate sprays will ensure that the entire top surface of an easy-to-wet leaf is covered with much less water than run-off volume (Photo 4).

Photo 4: Coverage of a leaf top surface with (LHS) dilute spray containing Latron B, and (RHS) 3x concentrate spray containing Du-Wett superspreader
(both sprays contain a UV dye to visualise deposits)

Deposits on the 'hairy' bottom side of leaves in this study, from dilute sprays containing Latron B adjuvant, were consistently lower than from concentrate sprays containing a superspreader (Du-Wett) adjuvant in our previous study (Gaskin *et al.* 2011). The reason for this is illustrated in Photos 5-7. The dilute spray containing Latron B (which does not superspread) accumulates on the top of the hair layer (Photo 5). Many droplets coagulate together on the hairs when sprays are applied to run-off, and if/when they reach a critical size they will fall from the leaf. Those droplets that remain are retained primarily on top of the hair layer and very few contact the true leaf surface. If no adjuvant is included in a dilute copper spray (e.g.Nordox), droplet accumulation and coalescence on hairs is exacerbated with even less spray contacting the leaf surface (Photo 6).

In contrast, the superspreader allows the spray to completely wet hairs, droplets run down them, contact the leaf surface and continue to spread there (Photo 7). More of the concentrate spray is retained on the hairy surface because droplets constantly 'wick' away from the top of the hair layer onto the true leaf surface. They do not coagulate on the hair layer.

Concentrate sprays applied in lower volume, with inclusion of a superspreader, will increase chemical deposits on the hairy underside of kiwifruit leaves and ensure the chemical contacts and covers the true leaf surface. The concentrate, low-volume sprays do not accumulate as 'clumped' discrete droplets and they dry faster. As a result they should reduce the risk of spray phytotoxicity.

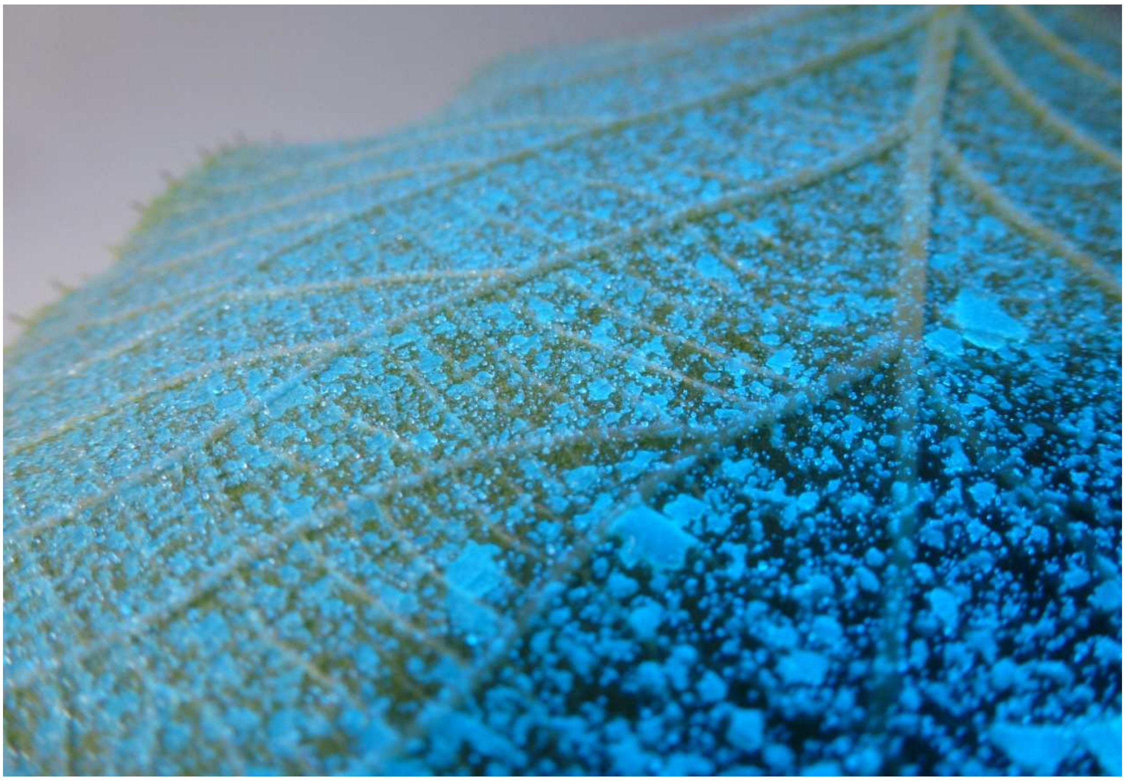

Photo 5: Coverage of a leaf bottom surface with dilute spray containing Latron B

Photo 6: Coverage of a leaf bottom surface with dilute copper spray (Nordox 75WG at 30 g/100 L) containing no adjuvant

Photo 7: Coverage of a leaf bottom surface with concentrate spray containing Du-Wett superspreader

General discussion

This study was originally conceived as a more extensive set of treatments designed to assess the relative importance and interactions of canopy density, application volume, travel speed and sprayer air assistance volumes. Unfortunately, budget constraints meant that the proposed work had to be reduced to the limited number of treatments reported here. Earlier work (Manktelow *et al.* 2012) had indicated that canopy density was the overriding factor in determining spray deposit levels and distribution, so this study concentrated on quantifying canopy density effects.

The difference between the canopy densities achieved by pruning in the light and moderate canopies in this experiment was less than originally planned. The light canopy would ideally have received some additional pruning to open it up further and increase the differences between these two treatments. However, the light canopy was considered to be at the limits of a fully developed, commercially viable, productive canopy. The relative similarity in deposits between the light and moderate canopies was heartening. Deposit and coverage failures were only observed in the dense canopy treatment, despite it receiving the highest volume of spray.

The air assistance volume used on the three different canopies was held constant despite the differences in canopy density. This was a compromise, with possibly too much air in the light and moderate canopies and too little in the dense. However, it was considered necessary to limit changes to sprayer setup and application volume was the only significant sprayer adjustment made in relation to the main canopy density variables being tested.

Optimising spray application is a trade-off between spray retention efficiency and the time and dollar cost of application. A general rule of thumb has been that slowing down and/or increasing spray application volume will improve spray deposits and evenness of spray coverage. Increasing application volumes to the point of runoff, or beyond, assumes that easily covered regions close to the sprayer (lower canopy zones in pergola trained kiwifruit) will be wetted until excessive spray runs off. Thus, a stable deposit will be achieved on fully wetted tissues. The introduction of superspreader adjuvants has challenged this assumption, with highest deposits and most effective coverage usually seen at volumes 2 to 5-fold less than run-off volumes.

The deposit data presented in this (and related) report(s) is expressed in terms of equivalent chemical application rates across all treatments (at 1 kg ai/ha). This work demonstrates the differences in deposits that can be expected when equivalent amounts of chemical are applied to canopies with different total surface areas – the greater the surface area the chemical must cover, the lower the average expected deposit per square centimetre of tissue. The kiwifruit industry lacks useful guidelines as to how best to adjust chemical application rates for canopies of different sizes and densities. However, this work indicates that deposits in hard-to-reach areas of dense canopies will almost certainly be too low and variable to provide reliable efficacy, even if chemical application rates were to be increased to compensate for the greater canopy surface area.

Control of a disease like Psa, using contact acting products, requires relatively even spray deposits and coverage. This work confirmed the hypothesis that overly dense canopies present too hard a spraying target for reliable spray coverage and that canopy management to achieve and maintain relatively open canopies is required.

CONCLUSIONS

- The dense, unmanaged canopy received lower spray deposits in all zones than managed (pruned) canopies.

- Mean deposits on the dense canopy (2000 L/ha spray volume) were approximately 40% less than for the medium (1500 L/ha) and light (1000 L/ha) canopies despite receiving the highest volume spray (deposit measurements are based on equivalent chemical application rates per ha in different spray volumes).

- Spray deposits on all foliage in the dense unmanaged canopy were unacceptable, apart from on leaves directly exposed to the sprayer.

- **Even using the current best type of airblast sprayer and setup available, dense unmanaged canopies cannot be adequately covered with protectant sprays applied in the typical dilute spray volumes used by the kiwifruit industry.**

- Spray deposits on all foliage in the managed canopies were acceptable, with the proviso that the lower canopy, directly exposed to the sprayer, received excessively high deposits.

- In a pergola structure, airblast sprayers will always overdose the lower exposed foliage.

- **All foliage can be covered with protectant sprays, using a well set-up airblast sprayer, if canopies are managed to reduce their density.**

- The bottom surfaces of kiwifruit leaves have the capacity to retain more spray deposits than the top surface due to their hairy character, but those deposits may not always contact the leaf surface and thus, may not protect it adequately.

- Concentrated, reduced-volume airblast sprays will be more efficient in managed canopies compared to dilute, high volume sprays, and their retention and coverage on foliage will benefit from the addition of a superspreader-type adjuvant.

ACKNOWLEDGEMENTS

Thanks to Mike Muller for sourcing the orchard, for pruning the canopies and giving helpful advice. Thanks also to D&K Walker for the use of their orchard. R&R Tractors Ltd provided the tractor and sprayer. Technical assistance was provided by Kevin Steele, Alison Forster, David Horgan and Justin Nairn. Funding was provided by ZESPRI and the MAF Sustainable Farming Fund.

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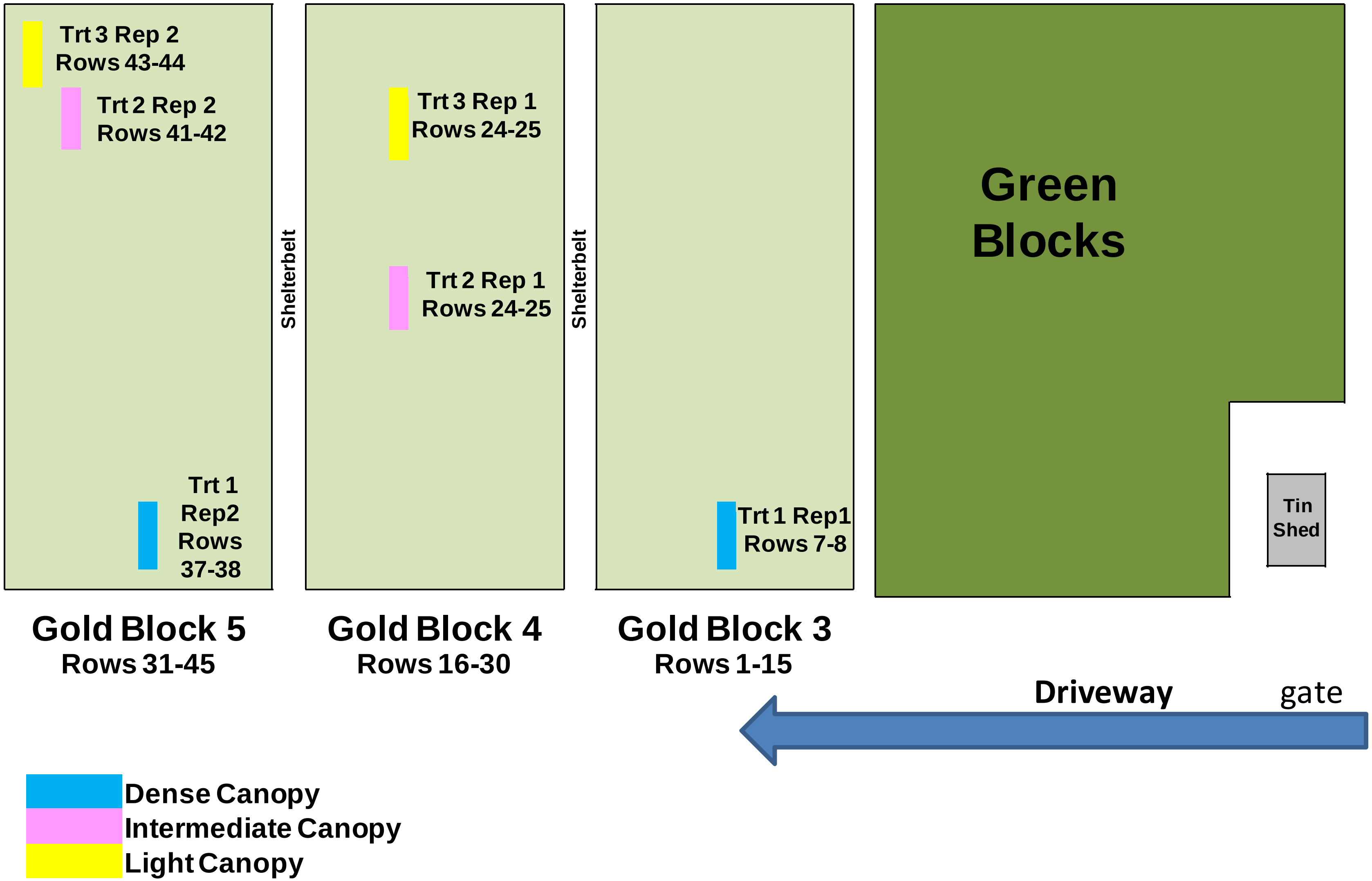
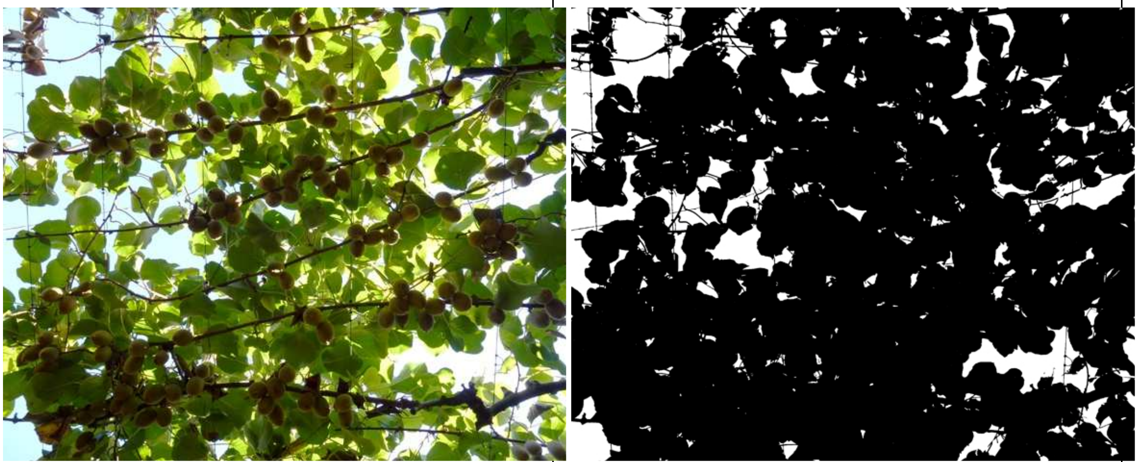
APPENDIX 1

Map of orchard site showing location of treated plots: DL & KN Walker Orchard, Wilson Rd Sth: (3.3 m rows)

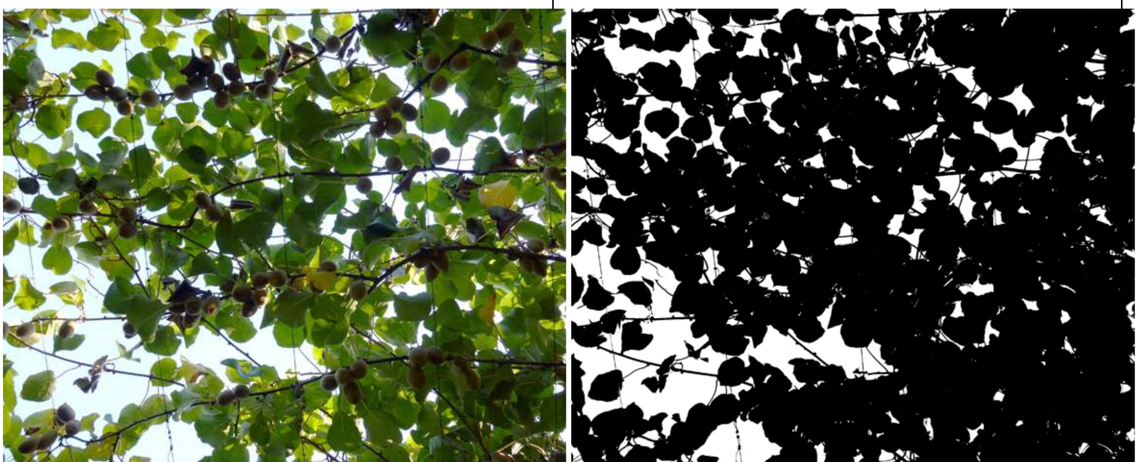


APPENDIX 2
Examples of canopy “gap fraction” photos

DENSE canopy: canopy area = 96.82%; sky area = 3.18%



MEDIUM canopy: canopy area = 85.56%; sky area = 14.44%



LIGHT canopy: canopy area = 81.70%; sky area = 18.30%

APPENDIX 3
Summary of meteorological conditions for the study

Tmt	Rep	Time sprayed	Mean wind speed (m/s)	Max. wind speed (m/s)	Wind direction	Temp ºC
1	1	1520	0.26	1.1	E	26
	2	1530	0	0	-	26
2	1	1230	0.02	0.12	E	23
	2	1310	0	0	-	24
3	1	1400	0.12	0.60	E	25
	2	1430	0.06	0.41	E	22

APPENDIX 4
Sprayer setup

The sprayer was a trailed Eco 2000 sprayer with an Arivac front entry 36 inch fan and three spray rings consisting of eight nozzles per side. All three spray volume treatments were achieved using Article 58 pink ceramic tips and stainless steel cores (nozzle details below). Spray droplet sizes from these nozzles were expected to be relatively similar, and coarser than those from hollow cone ceramic TX or Albuz ATR nozzles (that would normally be used for the lower application volume treatments). Travel speed was ca. 6.1 km/h in all applications. The sprayer was fitted with an automatic rate controller that delivered the target application volumes by adjusting operating pressures in response to any slight travel speed variations. The sprayer was operated using the low fan gear with a PTO speed of 440 rpm.

TREATMENT 1 - Open canopy

Target Volume	1000	l/ha
	33	l/100m row
Target speed	6.1	km/hr
Row spacing	3.3	metres
Output required	33.6	l/min total

Setup Details: Atom eco 2000 3 ring - 8 nozzle per side / Gold pergola / open canopy art 58 nozzles

NOZZLING DETAILS

Nozzle pressure: 1500 kPa (aprox)

Description		Nozzle name	Measured outputs	%	Cum%
Front nozzle ring	1	M1.5-nch	2.8	16.4%	16%
	2	M1.5-nch	2.8	16.4%	33%
	3	M1.5-1.0	4.1	24.1%	57%
	4	M1.5-1.2	4.3	25.6%	83%
	5	M1.2-1.0	2.9	17.4%	100%
	6	Off			
	7	Off			
	8	Off			
Output from one side (l/min)			16.9		
Total output (l/min)			33.8		

TREATMENT 2 - Medium canopy

Target Volume	1500	l/ha
	49.5	l/100m row
Target speed	6.1	km/hr
Row spacing	3.3	metres
Output required	50.3	l/min total

Setup Details: Atom eco 2000 3 ring - 8 nozzle per side / Gold pergola / Medium canopy art 58 nozzles

NOZZLING DETAILS

Nozzle pressure: 1500 kPa (aprox)

Description		Nozzle name	Measured outputs	%	Cum%
Front nozzle ring	1	M1.5-1.0	4.1	16.3%	16%
	2	M1.8-1.0	5.3	21.2%	37%
	3	M1.8-1.2	5.3	21.2%	59%
	4	M1.8-1.5	6.0	23.8%	83%
	5	M1.5-1.5	4.4	17.5%	100%
	6	Off			
	7	Off			
	8	Off			
Output from one side (l/min)			25.2		
Total output (l/min)			50.3		

TREATMENT 3 - Dense canopy

Target Volume	2000	l/ha
	66	l/100m row
Target speed	6.1	km/hr
Row spacing	3.3	metres
Output required	67.1	l/min total

Setup Details: Atom eco 2000 3 ring - 8 nozzle per side / Gold pergola / Dense canopy art 58 nozzles

NOZZLING DETAILS

Nozzle pressure: 1750 kPa (aprox)

Description		Nozzle name	Measured outputs	%	Cum%
Front nozzle ring	1	M1.8-1.2	6.0	17.9%	18%
	2	M2.0-1.5	7.0	20.9%	39%
	3	M2.0-1.8	7.6	22.6%	61%
	4	M2.0-1.8	7.8	23.1%	85%
	5	M1.5-1.2	5.2	15.5%	100%
	6	Off			
	7	Off			
	8	Off			
Output from one side (l/min)			33.6		
Total output (l/min)			67.1		

APPENDIX 5
Water sensitive paper records of single replicate from each treatment

Canopy densities_Ground based sprays, on Hort 16A foliage canopy using water sensitive papers.

Location: Wilson Rd South, Paengaroa.
Walker Orchard.

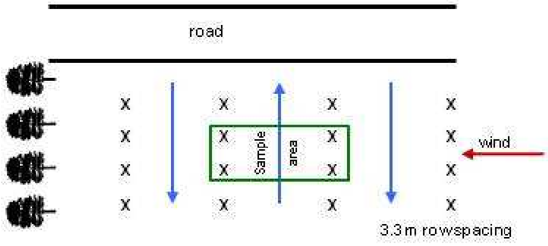
Sprayer: Eco 2000.
Arivac front entry 36 inch fan. Triple nozzle ring.

Nozzles: 5x Masoti Article 58 ceramic disk (pink) & stainless core nozzles. (per side). Front ring operating.
Pressure: 18.3 bar
Water rate (L/ha): 2000L
Travel speed (km/h): 6.2 km /hr

Date: 14th March 2012

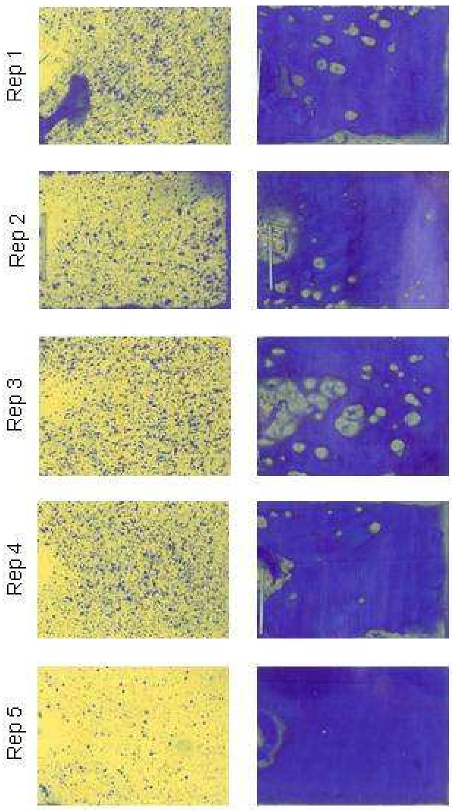
Wind speed (m/s): 0.26 m/s (1.0 max)
Temperature: 26 °c

Sprayer travel direction:

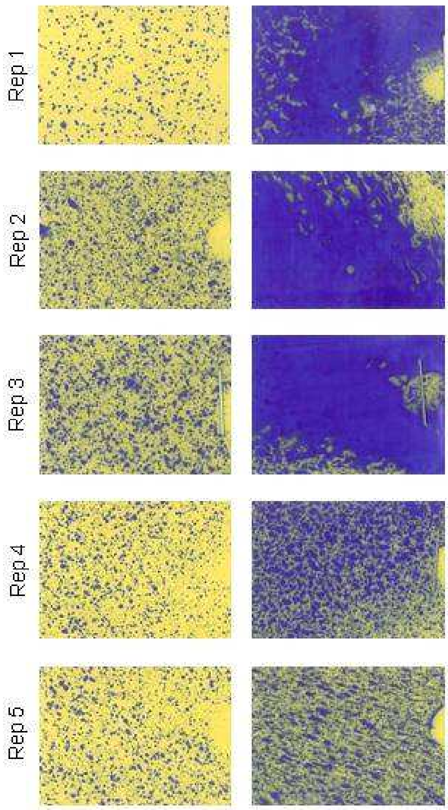


Trt: 1: Dense canopy - 25ml /100L Latron B (0.025%)

Centre lower canopy deposits
Upper surface Lower surface



Centre upper canopy deposits
Upper surface Lower surface



Canopy densities_Ground based sprays, on Hort 16A foliage canopy using water sensitive papers.

Location: Wilson Rd South, Paengaroa.
Walker Orchard.

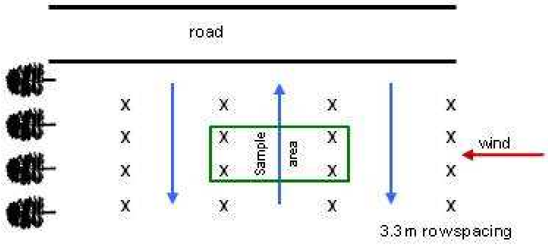
Date: 14th March 2012

Sprayer: Eco 2000.
Arivac front entry 36 inch fan. Triple nozzle ring.

Wind speed (m/s): 0.26 m/s (1.0 max)
Temperature: 26 °C

Nozzles: 5x Masoti Article 58 ceramic disk (pink) & stainless core nozzles. (per side). Front ring operating.
Pressure: 18.3 bar
Water rate (L/ha): 2000L
Travel speed (km/h): 6.2 km /hr

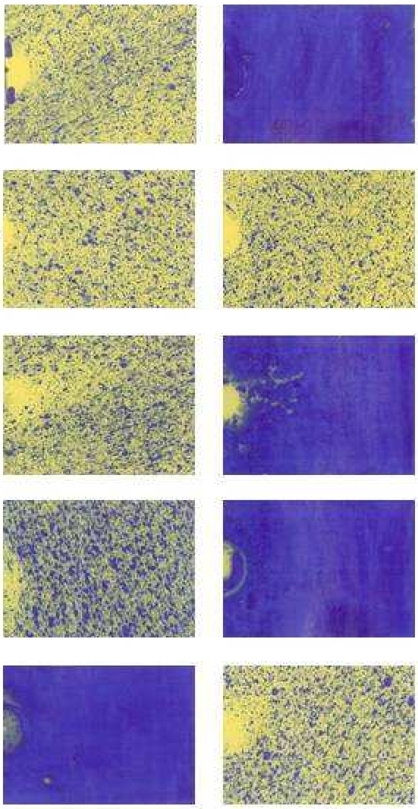
Sprayer travel direction:



Trt: 1: Dense canopy - 25ml /100L Latron B (0.025%)

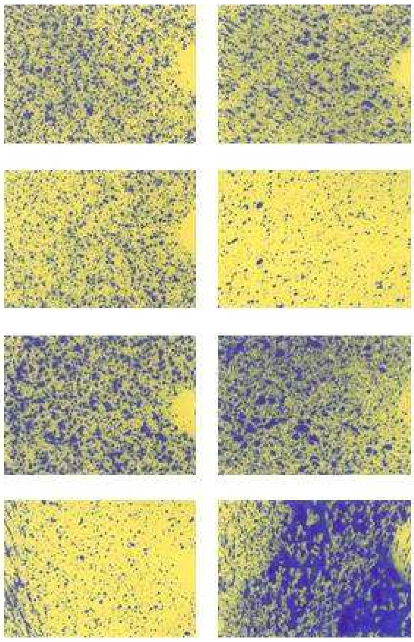
Leader lower canopy deposits
Upper surface / Lower surface

Rep 1
Rep 2
Rep 3
Rep 4
Rep 5



Leader upper canopy deposits
Upper surface / Lower surface

Rep 1
Rep 2
Rep 3
Rep 4
Rep 5



Canopy densities_Ground based sprays, on Hort 16A foliage canopy using water sensitive papers.

Location: Wilson Rd South, Paengaroa.
Walker Orchard.

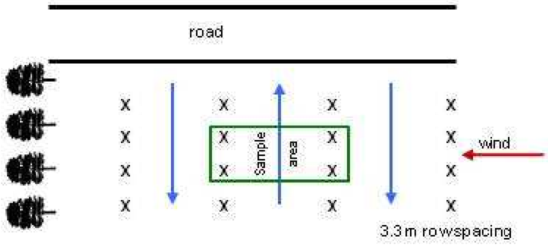
Date: 14th March 2012

Sprayer: Eco 2000.
Arivac front entry 36 inch fan. Triple nozzle ring.

Wind speed (m/s): 0.01 m/s (0.22 max)
Temperature: 23 °C

Nozzles: 5x Masoti Article 58 ceramic disk (pink) & stainless core nozzles. (per side). Front ring operating.
Pressure: 15.6 bar
Water rate (L/ha): 1500L
Travel speed (km/h): 6.2 km /hr

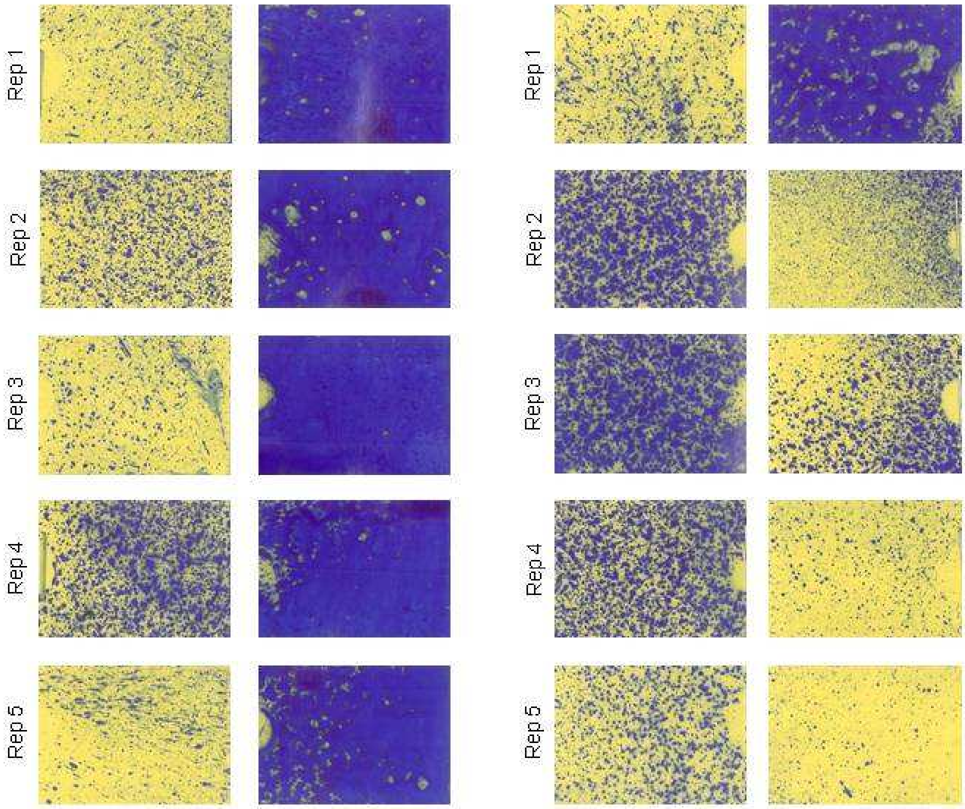
Sprayer travel direction:



Trt: 2: Medium canopy - 25ml /100L Latron B (0.025%)

Centre lower canopy deposits — Upper surface / Lower surface

Centre upper canopy deposits — Upper surface / Lower surface



Canopy densities_Ground based sprays, on Hort 16A foliage canopy using water sensitive papers.

Location: Wilson Rd South, Paengaroa.
Walker Orchard.

Date: 14th March 2012

Sprayer: Eco 2000.
Arivac front entry 36 inch fan. Triple nozzle ring.

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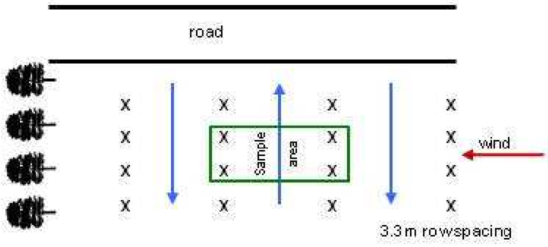
Pressure: 15.6 bar
Water rate (L/ha): 1500L
Travel speed (km/h): 6.2 km /hr

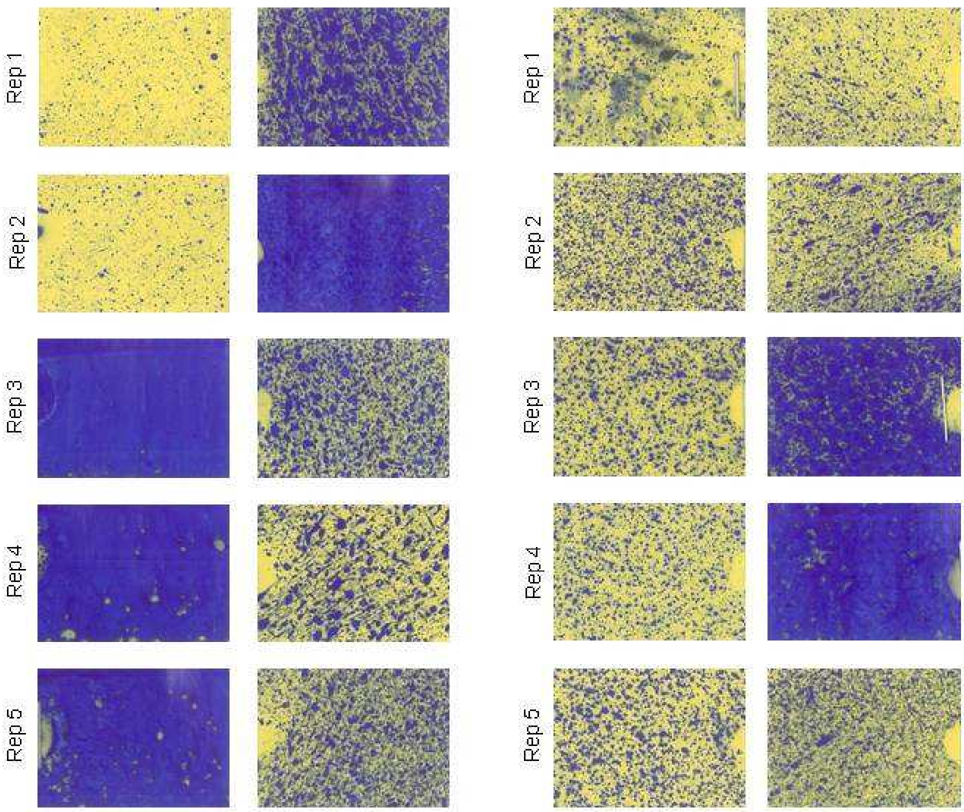
Sprayer travel direction:



Trt: 2: Medium canopy - 25ml /100L Latron B (0.025%)

Leader lower canopy deposits — Upper surface | Lower surface

Leader upper canopy deposits — Upper surface | Lower surface



Canopy densities_Ground based sprays, on Hort 16A foliage canopy using water sensitive papers.

Location: Wilson Rd South, Paengaroa.
Walker Orchard.

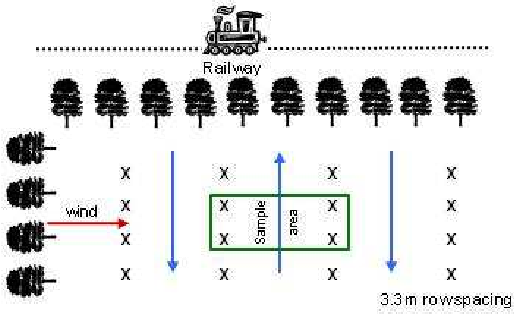
Date: 14th March 2012

Sprayer: Eco 2000.
Arivac front entry 36 inch fan. Triple nozzle ring.

Wind speed (m/s): 0.06 m/s (0.41 max)
Temperature: 22 °C

Nozzles: 5x Masoti Article 58 ceramic disk (pink) & stainless core nozzles. (per side). Front ring operating.
Pressure: 15.3 bar
Water rate (L/ha): 1000L
Travel speed (km/h): 6.2 km /hr

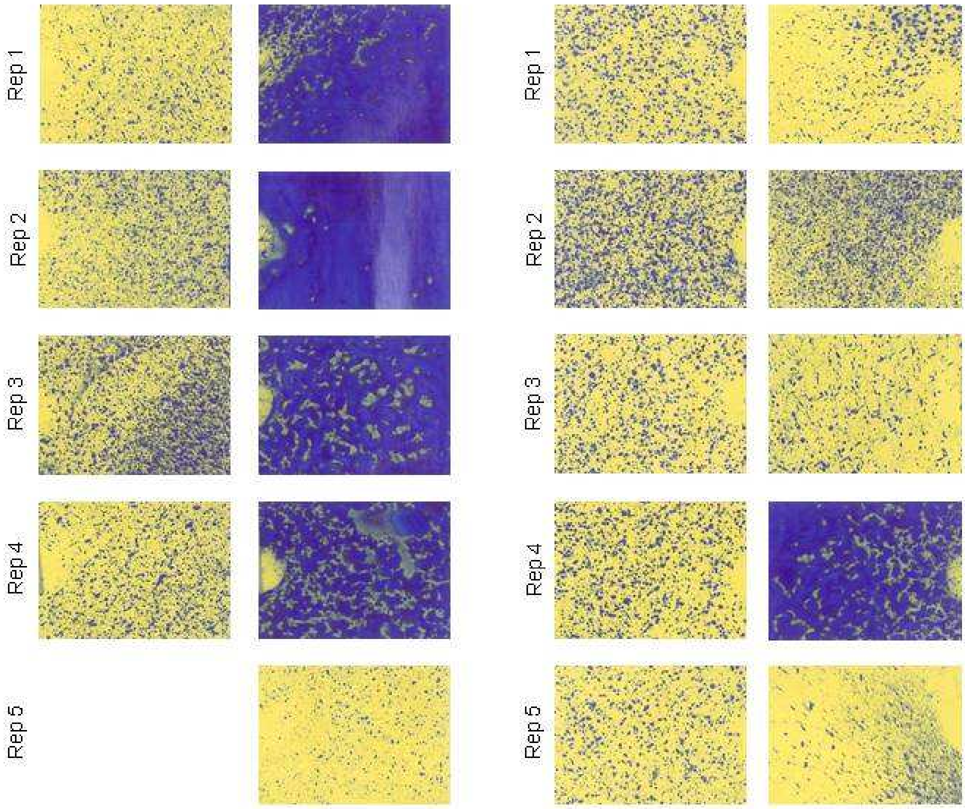
Sprayer travel direction:



Trt: 3: Light canopy - 25ml /100L Latron B (0.025%)

Centre lower canopy deposits — Upper surface / Lower surface

Centre upper canopy deposits — Upper surface / Lower surface



Canopy densities_Ground based sprays, on Hort 16A foliage canopy using water sensitive papers.

Location: Wilson Rd South, Paengaroa.
Walker Orchard.

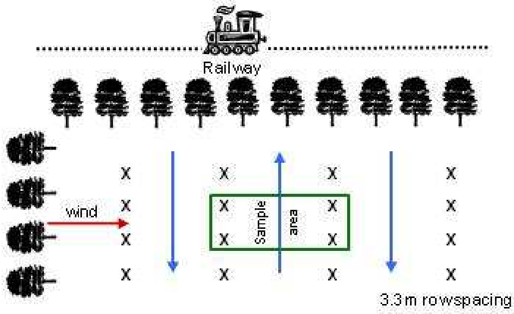
Date: 14th March 2012

Sprayer: Eco 2000.
Arivac front entry 36 inch fan. Triple nozzle ring.

Wind speed (m/s): 0.06 m/s (0.41 max)
Temperature: 22 °C

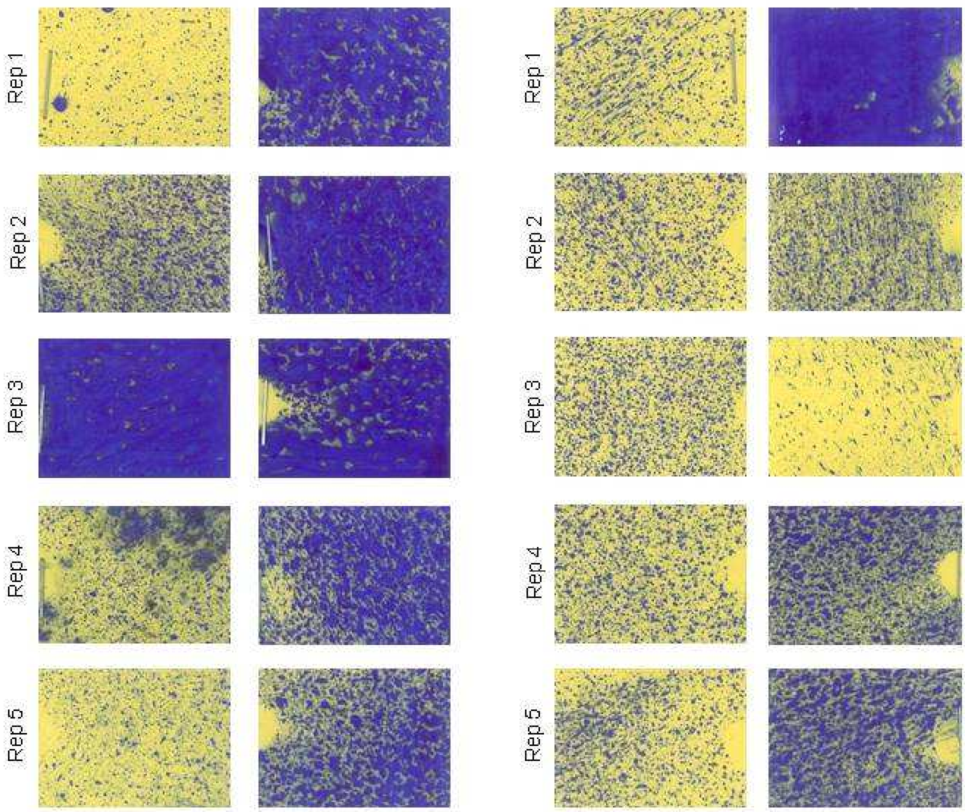
Nozzles: 5x Masoti Article 58 ceramic disk (pink) & stainless core nozzles. (per side). Front ring operating.
Pressure: 15.3 bar
Water rate (L/ha): 1000L
Travel speed (km/h): 6.2 km /hr

Sprayer travel direction:



Trt: 3: Light canopy - 25ml /100L Latron B (0.025%)

Leader lower canopy deposits		Leader upper canopy deposits	
Upper surface	Lower surface	Upper surface	Lower surface



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