Plant Protection Chemistry NEW ZEALAND

Report to Zespri Group Ltd

Optimising application of (Psa) protectant sprays on kiwifruit spring canopies

Robyn Gaskin, David Manktelow, Kevin Steele, Rebecca van Leeuwen and Bill May

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Contact Details: Robyn Gaskin
PPC_{NZ}
PO Box 6282
Rotorua
New Zealand

Ph: +64 7 343-5887
Fax: +64 7 343-5811
Email: robyn.gaskin@ppcnz.co.nz
Web: www.ppcnz.co.nz

David Manktelow
Manktelow and Associates Ltd
PO Box 3415
Napier
New Zealand

Ph: +64 6 877-8786
Fax: +64 6 844-0253
Email: dave.manktelow@gmail.com

EXECUTIVE SUMMARY

This study was undertaken to provide prescriptions for airblast application of protectant sprays to kiwifruit at the spring canopy stage.

The studies were undertaken in late May 2011 in a BOP orchard, on a Hort 16A and a Hayward pergola canopy, both on 3.8 m row spacing. Two preliminary studies were undertaken in which coverage from a range of spray application volumes, droplet sizes, travel speeds and air assistance volumes were compared on the basis of coverage on water sensitive papers. That work culminated in a quantitative deposit study in which six different spray applications (varying nozzles, fan speed, travel speed and adjuvant rate) were compared. Deposits were quantified on four different canopy zones in the pergola; upper and lower canopy in the centre row and leader positions. Additionally, deposits on the top and bottom surfaces of individual leaves in two treatments were determined.

In summary:

- ❖ Most pergola kiwifruit canopies can be expected to require no more than 1000 L/ha to spray to the point of run-off in the period from bud break to pre-bloom. Point of run-off spray volumes required over the bloom period are unlikely to exceed 1500 L/ha.

- ❖ This work confirmed that both dilute and lower volume concentrate sprays can achieve excellent spray coverage and spray deposits throughout the canopy and on both surfaces of leaves.

- ❖ The use of Du-Wett adjuvant in spring canopy sprays will assist in complete coverage of leaf surfaces. The use rate should be 400 ml/ha, for application volumes of 400-1000 L/ha (rates and volumes for flowering sprays have yet to be confirmed).
    - o For 800-1000 L/ha applications Du-Wett rate = 400 ml/ha (= 50 ml/100 L in an 800 L/ha spray; 40 ml/100 L in a 1000 L/ha spray) to ensure maximum spray coverage.
    - o When spraying at volumes below the point of run-off, fine droplet nozzles should be used to deliver 400-500 L/ha (half run-off volume) with chemical at 2x concentrate (i.e. apply the same amount of chemical per ha that you would apply using a dilute spray). For concentrate sprays use Du-Wett adjuvant at 400 ml/ha (=100 ml/100 L in a 400 L/ha spray; 80 ml/100 L in a 500 L spray) to ensure maximum coverage of foliar surfaces.
    - o **Use of low volume sprays without both concentrate spraying and superspreader addition is not recommended**.

- ❖ Sprayer setup and operational decisions are a critical part of achieving even spray coverage on target canes and leaves.
    - o Sprayer fan speed should be sufficient to consistently project spray at least a metre above and beyond the most distant upwind canopy within the sprayed row

- A maximum travel speed of 6-7.5 km/h is recommended, with slower speeds and/or greater air assistance required in wider row spacings, denser canopies and/or stronger winds.
- Deposit variability is likely to increase with increasing speed. Lower travel speeds may improve coverage.
- **The use of large droplet air induction (AI) nozzles for applying protectant sprays to spring canopies is not recommended**; they deliver highly variable and often unacceptably low deposits on foliated kiwifruit canopies.
- Avoid the use of spray application volumes of less than half the run-off volume (2x concentrate) required for any given canopy.

❖ Spray coverage monitoring can be easily undertaken using water sensitive papers pinned onto the top and bottom surfaces of leaves.
  - These give immediate feedback as to whether spray is reaching all parts of the canopy and of the droplet distributions achieved (they do not show potential spreading from superspreader adjuvants).
  - The use of 20 half papers (10 each on top and bottom leaf surfaces) should be sufficient to gain a good appreciation of coverage achieved.
  - Staple or glue papers to a record sheet and rate them for Excellent, Adequate or Inadequate coverage. Expect to see no more than 20% of papers (4 out of 20) with inadequate coverage after spraying the immediate and adjacent rows.

❖ On pergola canopies for ground-applied sprays in the period bud-break to pre-bloom:
  - Foliage in the lower canopy will receive higher deposits than the upper canopy
  - The bottom surfaces of leaves will retain higher deposits than the top surfaces.
  - Chemical over-dosing is most likely to occur on lower zone foliage in the centre row and on bottom surfaces of leaves.
  - Chemical under-dosing is most likely to occur on the top surfaces of leaves in the upper canopy and aerial application may be beneficial to address this when water sensitive papers indicate a problem exists.

Optimising application of (Psa) protectant sprays on kiwifruit spring canopies

INTRODUCTION

The infection of kiwifruit by *Pseudomonas syringae pv Actinidiae* (Psa) is associated with heavy rain and strong winds. The bacterium is believed to infect kiwifruit primarily by airborne transmissions settling on exposed foliage. Application of protectant sprays to vines is considered essential to protect against Psa infection. At this stage the most effective Psa control options are based on application of protectant sprays, especially copper compounds. Recent work on the rainfastness of copper compounds has provided encouraging data on the potential longevity of copper compounds on foliage and dormant canes (Gaskin *et al*. 2011a, b). However, the level of copper deposits required to kill Psa bacteria on kiwifruit plant surfaces is unknown at this time.

In the absence of any other information, it is assumed that protectant products will have the greatest chance of preventing bacterial infections if all plant surfaces are evenly covered. There are at least four separate application decisions that will determine spray coverage and dose of chemical achieved across target canopies. These are; chemical application rate, spray application volume, sprayer setup and the spreading and wetting properties of the spray liquid. It is possible and sensible to adjust any or all of these factors in relation to the size and density of the target canopy in order to achieve even and consistent spray deposits. Unfortunately there is currently no consensus within the New Zealand kiwifruit industry as to how, or even whether, such adjustments should be undertaken.

The studies reported here were undertaken to develop guidelines for efficient airblast application of protectant sprays to spring kiwifruit canopies in a pergola orchard and to provide spray prescriptions to maximise coverage on foliage in all canopy zones. The studies also aimed to refine the use of water sensitive papers (WSP) as a coverage assessment tool that could be used by growers in spring spraying. The use of water sensitive papers as rapid feedback tools is seen as extremely important in assisting growers to identify when spray coverage may be a limiting factor in their Psa control programmes and to give them confidence in their sprayer setup and operational decisions.

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METHODS AND MATERIALS

The deposit studies were undertaken on 24th, 30th and 31st May 2011, on M. Brick's "Omega" orchard, 220 Maniatutu Road, Pongakawa (Bay of Plenty). The first two days were preliminary studies, utilising water sensitive papers (WSP) to select the most promising sprayer setups and adjuvant use rate. The deposit study was undertaken on the third day, monitoring deposits from six selected treatments (varying spray volume, nozzling, pressure, travel speed, air volume) in four different canopy zones.

Preliminary WSP studies

The first study involved water sprays (no adjuvant addition) applied with a self-propelled Atom 2000 Turbo Sprayer (front entry air) through six different setups (Appendix 1) to a light Hort 16A canopy (approx. 20% leaf drop; at least three leaves deep) on 3.75 m rows (Photograph 1). In each test, three bays in three adjacent rows were treated, with both sides of the sprayer operating (four nozzles per side) on each pass. The sprayer was driven in the opposite direction down each row. WSPs were positioned in the centre bay of the grid of nine treated bays, with the same area used for all treatments. Prior to each test fresh papers were laid out to collect deposits. WSP were located in two different positions within the centre bay.

WSP Position 1: A five metre high pole was positioned in the leader zone trunk line on each side of the spray bay (Photographs 1 & 2) and WSPs were folded in half and placed horizontally (to give an upper and lower surface) at metre intervals on each pole (10 papers equalled 20 surfaces). The 2 m height position was in the middle of the canopy leaf layer and papers at 3, 4 and 5 m were all above the canopy. While there were no canes strung above this canopy, the above-canopy WSP sought to determine if sprays could potentially reach them.


Photograph 1: LHS = Post-harvest autumn Hort 16A canopy. RHS = canopy density viewed from beneath pergola.

WSP Position 2: An additional 10 WSPs were cut in half and pinned to the centres of upper and lower surfaces on each of 10 leaves (20 surfaces) within the canopy (Photograph 3). Leaves were located in the leader zone and row centre, and in the upper, mid and lower canopy of each zone. The sample leaves were tagged with ribbon and the WSPs were placed on the same leaves for each of the sprayer runs. After each run, WSPs were retrieved and stapled onto template recording sheets for scanning and examination. The WSP template sheets were assessed for (1) relative coverage on upper and lower surfaces, (2) droplet size and (3) height of spray plume projection above canopy and overall WSP coverage. A summary of the WSPs and spray application parameters tested in this preliminary study are given in Appendix 1.

Photograph 2: LHS = WSP folded in clip on pole. RHS = pole set up in leader canopy zone with WSPs at 1-5 metre intervals.

Photograph 3: Half sections of water sensitive papers (25 x 37 mm) pinned onto lower (LHS) and upper (RHS) leaf surfaces for in-canopy deposit assessments

The second WSP study was undertaken on a less dense Hayward canopy in the same orchard which was thought to better approximate spring canopies (Photograph 4). However, it was flatter and more continuous than a typical spring canopy. Nine water treatments (all containing Du-Wett® superspreader adjuvant at 400 ml/ha) were applied, concentrating on the nozzles identified as providing best coverage in the first study. These were the Masotti Article 58 disk and cores and the Albuz ATR hollow cones, with varying pressures (15-21 bar), fan speeds (1300-2000 rpm), spray volumes (400-1000 L/ha) and travel speeds (6 & 7.5 km/h).

A single treatment using Billericay bubble jet air induction flat fan nozzles at very low pressure (<4 bar) and volume (200 L/ha), as recommended by Garry Moffat (Canadian consultant), was included for comparison. Sprayer setup is detailed in Appendix 2. WSPs were placed within the canopy and processed as described above. Poles were not used to elevate WSPs above the canopy in the second study. A summary of the WSPs and spray application parameters tested in the study are given in Appendix 3.

Photograph 4: LHS = Post-harvest autumn Hayward canopy. RHS = canopy density viewed from beneath pergola.

Quantitative deposit study

Treatments

Six treatments were included in the quantitative deposit study (Table 1). They were all fine droplet sprays applied with a self-propelled Atom 2000 Turbo sprayer (Photograph 5) through either Masotti Article 58 disk and core or Albuz ATR hollow cone nozzles. Sprayer operational variables tested in this experiment were travel speed (6 or 7.5 km/h) and air assistance volumes (ca. 23,000, 27,500 and 33,500 m^3/hr, achieved using sprayer engine speeds of 1300, 1650 and 2000 rpm), recognising that high fan speeds can damage fragile spring growth.

Adjuvant (Du-Wett superspreader, Etec) was included in all treatments at 400 ml/ha, thus the adjuvant concentration in the spray mixture increased with decreasing application volumes (0.04-0.1% for spray volumes of 1000 down to 400 L/ha respectively). This adjuvant use rate is slightly higher than the current recommendation of 350 ml/ha, but was increased because of the need to ensure complete coverage of canopies with ‘spring’ protectant sprays.

No pesticide was included in any treatment as commercial copper sprays have no effect on the physical properties of sprays containing Du-Wett (data not presented). The yellow food dye, tartrazine, was included as a tracer to measure deposits in all treatments, at 3 kg/ha. All treatments were applied between midday and 3 pm in warm, moderately calm conditions. The block was sheltered and wind blew lightly down rows throughout the day.

Table 1: Treatments applied with an Atom 2000 Turbo sprayer.

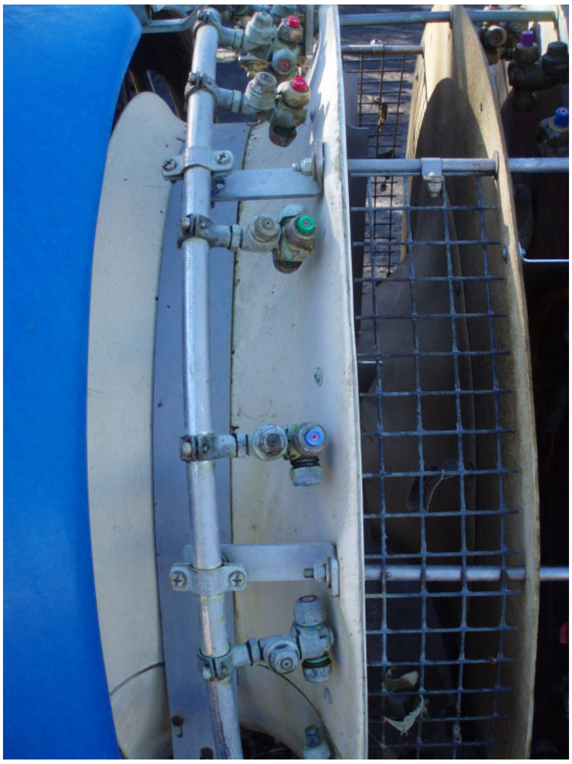
Tmt #	Nozzles[1]	Spray volume (L/ha)	Pressure (bar)	Fan speed (rpm)	Travel speed (km/h)	Adjuvant rate L/ha (%)
1	Art. 58	1000	17.5	1650	6.0	400 (0.04)
2	ATR	600	14.0	1650	6.0	400 (0.07)
3	ATR	400	14.5	1650	6.0	400 (0.10)
4	ATR	400	14.5	1300	6.0	400 (0.10)
5	ATR	400	14.5	2000	6.0	400 (0.10)
6	ATR	400	12.0	2000	7.5	400 (0.10)

[1]Art. 58 = Masotti disk & core nozzles; ATR = Albuz ceramic hollow cone nozzles (see Appendix 2 for nozzling details)

Photograph 4: Self-propelled Atom 2000 Turbo sprayer

Sprayer set-up

The sprayer used was a self propelled Atom 2000 Turbo with a front entry axial fan fitted with straightening vanes designed for use in kiwifruit. However, the top baffles in the sprayer had been removed to increase air output into the centre section of the rows (Photograph 5). The sprayer fan air output volumes were adjusted by varying engine speeds (described above and in Table 1). The hydrostatic drive system on this type of sprayer allowed target travel speeds to be maintained while air output volumes could be varied using engine speed changes. The 1300 rpm fan speed was visually assessed as a little low for the canopy and wind conditions, but all fan speeds were observed to project the spray plume beyond the most distant upwind cane targets under the conditions experienced during application. Sprayer nozzling is detailed in Appendix 2.




Photograph 5: LHS =Detail of Atom nozzles and air outlet showing top baffle removed. RHS = Detail of Atom sprayer showing rearward direction of spray plume output as a consequence of the front entry axial fan.

Spray application

Sprays were applied to a post-harvest Hayward pergola canopy on 3.8 m row spacing as used in the second WSP study (Photograph 4). Rows were oriented north-south (Block 11). Two replicate applications were made for each treatment, with each treatment applied to three bays in each of three adjacent rows. After spray treatments had dried, leaf samples were collected from the central bay in each grid of nine treated bays. Samples were taken from four different canopy zones in each treatment bay; upper (leaves shielded from sprayer) and lower (exposed to sprayer) positions at the row centre and leader edge. Five replicate samples (of five random leaves each) were sampled in each zone. They were processed as described in Gaskin *et al.* 2009. Briefly, they were washed to recover dye and quantify spray deposits and leaf areas were determined with a Leaf Area Meter. Deposits were calculated as dose (μg/cm^2) normalised to 1 kg a.i. applied per ha. Results were statistically analysed using ANOVA to determine the significance of treatment on spray deposits retained on leaves in different zones.

Additionally, single leaves were sampled and processed from two treatments (#1 and #5, Table 1), where their top and bottom surfaces were washed separately to determine the deposits on each surface. Five leaves were randomly sampled from each of the four canopy zones in one replicate bay within each treatment (i.e. 80 total washes from 40 separate leaves). Results were statistically analysed using ANOVA to determine the significance of treatment on spray deposits retained on upper and lower leaf surfaces of leaves in different zones.

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RESULTS AND DISCUSSION

Preliminary WSP studies

Study 1

The WSPs in a 2000 L/ha spray (Tmt 6) confirmed visual observations; extensive saturation of the canopy and excessive run-off of sprays from the majority of surfaces, with some significant gaps in coverage still apparent (Appendix 1). Coverage on water sensitive papers can be assessed on the basis of what can be expected at dilute (the point of run-off) and lower spray volumes. Typically papers are rated as showing excellent, adequate or inadequate coverage. On this basis, the leaf papers at 2000 L/ha showed 7 out of 20 (35%) with coverage well below the point of run-off, with coverage on one paper (5%) considered inadequate for the applied volume.

More of the spray from this 2000 L/ha treatment was projected up to 3 m above the pergola canopy (5 m above the ground) than any other treatment. However, as with all other treatments, there was proportionally little spray projected above the canopy. The 2000 L/ha application volume was considered excessive for this canopy, with spray applied well beyond the point of run-off. Based on observations of the deposits in the canopy and on water sensitive papers, the point of run-off for sprays applied to this canopy was estimated to have been between around 1000 L/ha. Note that water only was sprayed in this study and that any addition of formulated products or adjuvants to the spray will likely increase run-off at this application volume.

Application volumes above 1000 L/ha were not included in subsequent quantitative deposit tests as these were not expected to be required or recommended for spring canopies. It is well recognised that application volumes beyond the point of run-off represent extremely inefficient use of chemical, with excess chemical and volume lost to the ground as run-off (Manktelow *et al.* 2000, 2004). The only argument for applying sprays in volumes above the point of run-off is to achieve more complete and even spray coverage of target plant surfaces. There is no doubt that this approach can work and was used in the 1970's in the US and Australian citrus industries to achieve control of citrus red scale on internal canopy wood with mineral oils. However, the application volumes required in that situation were more than three times the point of run-off. A similar strategy could be expected to achieve good coverage of protectant sprays in kiwifruit. However, such a strategy is considered non-viable because of; (1) the quantities of chemical that would be required, (2) the drop in spraying work rates associated with high volume spraying, and (3) the environmental contamination associated with excessive loss of spray to the ground and as drift.

The 1000 L/ha sprays (Tmts 4 & 5) were observed to result in some spray run-off on buds and leaf tips in this canopy and WSPs confirmed this (Appendix 1), with both runs showing 35% of papers with full wetting. Increasing the sprayer travel speed from six to 7.5 km/h increased the variability of deposits on WSP placed in this canopy, in particular by reducing deposits on upper surfaces. The 1000 L/ha sprays were both projected only to 1 m above the canopy (3 m above ground) and travel speed had no effect on this (sprayer air output was increased in the 7.5 km/h run).

The ATR hollow cone nozzles applying 400 L/ha spray (Tmt 3) gave generally good spray coverage with fine droplets on WSP mounted within the canopy and no spray run-off (Appendix 1). Spraying at volumes below the point of run-off requires increasing the concentration of chemical in the spray tank to maintain the chemical application rate at that which would be used in a "dilute to run-off" application. While these WSP look less "blue" than in the higher volume treatments, each spray droplet would, at this volume, contain 2.5 times more chemical than in the 1000 L/ha sprays. Additionally, the even droplet deposits on these papers would be likely to result in total target coverage with the addition of a superspreader adjuvant (Fig. 1). WSPs do not demonstrate the super-spreading on plant surfaces afforded by adjuvants such as Du-Wett (Gaskin *et al.* 2011b).

The 400 L/ha spray was projected to only 1 m above the canopy at best. This sprayer set-up was identified as very promising for targeting spring canopies without strings. However, the lack of projection of small droplet low volume sprays (compared with higher volume sprays from the same sprayer) highlights a potential risk from low volume spraying. Sprayer operators need to be confident that the spray plume is being reliably projected at least a metre above and beyond the most distant upwind canopy to be confident that coverage will be achieved. This rule of thumb applies to all spray applications, however small droplet sprays are more at risk of being blown off distant targets than higher volume sprays (where the usually larger droplet size and mass of projected liquid helps to overcome some wind effects).

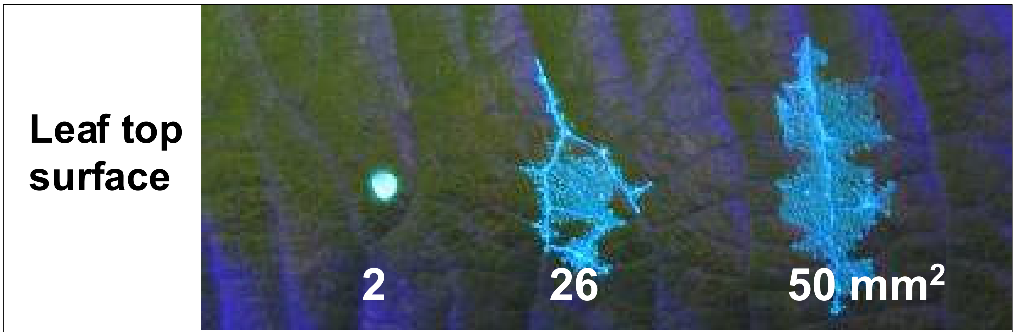

Figure 1: Spreading (mm^2) of spray droplets (0.25 µl) of (left-right) Nordox spray alone, plus Du-Wett (0.05%), plus Du-Wett (0.1%), on Hayward leaf surface. Note each droplet contains the same volume of spray.

The WSPs indicated that air induction (AI) nozzles produced large droplets, which gave very patchy coverage that was often unacceptably poor on the upper leaf surfaces (Appendix 1). The bubble jet AI flat fan nozzles operated at low pressure (Tmt 2) gave more even deposits than the AI hollow cone (Hi-Cane) nozzles (Tmt 1). However, the sprayer controller struggled to maintain even pressure and output at this volume and low operating pressure, and a partial blockage of nozzles occurred even without pesticide in the tank. Spray was projected to only 1 m above the canopy (3 m above ground) by both AI nozzle types.

Study 2
There were no WSPs mounted above the pergola canopy in this study, but the in-canopy assessments were deliberately biased towards the leader zone because of its difficulty as a spray target. Adjuvant was included in all treatments (Du-Wett at 400 ml/ha) because although superspreading is not reflected on WSPs, the adjuvant has effects on deposition and retention of sprays on kiwifruit leaves (Gaskin *et al.* 2010). No pesticide was included in the treatments because generally these have little or no effect on the

physical properties of sprays containing Du-Wett at the rate used here (data not presented).

The summary of the WSP coverage is presented in Table 2 and WSPs are included in Appendix 3. The upper surface of leaves was generally well targeted by most of the treatments tested, with the exception of the low volume AI nozzles (Tmt 10). The lower surfaces of leaves were best targeted by the 400 L/ha ATR hollow cone (fine) nozzle sprays; higher volumes of 600-1000 L/ha caused excessive run-off in some canopy zones. Based on observations of the deposits in the canopy and on WSPs, the point of run-off for sprays applied to this canopy was estimated to have been around 800 L/ha. While coverage of WSPs appeared to decrease with decreasing application volumes (Appendix 3), the addition of a superspreader and use of concentrate chemical rates is expected to completely compensate for this. Concentrated low volume sprays contain more chemical per litre than higher volume sprays and with superspreader adjuvant addition are likely to cover target surfaces fully with less loss of spray to run-off.

Table 2: Assessment of coverage on 20 WSPs mounted in-canopy on a Hayward pergola in Study 2 (as % rated excellent, adequate, inadequate, and with run-off).

Tmt #	Spray vol. (L/ha)	Fan speed (rpm)	Excellent	Adequate	Inadequate	Run-off
1	1000	1650	85	10	5	55
2	1000	2000	90	10	0	45
4	600	1650	60	35	5	20
5	800	1650	75	20	5	35
6	400	1300	60	30	10	20
7	400	1650	50	35	15	20
8	400	2000	80	15	5	15
9*	400	2000	50	35	15	20
10	200	1650	21	37	42	5

*all tmts applied at 6 km/h, except Tmt 9 at 7.5 km/h
Refer to Appendix 2 for nozzling details and to Appendix 3 for photographs of WSPs

Leader zones were well targeted by the concentrate 400 L/ha ATR hollow cone (fine) nozzle sprays while higher volume sprays were often lost to run-off (Table 2). This trend was even more evident in the centre canopy zone, particularly on lower surfaces of leaves, which are the most exposed to sprays (Appendix 3).

In high volume sprays of 1000 L/ha, higher fan speed appeared to reduce spray run-off slightly. Lowering spray volumes definitely reduced run-off for little compromise in deposit distribution and this is likely to be compensated for by better coverage of target surfaces by sprays containing higher concentrations of the superspreader.

The AI flat fan nozzles (Tmt 10) were included to test the sprayer setup recommendations supplied by Garry Moffat for very low volume sprays. They were found to deliver highly variable and poor deposits in comparison to the ATR hollow cone nozzles and were not tested any further; in particular coverage was most compromised on the upper leaf surface. The Canadian advice to use wide angle flat fan nozzles in a kiwifruit airblast spray application does not match current, well established, best practice nozzling recommendations. Narrow angle projecting nozzles are routinely used to target canopy out towards the leader zones, especially on row spacings greater that 4 m. Narrow angle flat fan AI nozzles are recommended on canes in the low drift hydrogen cyanamide nozzling, with wide angle nozzles used to target the mid-row sections of cane canopy closest to the sprayer. Our experience with large droplet AI nozzles in a kiwifruit and other crops suggests that their use on foliated canopy will compromise coverage, especially between leaf surfaces (one side tends to be well covered, the other often severely under dosed). **The use of large droplet AI nozzles for application of protectant sprays to kiwifruit foliage is not recommended.**

All setups tested in this study, with the exception of the AI nozzles, demonstrated good coverage on WSPs, at a level that is expected to be highly effective for the application of protectant sprays.

Quantitative deposit study

Deposits on full canopy

The six selected treatments all provided mean deposits on leaves between 2.2-2.7 µg/cm^2 (Table 3, Fig. 2), which is similar to those measured in previous deposit studies (Gaskin *et al.* 2010). While mean data reveals little of where deposits are landing, some trends were implied (Fig. 2). The 1000 L/ha Masotti Article 58 nozzles gave mean deposits equivalent to 400 L/ha applied through ATR HC nozzles (at 1650 rpm fan speed) and both of these nozzle setups (Appendix 2) were slightly (but significantly) better than the 600 L/ha nozzling. The low (1300 rpm) and high (2000 rpm) fan speeds, with the 400 L/ha ATR nozzle setup, significantly reduced mean deposits over those achieved with the mid fan speed at 6km/h. Increasing travel speed (from 6 to 7.5 km/h) had little effect on mean deposits, but deposit variability as seen on WSP appeared to increase at the higher travel speed.

The foliage in the leader position received approx. 20% lower deposits overall than that in the row centre (Table 3). The 1000 L/ha control had the greatest variation in deposits with the centre row receiving ca. 40% more than the leader; this variation was greatly reduced in the lower volume treatments (Fig. 3). The leader foliage was targeted similarly by all treatments, as was the row centre with the exception of higher deposits from the 1000 L/ha Article 58 and 400 L/ha ATR (1650 rpm, 6 km/h) setups (Fig. 3).

Table 3: Deposits (µg/cm^2, normalised to a 1 kg/ha application of dye) on leaves in four zones, from sprays applied with varying spray volume, fan speed and travel speed. (All treatments contained 400 ml/ha Du-Wett adjuvant).

Tmt #, nozzles	Treatment description L/ha, rpm, km/h	Canopy zone Leader	Canopy zone Centre	Canopy position upper	Canopy position lower	Tmt mean
1, Art 58	1000, 1650, 6	2.08 cd	3.33 a	1.83 d	3.59 a	2.71 A
2, ATR	600, 1650, 6	1.97 d	2.61 b	1.29 f	3.30 abc	2.29 B
3, ATR	400, 1650, 6	2.36 bc	2.98 a	1.91 d	3.43 ab	2.67 A
4, ATR	400, 1300, 6	2.11 cd	2.31 bcd	1.46 ef	2.96 c	2.21 B
5, ATR	400, 2000, 6	2.26 bcd	2.58 b	1.75 de	3.08 bc	2.42 B
6, ATR	400, 2000, 7.5	2.18 cd	2.60 b	1.75 de	3.04 c	2.40 B
Mean		2.16 B	2.74 A	1.67 B	3.23 A	

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

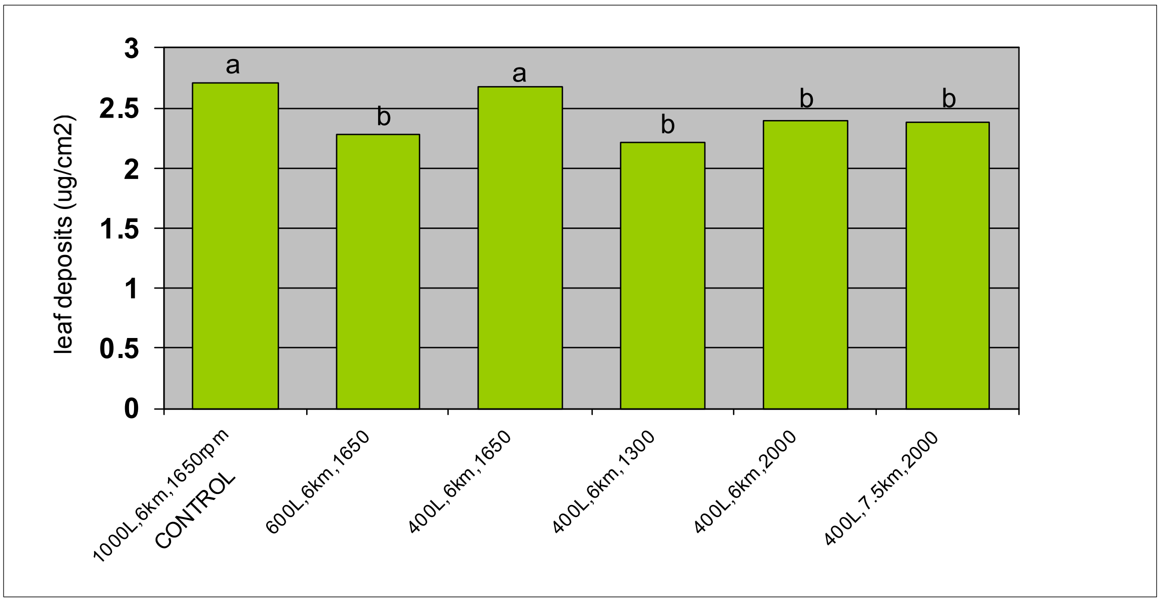

Figure 2: Mean deposits on foliage over all samples. All treatments contain Du-Wett 400 ml/ha. (Means sharing common letters are not significantly different, $P_{0.05}$)

Typically large variations were seen between deposits on foliage in the upper and lower canopy zones (Table 3), with upper leaves intercepting only ca. 50% of deposits on lower leaves (Fig. 4). This pattern and level of lower deposit levels on distant canopy is typical of that seen in other crops and is unavoidable. The 600 L/ha ATR nozzle setup targeted the upper canopy zone poorly, while the 400 L/ha ATR setup was similar to the 1000 L/ha treatment. The only exception was when the fan speed was reduced with the ATR nozzles (Fig. 4). All sprayer setups targeted the lower canopy zone well.

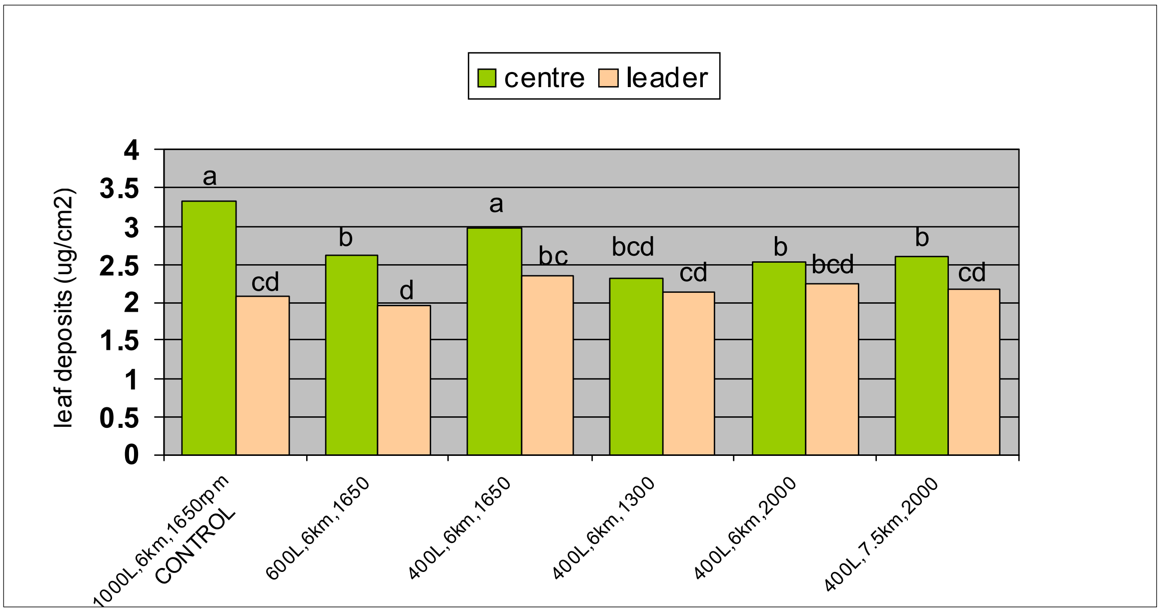

Figure 3: Mean deposits on foliage in centre row and leader canopy positions. All treatments contain Du-Wett 400 ml/ha. (Means sharing common letters are not significantly different, $P_{0.05}$)

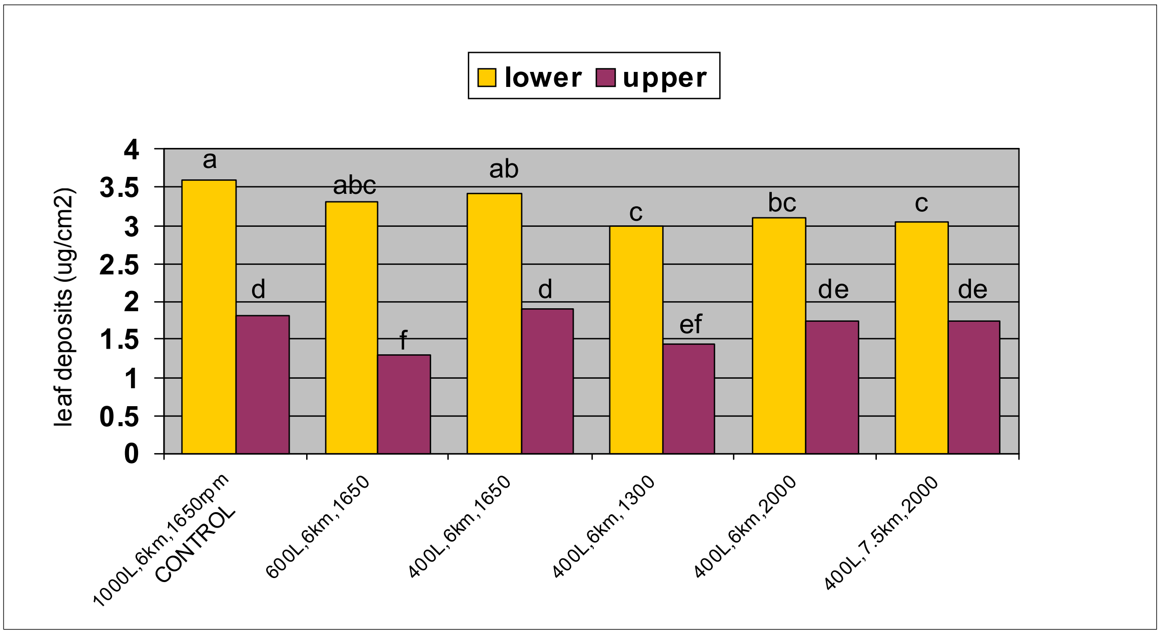

Figure 4: Mean deposits on foliage in upper and lower canopy zones. All treatments contain Du-Wett 400 ml/ha. (Means sharing common letters are not significantly different, $P_{0.05}$)

There were few instances when deposits were reduced compared to those in the same zone in the 1000 L/ha control treatment (Fig. 5). The 400 L/ha ATR nozzle setup (1650 rpm, 6 km/h) was equivalent to the 1000 L/ha Masotti Article 58 nozzle control in all respects and is considered to be the preferred sprayer setup for spraying spring canopies. The 1000 L/ha sprays resulted in significant (but not unexpected or unacceptable) run-off on these light canopies. Concentrate sprays (containing a superspreader adjuvant such as Du-Wett) delivering the required dose (once known!) of chemical to control Psa on leaf surfaces is expected to provide a far more efficient and environmentally justifiable means of applying protectant sprays than high volume dilute spraying.

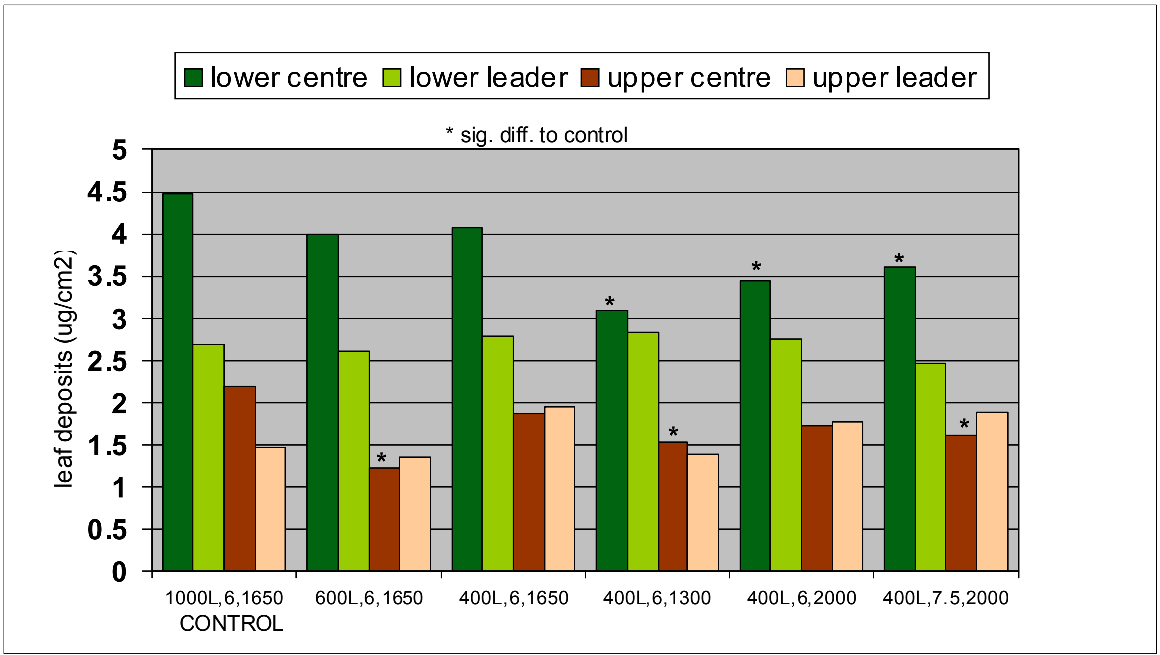

Figure 5: Mean deposits on foliage in all canopy zones. All treatments contain Du-Wett 400 ml/ha. (*are significantly different to same zone in 1000 L/ha control tmt, $P_{0.05}$)

It is important to note that these tests were conducted with what is generally considered to be an excellent sprayer in a relatively narrow row spacing (3.75m). Deposit variability on wider row spacings would be expected to be higher than that observed here, especially on more dense canopies. While this is again a fact of life, it is possible to partly compensate for these factors by adjusting sprayer nozzling and setup (air output and travel speed) in relation to row spacing and canopy density. The sprayer used in these tests had a front entry fan, with air and spray projected upwards and back from the direction of travel. Many of the sprayers used in the NZ kiwifruit industry have rear entry fans with a more forward projecting air and spray output. We simply do not have any data to confirm which of these air and spray delivery patterns will work best and in which canopies. It can be expected that different maximum travel speeds will apply to the different types of air profile, but these factors may be influenced in unexpected ways by different canopy densities.

In this limited study, the effect of lowering fan speed (to 1300 rpm) was to reduce deposits, particularly on the upper and lower row centre foliage. Increasing fan speed (to 2000 rpm) provided no benefits over 1650 rpm, and additionally is likely to damage fragile new growth in spring. Increasing sprayer travel speed from 6.0 to 7.5 km/h had no negative effects on deposits in a single comparison, but it is highly probable that reducing speed, to e.g. 4 km/h, may markedly improve spray coverage on pergola canopies. This requires clarification in a future study, with work to establish "tipping points" at which travel speed and/or air output volumes begin to significantly compromise deposits and coverage.

Deposits on top and bottom surfaces of single leaves

Comparative spray deposits on separate leaf surfaces have not been determined previously for kiwifruit, but the significance of where spray is deposited on leaves has assumed greater importance with the arrival of Psa. Because of the difficulty involved in accurately processing samples for top and bottom leaf surface deposits, only two treatments were examined in this study; the 1000 L/ha Masotti Article 58 Control and the 400 L/ha ATR nozzle setup, at high fan speed (Tmts 1 & 5 respectively, Table 3). The latter selection was necessarily made prior to analysis of the canopy deposit results.

As expected, mean deposits on the bottom surfaces of leaves were always greater than on the tops ($P<0.001$) (Fig. 6, Tables 4 & 5). This is readily explained by the exposure of the underside of leaves to sprays in a pergola canopy and also by their greater surface area available (i.e. hairs) to capture and retain spray droplets. The top surfaces (adaxial) of both Hayward and Hort 16A kiwifruit leaves are moderately wettable, while the bottom surfaces are very difficult-to-wet (Gaskin *et al.* 2005). This suggests that spray should be repelled more by the bottom leaf and thus, deposits should be lower. This is indeed the case when water, or non-formulated products, are sprayed on kiwifruit leaves. Water droplets readily adhere to the more easily-wetted top surface of the leaf, and are retained less on the bottom. Spreader adjuvants are used to overcome the repellency of difficult-to-wet leaf surfaces and their benefits are far greater on these surfaces than on an easy-to-wet surface, where they can lead to run-off. The superspreader adjuvant, Du-Wett, is the reason why more spray is retained on the bottom surface of leaves in this study. Because Du-Wett is prescribed at a use rate per hectare, then its concentration in solution rises as spray volume is reduced (Fig. 6), and proportionally more a.i. is retained on the difficult-to-wet bottom surface of leaves.

There were no differences between the two treatments in deposits on top surfaces of leaves at the leader and centre row positions (Table 4) or in the upper and lower canopy zones (Table 5). **All leaves in all canopy positions retained similar chemical deposits on the top surfaces of leaves from dilute and concentrate sprays** (Fig. 7).

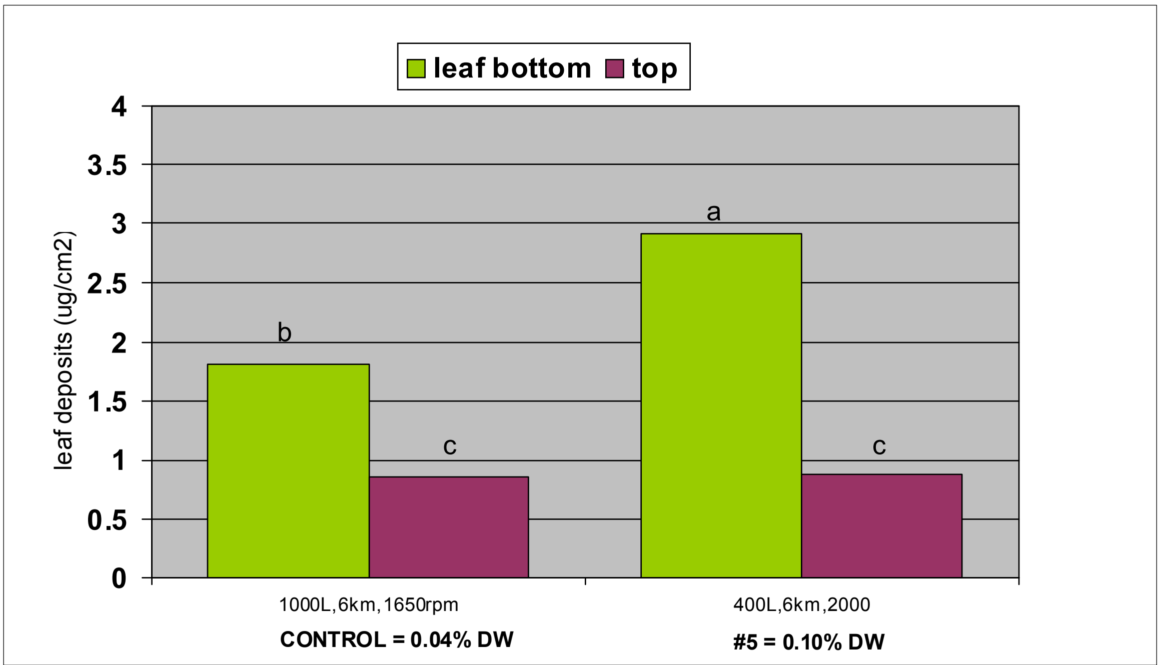

Figure 6: Mean deposits on top and bottom surfaces of leaves. All treatments contain Du-Wett 400 ml/ha. (Means sharing common letters are not significantly different, $P_{0.05}$)

Table 4: Deposits (µg/cm^2, normalised to a 1 kg/ha application of dye) on top and bottom surfaces of leaves in the LEADER AND CENTRE ROW CANOPY POSITIONS, from a dilute and concentrate spray.

Tmt #, nozzles	Treatment description L/ha, rpm, km/h	Top surface of leaf		Bottom surface of leaf	
		Leader	Centre row	Leader	Centre row
1, Art 58	1000, 1650, 6	0.92 a	0.78 a	1.41 c	2.21 bc
5, ATR	400, 2000, 6	0.72 a	1.04 a	2.38 b	3.44 a
Mean		0.82 A	0.91 A	1.90 B	2.83 A

Means within each coloured table sharing common postscripts are not significantly different (LSD, P=0.05). Both treatments contained 400 ml/ha Du-Wett adjuvant.

Table 5: Deposits (µg/cm^2, normalised to a 1 kg/ha application of dye) on top and bottom surfaces of leaves in the UPPER AND LOWER CANOPY ZONES, from a dilute and concentrate spray.

Tmt #, nozzles	Treatment description L/ha, rpm, km/h	Top surface of leaf		Bottom surface of leaf	
		upper canopy	lower	upper canopy	lower
1, Art 58	1000, 1650, 6	0.96 a	0.75 a	1.63 b	2.00 b
5, ATR	400, 2000, 6	0.85 a	0.91 a	1.99 b	3.83 a
Mean		0.90 A	0.83 A	1.81 B	2.91 A

Means within each coloured table sharing common postscripts are not significantly different (LSD, P=0.05). Both treatments contained 400 ml/ha Du-Wett adjuvant.

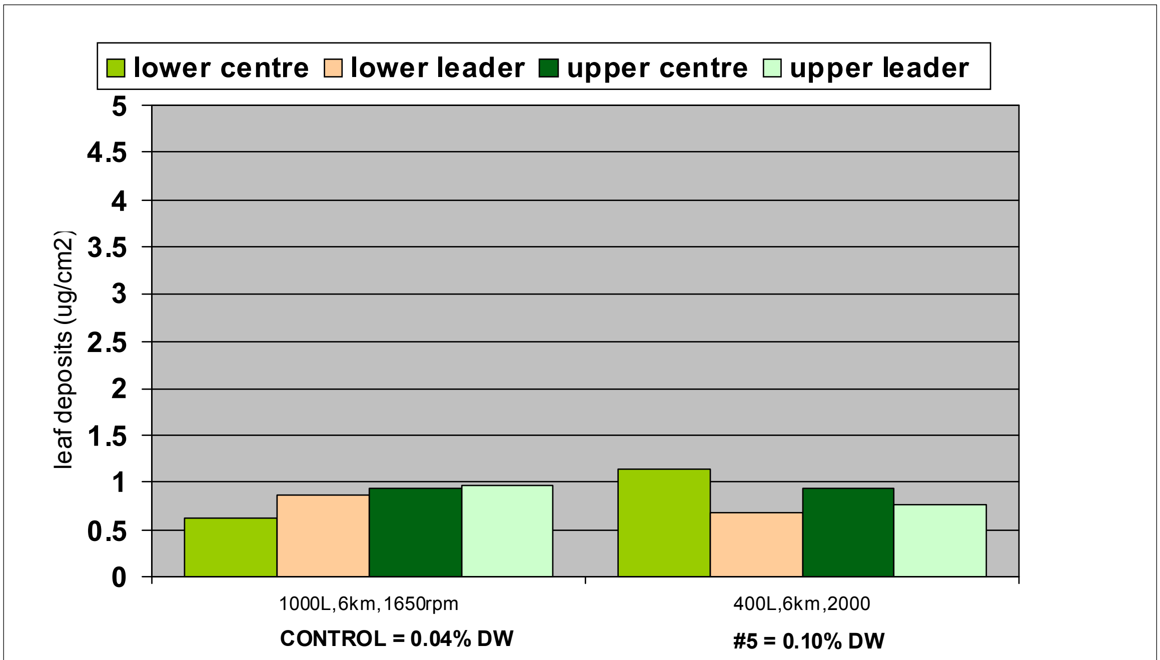

Figure 7: Mean deposits on top surfaces of leaves in four canopy zones. All treatments contain Du-Wett 400 ml/ha. (No treatments are significantly different, $P_{0.05}$)

There were large differences between the two treatments in deposits on the difficult-to-wet bottom surfaces of leaves. The 400 L/ha mean spray deposits were significantly higher than 1000 L/ha mean spray deposits on leaves in leader and centre positions (Table 4) and in the lower canopy zone (Table 5). The 400 L/ha setup showed a potential to overdose on the bottom surface of lower-centre row leaves, while the 1000 L/ha setup had potential to under-dose in the lower-leader position (Fig. 8).

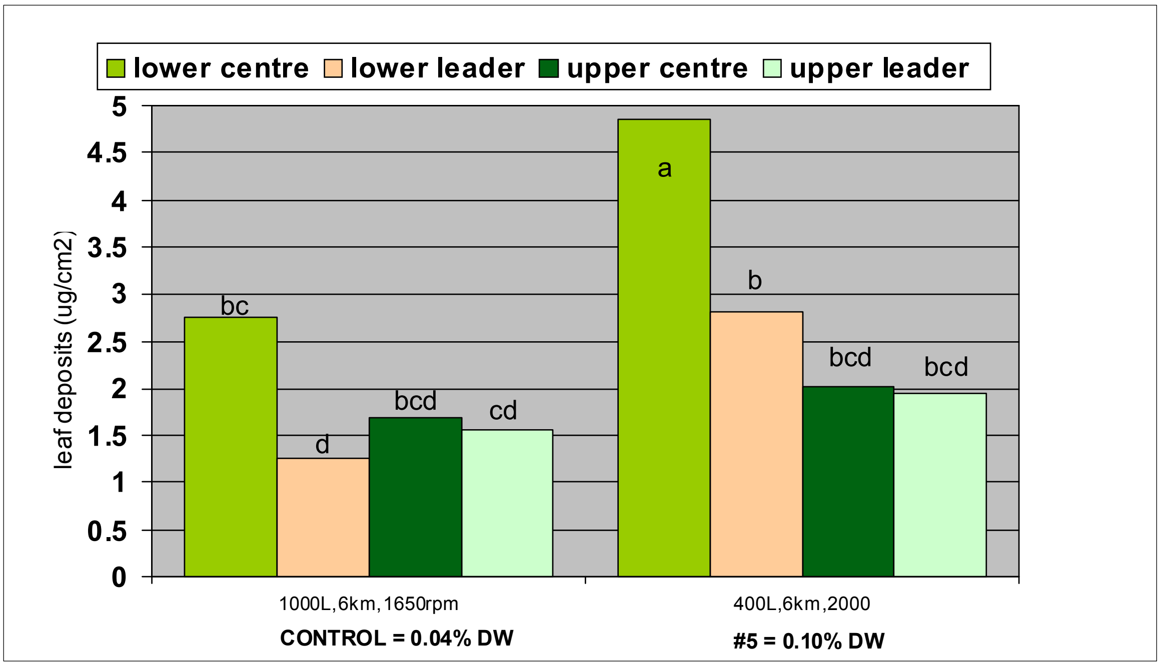

Figure 8: Mean deposits on bottom surfaces of leaves in four canopy zones. All treatments contain Du-Wett 400 ml/ha. (Means sharing common letters are not significantly different, $P_{0.05}$)

While the deposits are higher on the underside of leaves with the 400 L/ha concentrate spray, these deposits will provide a more even protectant dose over the entire surface of the lower leaf due to the concentration of the superspreader adjuvant in the spray. This is demonstrated in Figs 9 & 10. While there are fewer droplets of the concentrate spray deposited per area of leaf to achieve the same dose (mass per area) as the dilute spray, they contain a higher concentration of chemical (Fig. 9). With addition of superspreader (i.e. Du-Wett at 0.1%) to the concentrate spray, these fewer, more concentrated droplets spread to cover a much larger area of leaf (Fig. 10). Thus the chemical is spread more evenly and protects a larger area of foliage. If the superspreader is used at an inappropriately high rate in a concentrate spray or is added to the dilute spray, it is easy to comprehend how the leaf surface is unable to contain the spread and spray will be lost to run-off.

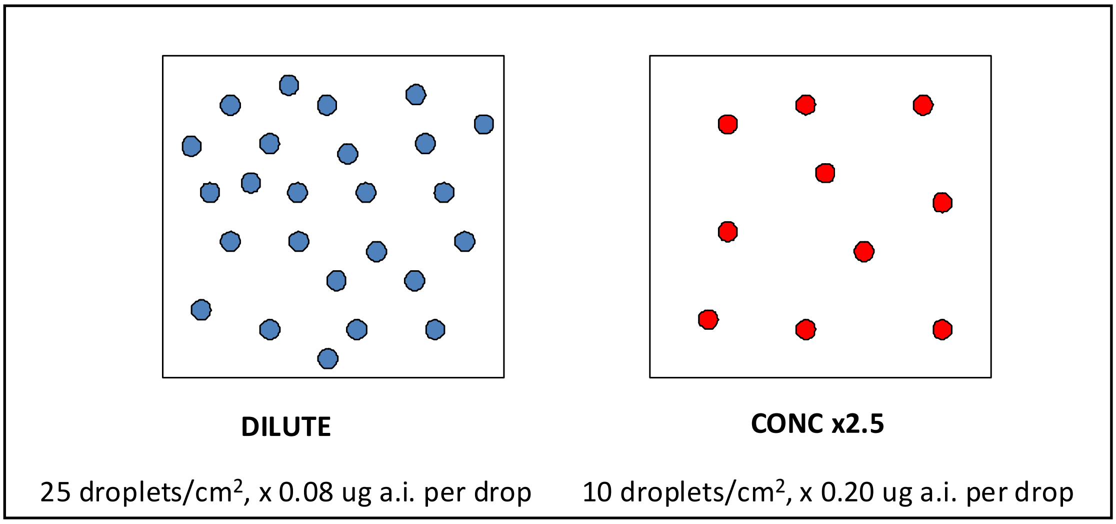

Fig. 9: Example of droplets of dilute (1000 L/ha) and 2.5x concentrate spray (400 L/ha + Du-Wett), both deposited at 2 µg/cm^2, <u>at time of impact</u> on leaf surface.

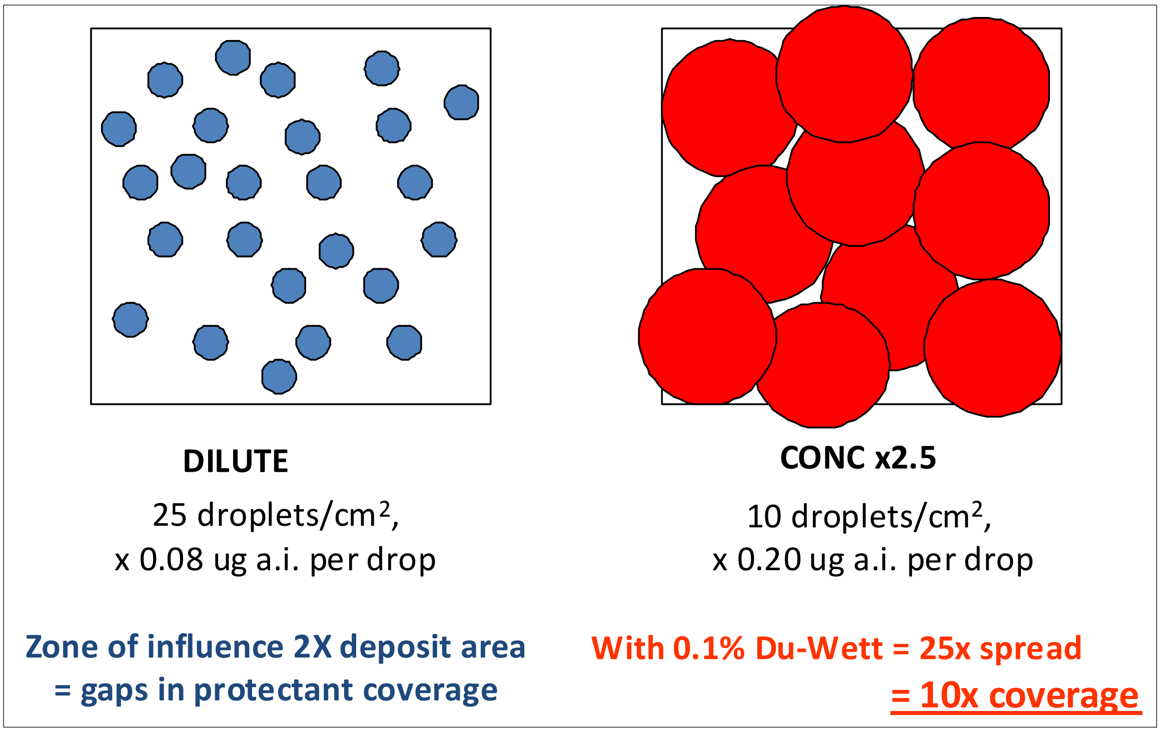

Fig. 10: Example of droplets of dilute (1000 L/ha) and 2.5x concentrate spray (400 L/ha + Du-Wett), both deposited at 2 µg/cm^2, <u>after spreading</u> on leaf surface.

RECOMMENDATIONS
for applying protectant sprays to spring canopies

- Most pergola kiwifruit canopies can be expected to require no more than 1000 L/ha to spray to the point of run-off in the period from bud break to pre-bloom. Point of run-off spray volumes required over the bloom period are unlikely to exceed 1500 L/ha.

- This work confirmed that both dilute and lower volume concentrate sprays can achieve excellent spray coverage and spray deposits throughout the canopy and on both surfaces of leaves.

- The use of Du-Wett adjuvant in spring canopy sprays will assist in complete coverage of leaf surfaces. The use rate should be 400 ml/ha, for application volumes of 400-1000 L/ha (rates and volumes for flowering sprays have yet to be confirmed).
    - For 800-1000 L/ha applications Du-Wett rate = 400 ml/ha (= 50 ml/100 L in an 800 L/ha spray; 40 ml/100 L in a 1000 L/ha spray) to ensure maximum spray coverage.
    - When spraying at volumes below the point of run-off, fine droplet nozzles should be used to deliver 400-500 L/ha (half run-off volume) with chemical at 2x concentrate (i.e. apply the same amount of chemical per ha that you would apply using a dilute spray). For concentrate sprays use Du-Wett adjuvant at 400 ml/ha (=100 ml/100 L in a 400 L/ha spray; 80 ml/100 L in a 500 L spray) to ensure maximum coverage of foliar surfaces.
    - **Use of low volume sprays without both concentrate spraying and superspreader addition is not recommended**.

- Sprayer setup and operational decisions are a critical part of achieving even spray coverage on target canes and leaves.
    - Sprayer fan speed should be sufficient to consistently project spray at least a metre above and beyond the most distant upwind canopy within the sprayed row
    - A maximum travel speed of 6-7.5 km/h is recommended, with slower speeds and/or greater air assistance required in wider row spacings, denser canopies and/or stronger winds.
    - Deposit variability is likely to increase with increasing speed. Lower travel speeds may improve coverage.
    - **The use of large droplet air induction (AI) nozzles for applying protectant sprays to spring canopies is not recommended**; they deliver highly variable and often unacceptably low deposits on foliated kiwifruit canopies.
    - Avoid the use of spray application volumes of less than half the run-off volume (2x concentrate) required for any given canopy.

- Spray coverage monitoring can be easily undertaken using water sensitive papers pinned onto the top and bottom surfaces of leaves.
    - These give immediate feedback as to whether spray is reaching all parts of the canopy and of the droplet distributions achieved (they do not show potential spreading from superspreader adjuvants).
    - The use of 20 half papers (10 each on top and bottom leaf surfaces) should be sufficient to gain a good appreciation of coverage achieved.
    - Staple or glue papers to a record sheet and rate them for Excellent, Adequate or Inadequate coverage. Expect to see no more than 20% of papers (4 out of 20) with inadequate coverage after spraying the immediate and adjacent rows.

- On pergola canopies for ground-applied sprays in the period bud-break to pre-bloom:
    - Foliage in the lower canopy will receive higher deposits than the upper canopy
    - The bottom surfaces of leaves will retain higher deposits than the top surfaces.
    - Chemical over-dosing is most likely to occur on lower zone foliage in the centre row and on bottom surfaces of leaves.
    - Chemical under-dosing is most likely to occur on the top surfaces of leaves in the upper canopy and aerial application may be beneficial to address this when water sensitive papers indicate a problem exists.

ACKNOWLEDGEMENTS

Thanks to Marty Brick for allowing us to use his orchard and sprayer. His orchard manager, Dennys Codingolla provided valuable technical assistance. Alison Forster, David Horgan and Justin Nairn (PPC_{NZ}), assisted in harvesting and/or processing samples.

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APPENDIX 1
Water sensitive paper record of spraying parameters assessed in preliminary study #1

Summary of treatments applied with an Atom 2000 Turbo sprayer.

Tmt #	Nozzles[1]	Spray volume (L/ha)	Pressure (bar)	Fan speed (rpm)	Travel speed (km/h)
1	AI-HC	400	20	1650	6.5
2	AI-FF	400	4.0	1650	6.5
3	ATR-HC	400	14.5	1650	6.5
4	Article 58	1000	17.5	1650	6.0
5	Article 58	1000	17	2000	7.5
6	Article 58	2000	18	1650	6.0

[1]See descriptions on WSP record templates

Water sensitive paper record of spraying parameters assessed in preliminary study#1.

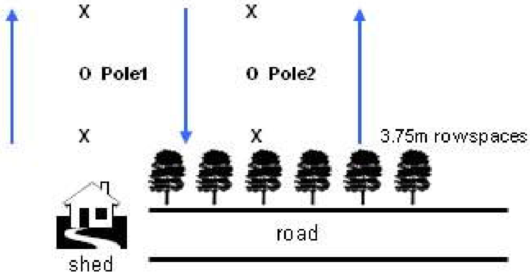
Location: 220 Maniatutu Rd, Pongakawa.
Marty Brick's Orchard.

Block: Omega (Block4)

Sprayer: Atom 2000 turbo
Nozzles: 4x TVI AI hollow cone nozzles 80° (per side), no flat fan nozzles.
Fan speed: 1650 rpm
Pressure: 20 bar
Water rate (L/ha): 400L
Travel speed (km/h): 6.5km

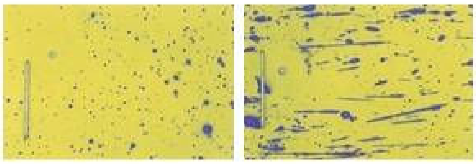
Date: 24th May 2011

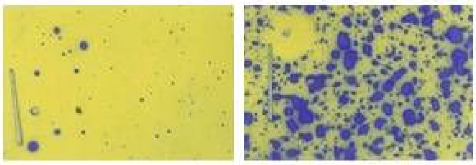
Wind speed (m/s): < 1m
Temperature: -
Sprayer travel direction:

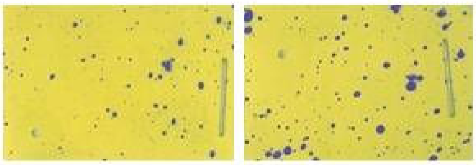


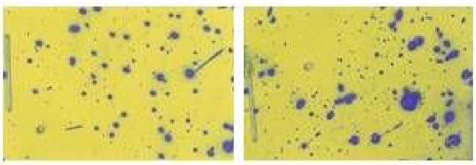
Trt: 1_water only

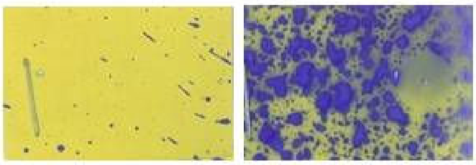
Leaf deposits
Upper surface   Lower surface


Upper canopy, leader section

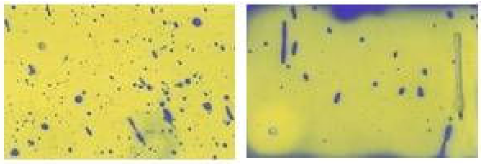

Lower canopy, leader section

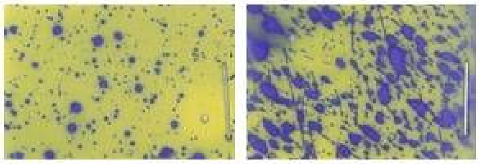

Upper canopy, centre section

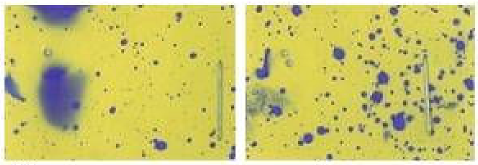

Mid canopy, centre section

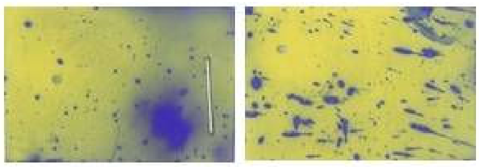

Lower canopy, centre section

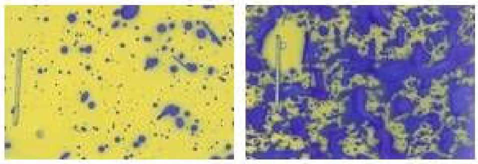
Leaf deposits
Upper surface   Lower surface


Upper canopy, leader section


Lower canopy, leader section


Upper canopy, centre section


Mid canopy, centre section


Lower canopy, centre section

Water sensitive paper record of spraying parameters assessed in preliminary study#1.

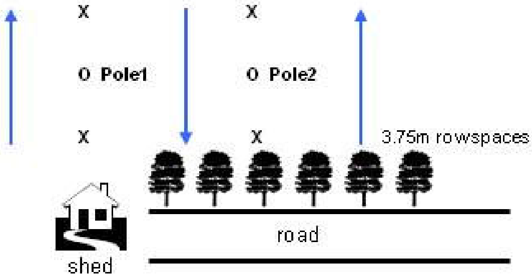
Location: 220 Maniatutu Rd, Pongakawa.
Marty Brick's Orchard.

Block: Omega (Block4)

Sprayer: Atom 2000 turbo
Nozzles: 4x TVI AI hollow cone nozzles 80° (per side), no flat fan nozzles.
Fan speed: 1650 rpm
Pressure: 20 bar
Water rate (L/ha): 400L
Travel speed (km/h): 6.5km

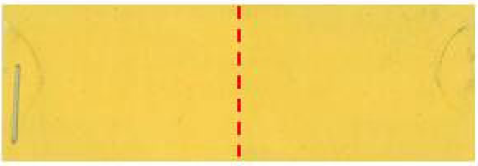
Date: 24th May 2011

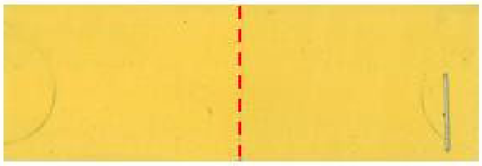
Wind speed (m/s): < 1m
Temperature: -
Sprayer travel direction:

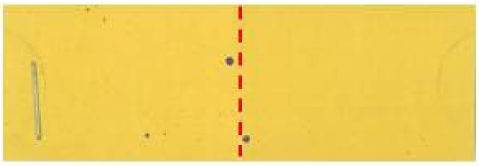


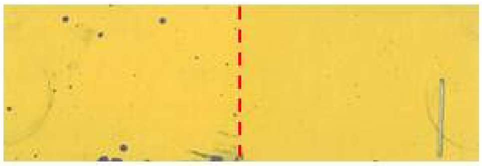
Trt: 1_water only

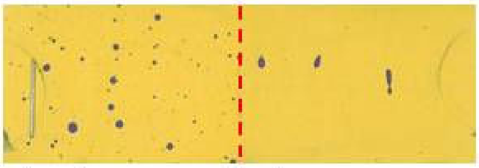
Pole 1		Pole 2	
Upper surface	Lower surface	Upper surface	Lower surface

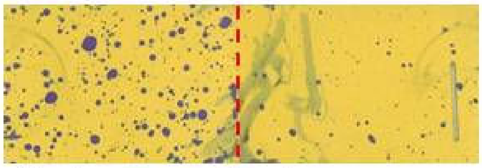

5m above ground level

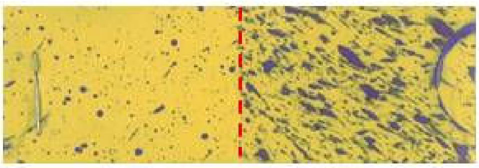

5m above ground level

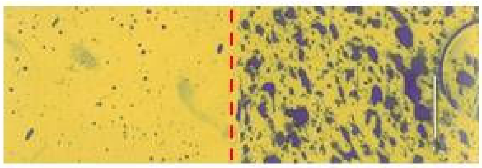

4m above ground level

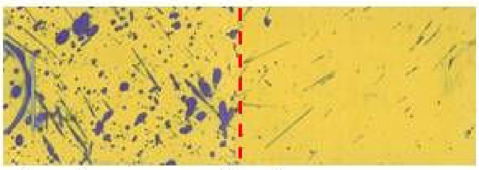

4m above ground level

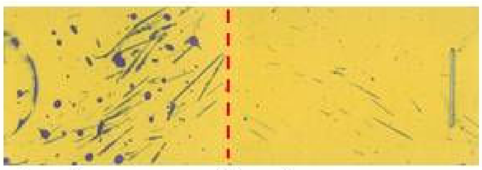

3m above ground level


3m above ground level


2m above ground level


2m above ground level


1m above ground level


1m above ground level

Water sensitive paper record of spraying parameters assessed in preliminary study#1.

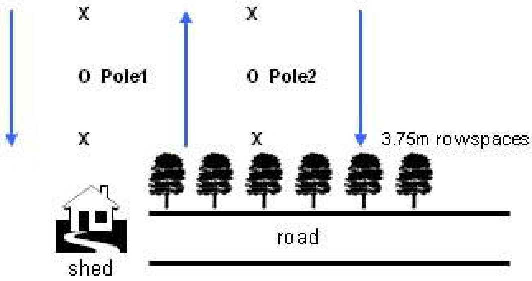
Location: 220 Maniatutu Rd, Pongakawa.
Marty Brick's Orchard.

Block: Omega (Block4)

Sprayer: Atom 2000 turbo
Nozzles: 4x Billericay bubble jet AI flat fan nozzles 110° (per side)
Fan speed: 1650 rpm
Pressure: 4 bar
Water rate (L/ha): 400L
Travel speed (km/h): 6.5km

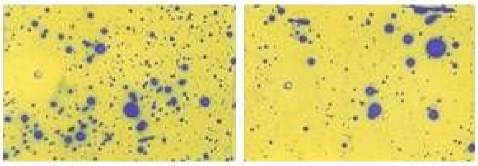
Date: 24th May 2011

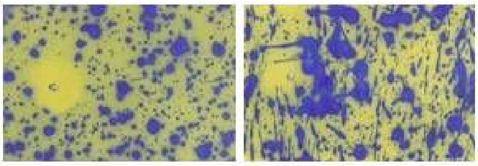
Wind speed (m/s): < 1m
Temperature: -
Sprayer travel direction:

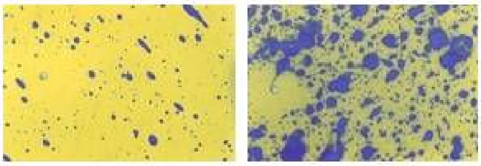


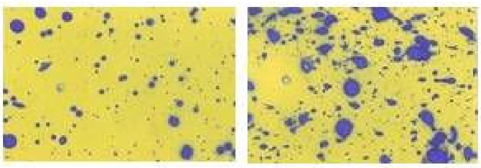
Trt: 2_water only

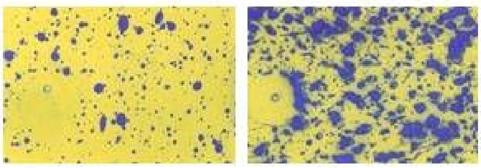
Leaf deposits
Upper surface Lower surface


Upper canopy, leader section

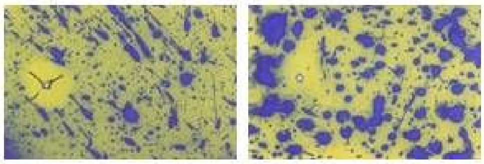

Lower canopy, leader section

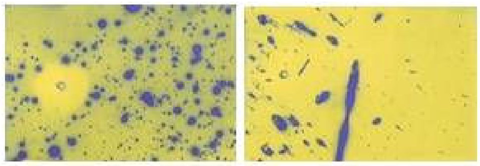

Upper canopy, centre section

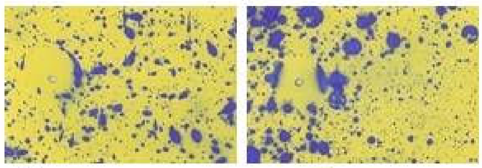

Mid canopy, centre section

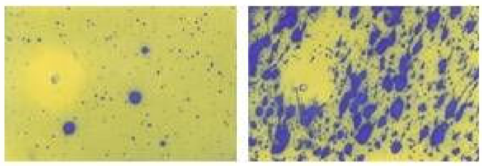

Lower canopy, centre section

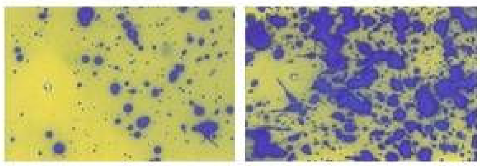
Leaf deposits
Upper surface Lower surface


Upper canopy, leader section


Lower canopy, leader section


Upper canopy, centre section


Mid canopy, centre section


Lower canopy, centre section

Water sensitive paper record of spraying parameters assessed in preliminary study#1.

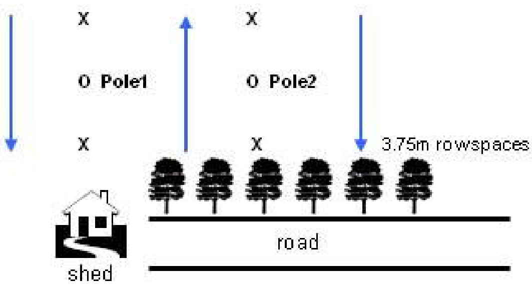
Location: 220 Maniatutu Rd, Pongakawa.
Marty Brick's Orchard.

Date: 24th May 2011

Block: Omega (Block4)

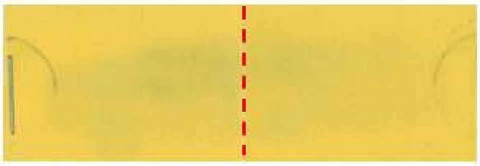
Wind speed (m/s): < 1m
Temperature: -
Sprayer travel direction:

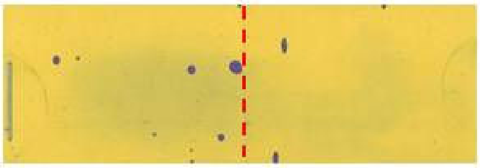
Sprayer: Atom 2000 turbo
Nozzles: 4x Billericay bubble jet AI flat fan nozzles 110° (per side).
Fan speed: 1650 rpm
Pressure: 4 bar
Water rate (L/ha): 400L
Travel speed (km/h): 6.5km

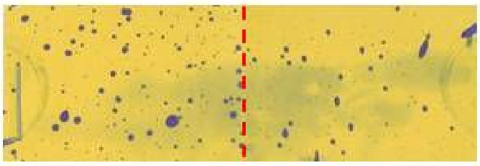


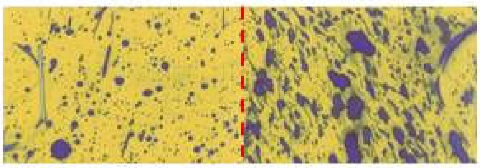
Trt: 2_water only

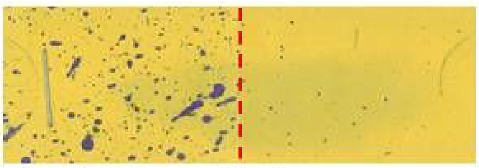
Pole 1
Upper surface | Lower surface


5m above ground level

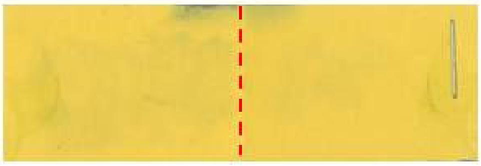

4m above ground level

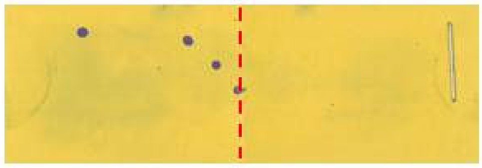

3m above ground level

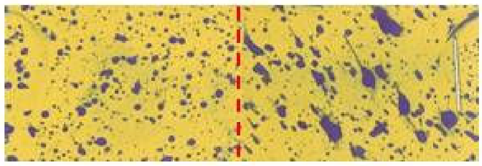

2m above ground level

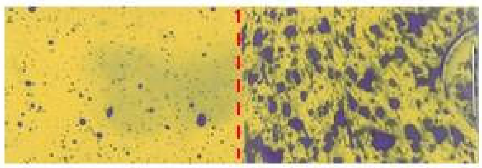

1m above ground level

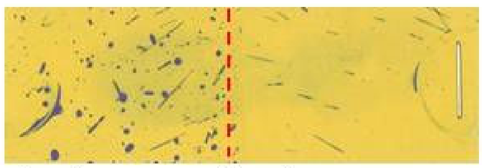
Pole 2
Upper surface | Lower surface


5m above ground level


4m above ground level


3m above ground level


2m above ground level


1m above ground level

Water sensitive paper record of spraying parameters assessed in preliminary study#1.

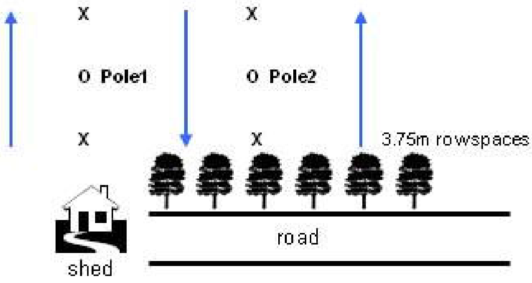
Location: 220 Maniatutu Rd, Pongakawa.
Marty Brick's Orchard.

Block: Omega (Block4)

Sprayer: Atom 2000 turbo
Nozzles: 4x Albuz ATR hollow cone (fine) nozzles (per side).
Fan speed: 1650 rpm
Pressure: 14.5 bar
Water rate (L/ha): 400L
Travel speed (km/h): 6.5km

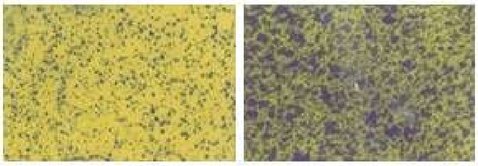
Date: 24th May 2011

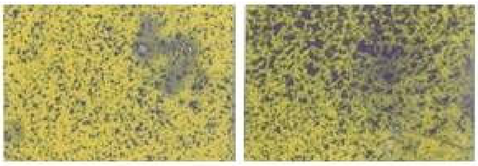
Wind speed (m/s): < 1m
Temperature: -
Sprayer travel direction:

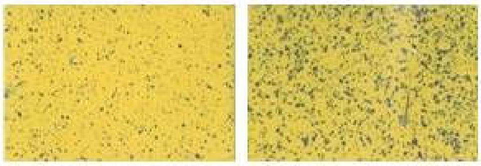


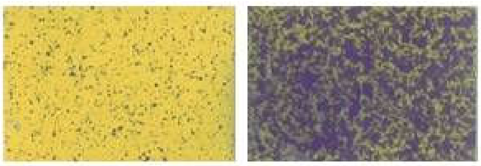
Trt: 3_water only

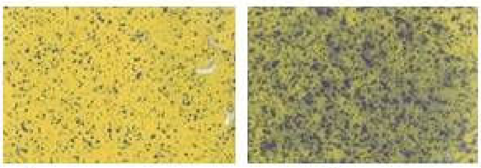
Leaf deposits
Upper surface Lower surface


Upper canopy, leader section

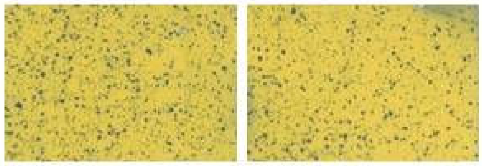

Lower canopy, leader section

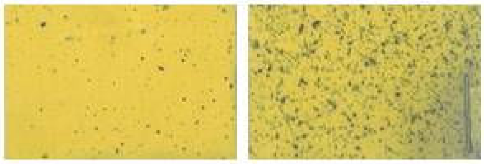

Upper canopy, centre section

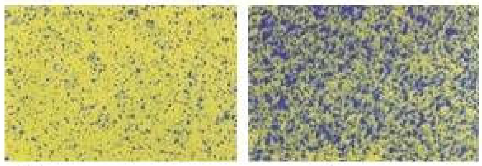

Mid canopy, centre section

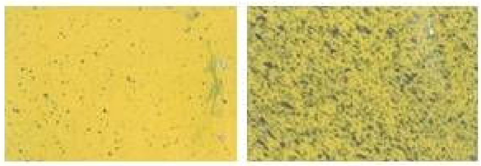

Lower canopy, centre section

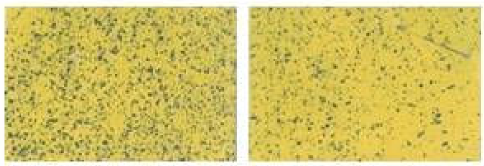
Leaf deposits
Upper surface Lower surface


Upper canopy, leader section


Lower canopy, leader section


Upper canopy, centre section


Mid canopy, centre section


Lower canopy, centre section

Water sensitive paper record of spraying parameters assessed in preliminary study#1.

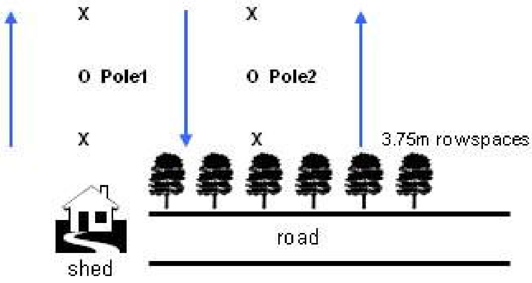
Location: 220 Maniatutu Rd, Pongakawa.
Marty Brick's Orchard.

Block: Omega (Block4)

Sprayer: Atom 2000 turbo
Nozzles: 4x Albuz ATR hollow cone (fine) nozzles (per side).
Fan speed: 1650 rpm
Pressure: 14.5 bar
Water rate (L/ha): 400L
Travel speed (km/h): 6.5km

Date: 24th May 2011

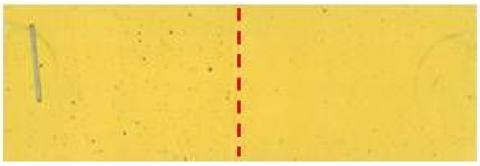
Wind speed (m/s): < 1m
Temperature: -
Sprayer travel direction:



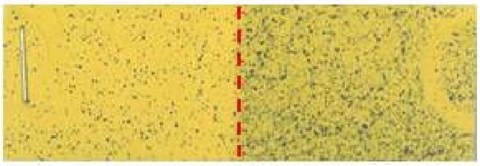
Trt: 3_water only

Pole 1

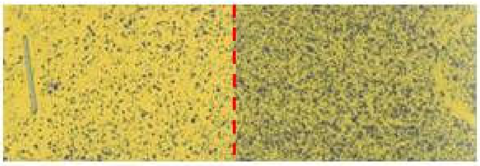
Upper surface | Lower surface



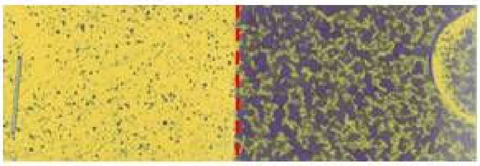
5m above ground level



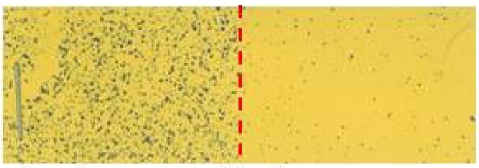
4m above ground level



3m above ground level



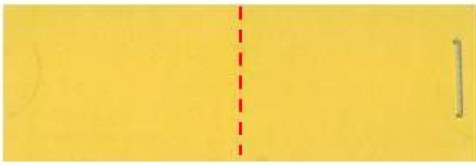
2m above ground level



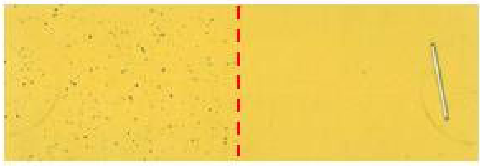
1m above ground level

Pole 2

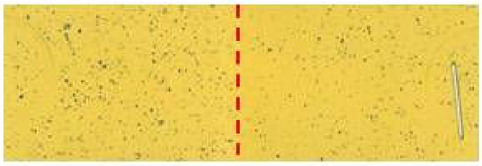
Upper surface | Lower surface



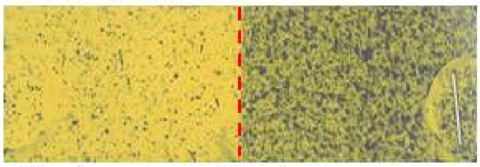
5m above ground level



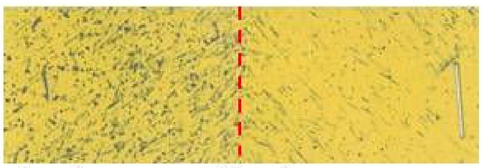
4m above ground level



3m above ground level



2m above ground level



1m above ground level

Water sensitive paper record of spraying parameters assessed in preliminary study#1.

Location: 220 Maniatutu Rd, Pongakawa.
Marty Brick's Orchard.

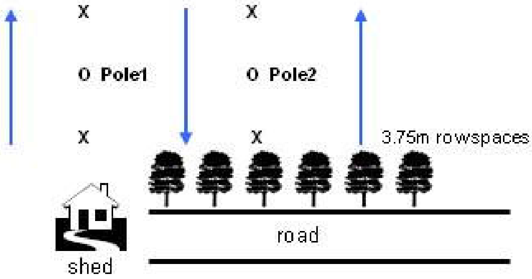
Block: Omega (Block4)

Sprayer: Atom 2000 turbo
Nozzles: 4x Masotti Article 58 ceramic disk (pink) & stainless core nozzles (per side)
Fan speed: 1650rpm
Pressure: 17.5 bar
Water rate (L/ha): 1000L
Travel speed (km/h): 6km

Trt: 4_water only

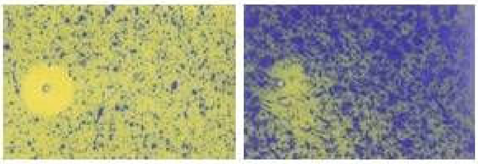
Date: 24th May 2011

Wind speed (m/s): < 1m
Temperature: -
Sprayer travel direction:

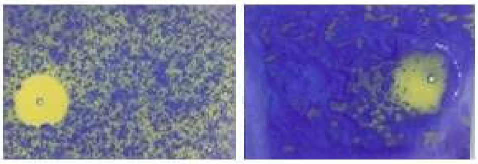


Leaf deposits

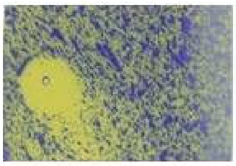
Upper surface Lower surface



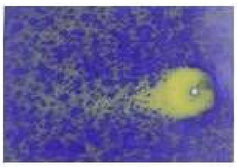
Upper canopy, leader section



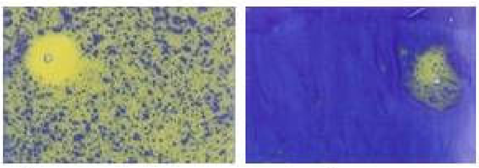
Lower canopy, leader section



Upper canopy, centre section



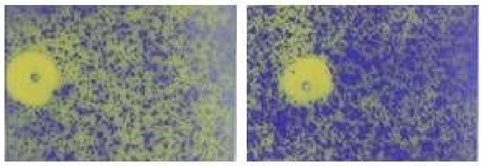
Mid canopy, centre section



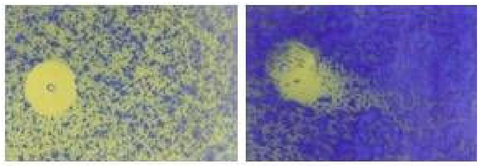
Lower canopy, centre section

Leaf deposits

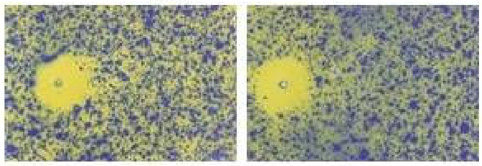
Upper surface Lower surface



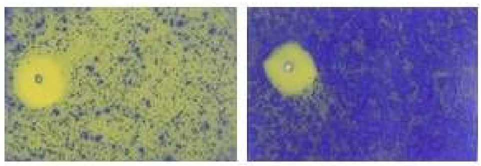
Upper canopy, leader section



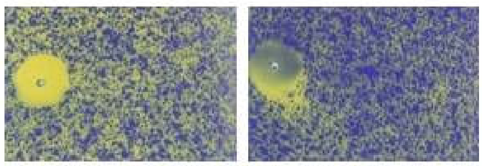
Lower canopy, leader section



Upper canopy, centre section



Mid canopy, centre section



Lower canopy, centre section

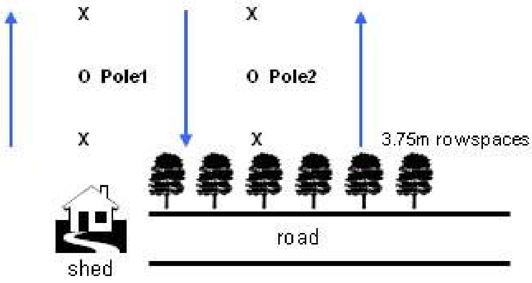
Water sensitive paper record of spraying parameters assessed in preliminary study#1.

Location: 220 Maniatutu Rd, Pongakawa.
Marty Brick's Orchard.

Date: 24th May 2011

Block: Omega (Block4)

Wind speed (m/s): < 1m
Temperature: -
Sprayer travel direction:

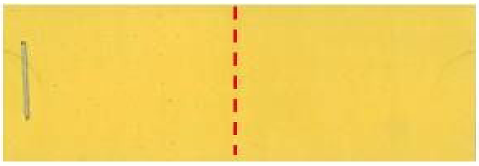


Sprayer: Atom 2000 turbo
Nozzles: 4x Masotti Article 58 ceramic disk (pink) & stainless core nozzles. (per side)
Fan speed: 1650rpm
Pressure: 17.5 bar
Water rate (L/ha): 1000L
Travel speed (km/h): 6km

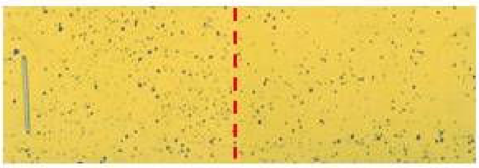
Trt: 4_water only

Pole 1

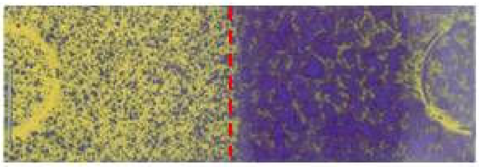
Upper surface | Lower surface



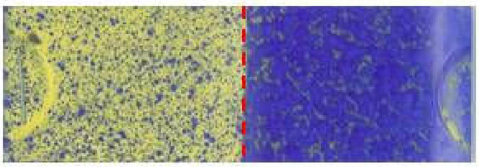
5m above ground level



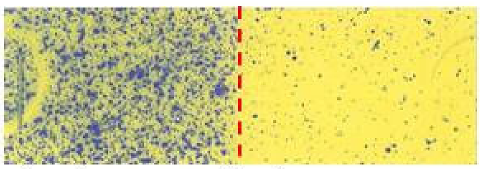
4m above ground level



3m above ground level



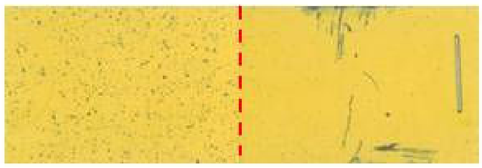
2m above ground level



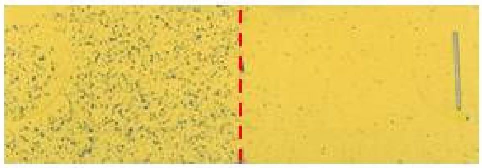
1m above ground level

Pole 2

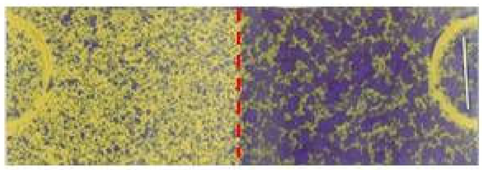
Upper surface | Lower surface



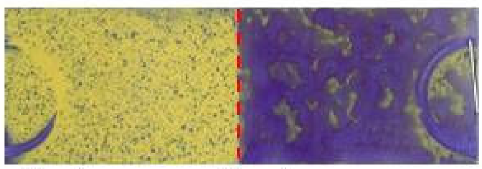
5m above ground level



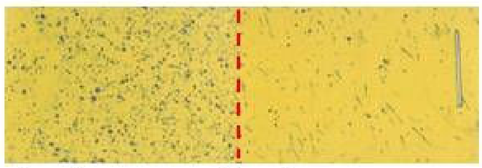
4m above ground level



3m above ground level



2m above ground level



1m above ground level

Water sensitive paper record of spraying parameters assessed in preliminary study#1.

Location: 220 Maniatutu Rd, Pongakawa.
Marty Brick's Orchard.

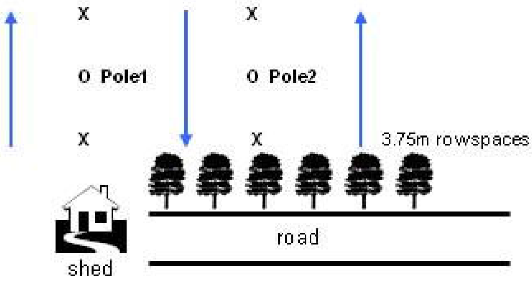
Block: Omega (Block4)

Sprayer: Atom 2000 turbo
Nozzles: 4x Masotti Article 58 ceramic disk (pink) & core nozzles (per side)
Fan speed: 2000 rpm
Pressure: 17 bar
Water rate (L/ha): 1000L
Travel speed (km/h): 7.5km

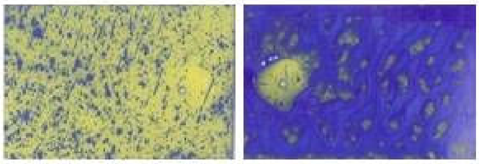
Trt: 5_water only

Date: 24th May 2011

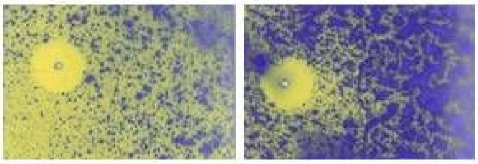
Wind speed (m/s): < 1m
Temperature: -
Sprayer travel direction:



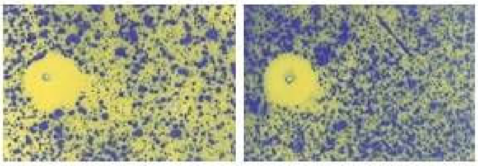
Leaf deposits
Upper surface Lower surface



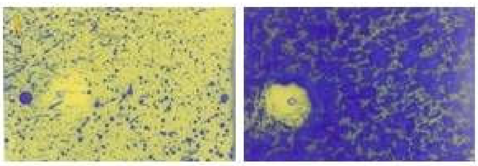
Upper canopy, leader section



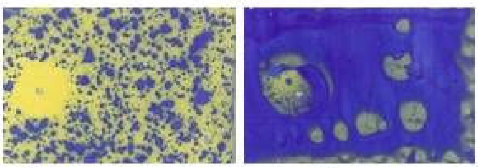
Lower canopy, leader section



Upper canopy, centre section

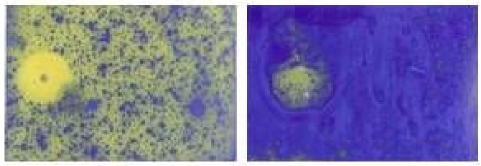


Mid canopy, centre section

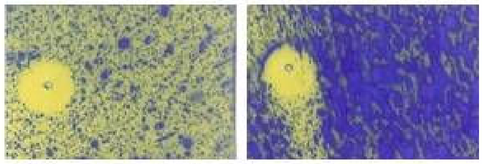


Lower canopy, centre section

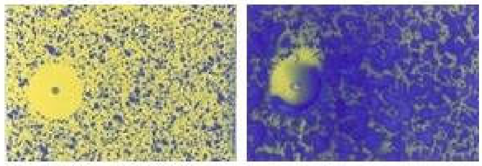
Leaf deposits
Upper surface Lower surface



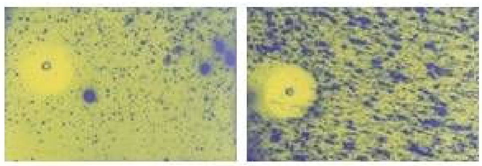
Upper canopy, leader section



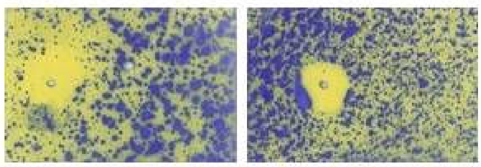
Lower canopy, leader section



Upper canopy, centre section



Mid canopy, centre section



Lower canopy, centre section

Water sensitive paper record of spraying parameters assessed in preliminary study#1.

Location: 220 Maniatutu Rd, Pongakawa.
Marty Brick's Orchard.

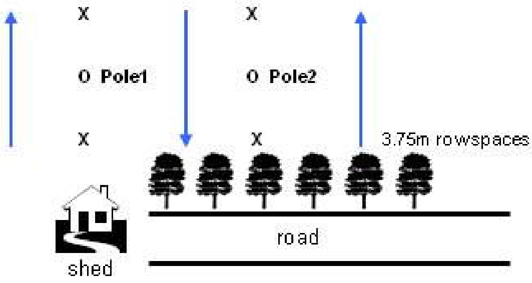
Block: Omega (Block4)

Sprayer: Atom 2000 turbo
Nozzles: 4x Masotti Article 58 ceramic disk (pink) & stainless core nozzles (per side)
Fan speed: 2000 rpm
Pressure: 17 bar
Water rate (L/ha): 1000L
Travel speed (km/h): 7.5km

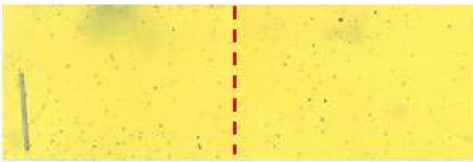
Trt: 5_water only

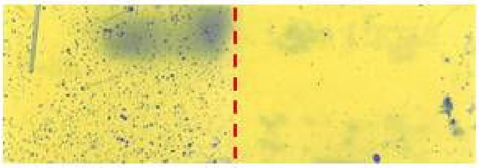
Date: 24th May 2011

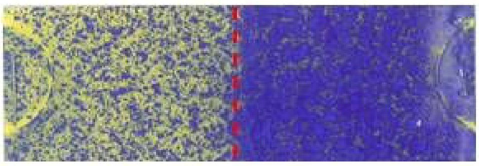
Wind speed (m/s): < 1m
Temperature: -
Sprayer travel direction:

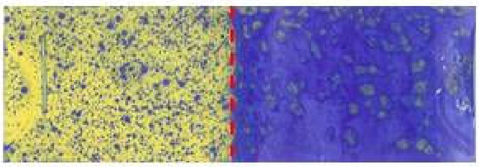


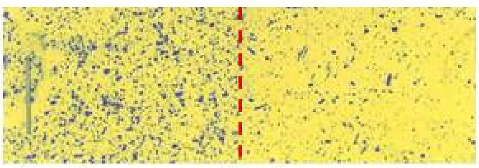
Pole 1
Upper surface Lower surface


5m above ground level

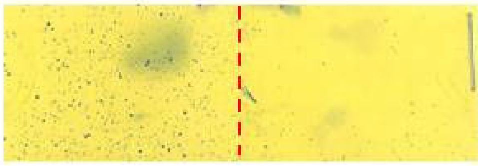

4m above ground level

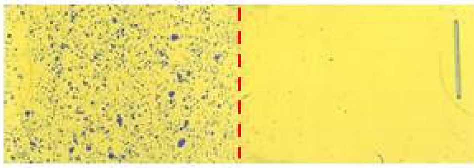

3m above ground level

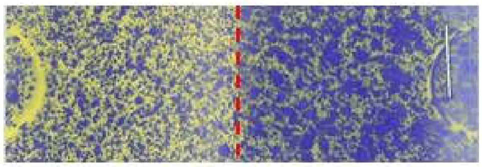

2m above ground level

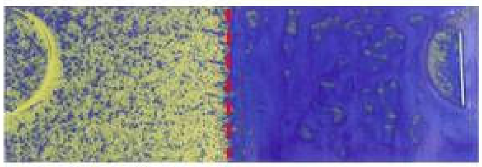

1m above ground level

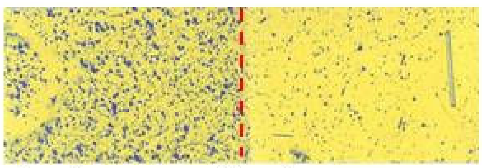
Pole 2
Upper surface Lower surface


5m above ground level


4m above ground level


3m above ground level


2m above ground level


1m above ground level

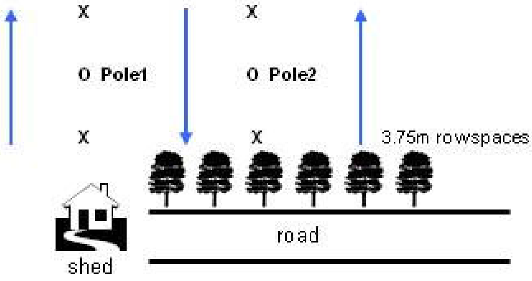
Location: 220 Maniatutu Rd, Pongakawa.
Marty Brick's Orchard.

Block: Omega (Block4)

Sprayer: Atom 2000 turbo
Nozzles: 4x Masotti Article 58 ceramic disk (pink) & stainless core nozzles (per side)
Fan speed: 1650 rpm
Pressure: 18 bar
Water rate (L/ha): 2000L
Travel speed (km/h): 6km

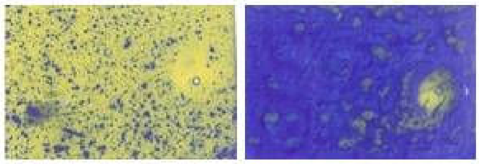
Date: 24th May 2011

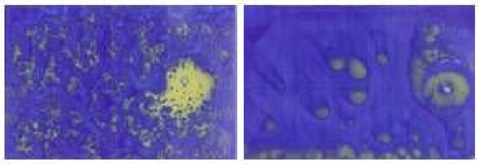
Wind speed (m/s): < 1m
Temperature: -
Sprayer travel direction:

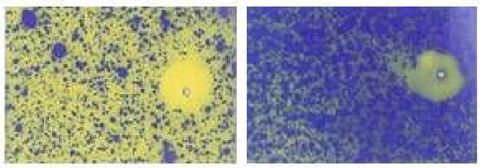


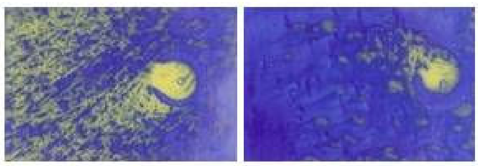
Trt: 6_water only

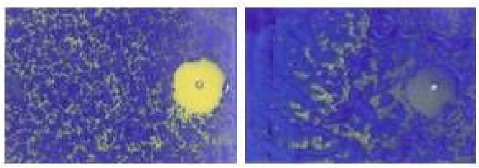
Leaf deposits
Upper surface Lower surface


Upper canopy, leader section

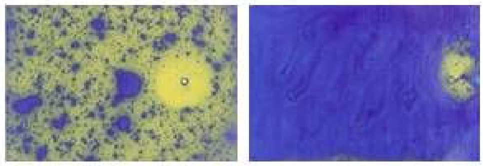

Lower canopy, leader section

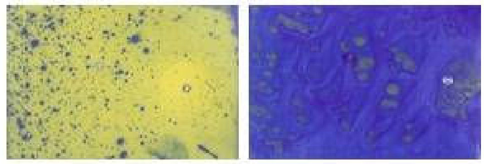

Upper canopy, centre section

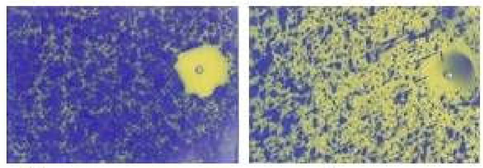

Mid canopy, centre section

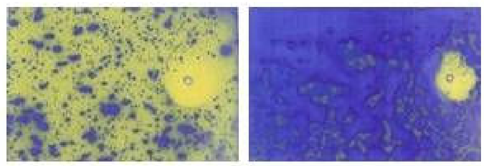

Lower canopy, centre section

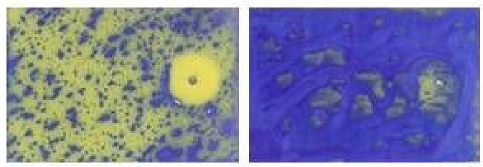
Leaf deposits
Upper surface Lower surface


Upper canopy, leader section


Lower canopy, leader section


Upper canopy, centre section


Mid canopy, centre section


Lower canopy, centre section

Water sensitive paper record of spraying parameters assessed in preliminary study#1.

Location: 220 Maniatutu Rd, Pongakawa.
Marty Brick's Orchard.

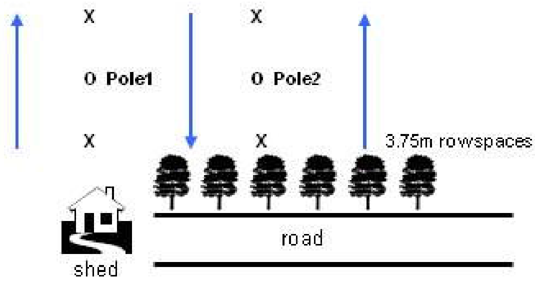
Block: Omega (Block4)

Sprayer: Atom 2000 turbo
Nozzles: 4x Masotti Article 58 ceramic disk (pink) & stainless core nozzles (per side)
Fan speed: 1650 rpm
Pressure: 18 bar
Water rate (L/ha): 2000L
Travel speed (km/h): 6km

Trt: 6_water only

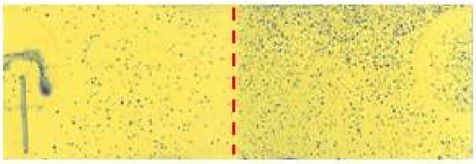
Date: 24th May 2011

Wind speed (m/s): < 1m
Temperature: -
Sprayer travel direction:

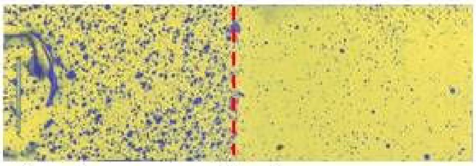


Pole 1

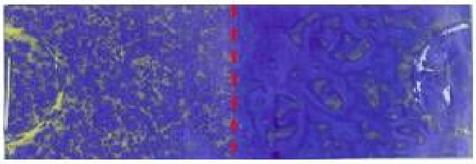
Upper surface   Lower surface



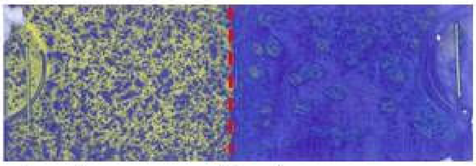
5m above ground level



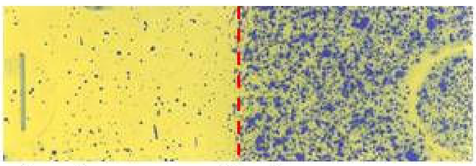
4m above ground level



3m above ground level



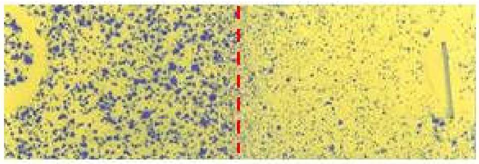
2m above ground level



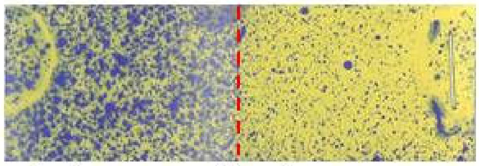
1m above ground level

Pole 2

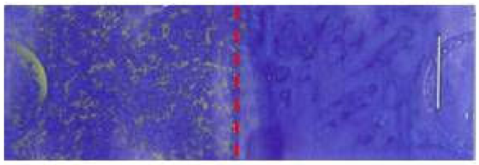
Upper surface   Lower surface



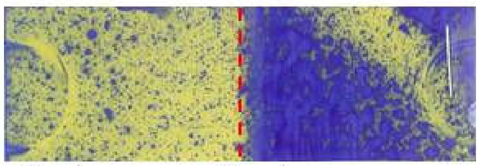
5m above ground level



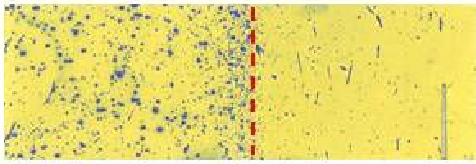
4m above ground level



3m above ground level



2m above ground level



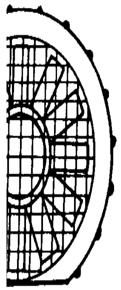
1m above ground level

APPENDIX 2: Sprayer setups

Orchard	Omega	
Tractor	Atom	Kiwi-Vac
Sprayer	Atom Modena - Omega	
Year	2011	

Calibration Summary

Kiwifruit, Pergola
PSA prevention spray trials
@ 3.75m row spacing



	1000 l/ha						800 l/ha			600 l/ha		
	Art.58			Art. 58 - fast			Art. 58			Hollow Cone		
	Tip	*Core*	%	*Tip*	*Core*	%	*Tip*	*Core*	%	*Tip*	*Core*	%
1	1.5	1.0	24	1.8	1.0	23	1.5	NCH	20	ATR	red	19
2	1.5	1.0	25	1.8	1.2	24	1.5	NCH	20	ATR	red	19
3	1.5	1.2	26	1.8	1.5	27	1.5	1.0	29	ATR	green	26
4	1.5	1.2	26	1.8	1.5	27	1.5	1.0	31	ATR	blue	37
5	----	----		----	----		----	----		----	----	
6	----	----		----	----		----	----		----	----	
7	----	----		----	----		----	----		----	----	
8	----	----		----	----		----	----		----	----	
9	----	----		----	----		----	----		----	----	
10	----	----		----	----		----	----		----	----	
Gauge Pressure	17.6	bar		16.4	bar		17.0	bar		14.0	bar	
Total Discharge	38.0	l/min		47.5	l/min		30.4	l/min		22.8	l/min	
Speed	6.0	km/hr		7.5	km/hr		6.0	km/hr		6.0	km/hr	

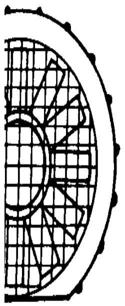
Air output:
At 1650 rpm = 27400 m3/hr
At 2000 rpm = 33400 m3/hr

Crop Details					Sprayer			Flow Monitor		Atom	Kiwi-Vac	Speed
Spray	App Rate (l/ha)	Setup #	Dilute/ Conc	Switches	Nozzles	Fan speed	Pressure (bar)	Flow Cal	Circ/ Wheel		Revs	km/hr
Foliar	1000		2 x Conc.		Art.58	1650	17.5	663	382		**1650**	**6.0**
Foliar	1000		2 x Conc.		Art.58	2000	17.0	663	382		**2000**	**6.0**
Foliar	1000		2 x Conc.		Art.58-fast	2000	16.5	663	382		**2000**	**7.5**
Foliar	800		2.5 x Conc.		Art. 58	1650	17.0	663	382		**1650**	**6.0**
Foliar	600		3 x Conc.		Hollow Cn	1650	14.0	663	382		**1650**	**6.0**

Calibration Summary

Orchard	Omega
Tractor	Atom | Kiwi-Vac
Sprayer	Atom Modena - Omega
Year	2011

Kiwifruit, Pergola
PSA prevention spray trials
@ 3.75m row spacing



	400 l/ha						200 l/ha				
	Hollow Cone			Hollow Cone - fast			Bubble-Jet				
	Tip	*Core*	%	*Tip*	*Core*	%	*Tip*	*Core*	%	*Tip*	*Core*
1	ATR	orange	22	ATR	red	21	bj-01	orange	11		
2	ATR	orange	22	ATR	red	21	bj-02	yellow	22		
3	ATR	red	28	ATR	green	29	bj-03	blue	33		
4	ATR	red	28	ATR	green	29	bj-03	blue	33		
5	----	----		----	----		----	----			
6	----	----		----	----		----	----			
7	----	----		----	----		----	----			
8	----	----		----	----		----	----			
9	----	----		----	----		----	----			
10	----	----		----	----		----	----			
Gauge Pressure	14.5	bar		12.2	bar		4.1	bar			
Total Discharge	15.2	l/min		19.0	l/min		8.2	l/min			
Speed	6.0	km/hr		7.5	km/hr		6.0	km/hr			

Air output:
At 1300 rpm = 22800 m3/hr
At 1650 rpm = 27400 m3/hr
At 2000 rpm = 33400 m3/hr

Crop Details					Sprayer			Flow Monitor		Atom	Kiwi-Vac	Speed
Spray	App Rate (l/ha)	Setup #	Dilute/ Conc	Switches	Nozzles	Fan speed	Pressure (bar)	Flow Cal	Circ/ Wheel		Revs	km/hr
Foliar	400		5 x Conc.		Hollow Cn	1300	14.5	663	382		**1300**	**6.0**
Foliar	400		5 x Conc.		Hollow Cn	1650	14.5	663	382		**1650**	**6.0**
Foliar	400		5 x Conc.		Hollow Cn	2000	14.5	663	382		**2000**	**6.0**
Foliar	400		5 x Conc.		HC - fast	2000	12.0	663	382		**2000**	**7.5**
Foliar	200		10 x Conc.		Bubble-jet	1650	4.0	663	382		**1650**	**6.0**

APPENDIX 3
Water sensitive paper record of spraying parameters assessed in preliminary study #2

Summary of treatments applied with an Atom 2000 Turbo sprayer.

Tmt #	Nozzles[1]	Spray volume (L/ha)	Pressure (bar)	Fan speed (rpm)	Travel speed (km/h)	Adjuvant rate L/ha (%)
1	Art. 58	1000	17.5	1650	6.0	400 (0.04)
2	Art. 58	1000	17.5	2000	6.0	400 (0.04)
4	ATR	600	14.0	1650	6.0	400 (0.07)
5	Art. 58	800	17.0	1650	6.0	400 (0.05)
6	ATR	400	14.5	1300	6.0	400 (0.10)
7	ATR	400	14.5	1650	6.0	400 (0.10)
8	ATR	400	14.5	2000	6.0	400 (0.10)
9	ATR	400	12.0	2000	7.5	400 (0.10)
10	AI-FF	200	4.0	1650	6.0	200 (0.10)

[1]Art. 58 = Masotti disk & core nozzles; ATR = Albuz ceramic hollow cone nozzles; AI-FF = Billericay Bubble Jet AI flat fan nozzles

Water sensitive paper record of spraying parameters assessed in preliminary study#2.

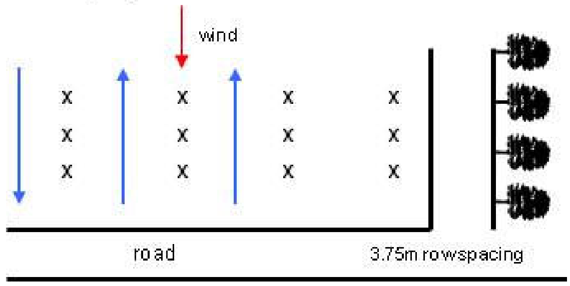
Location: 220 Maniatutu Rd, Pongakawa.
Marty Brick's Orchard.

Block: Omega (Block11)

Sprayer: Atom 2000 turbo
Nozzles: 4x Masotti Article 58 ceramic disk (pink) & stainless core nozzles. (per side)
Fan speed: 1650 rpm
Pressure: 17.5 bar
Water rate (L/ha): 1000L
Travel speed (km/h): 6km

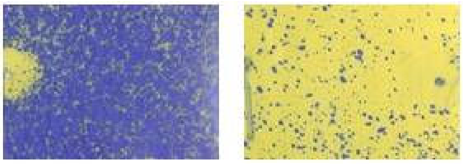
Date: 30th May 2011

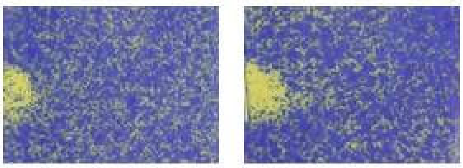
Wind speed (m/s): -
Temperature: -
Sprayer travel direction:

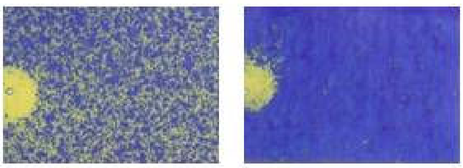


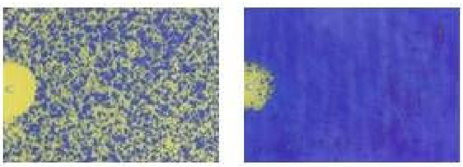
Trt: 1_400ml/ha Du-wett (0.04%)

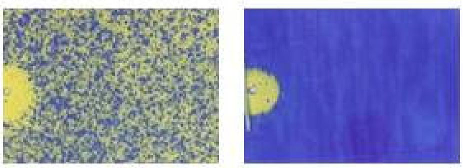
Leaf deposits
Upper surface Lower surface


Upper canopy, leader section

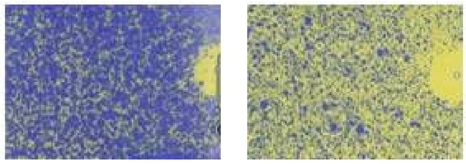

Mid canopy, leader section

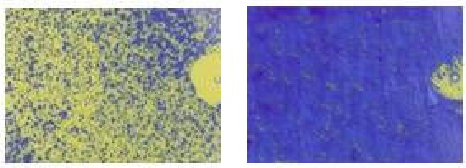

Lower canopy, leader section

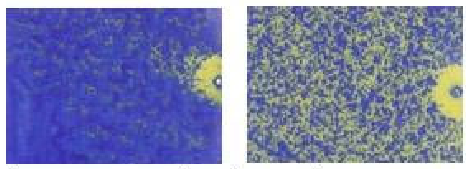

Upper canopy, centre section

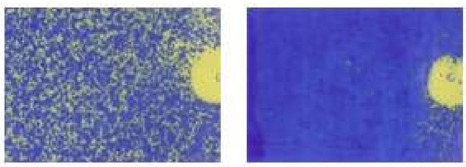

Lower canopy, centre section

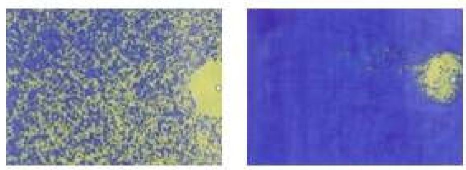
Leaf deposits
Upper surface Lower surface


Upper canopy, leader section


Mid canopy, leader section


Lower canopy, leader section


Upper canopy, centre section


Lower canopy, centre section

Water sensitive paper record of spraying parameters assessed in preliminary study #2.

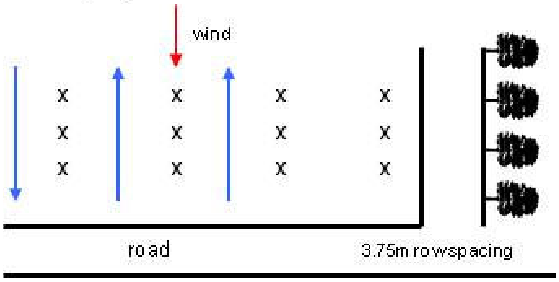
Location: 220 Maniatutu Rd, Pongakawa.
Marty Brick's Orchard.

Block: Omega (Block11)

Sprayer: Atom 2000 turbo
Nozzles: 4x Masotti Article 58 ceramic disk (pink) & stainless core nozzles. (per side)
Fan speed: 2000 rpm
Pressure: 17.5 bar
Water rate (L/ha): 1000L
Travel speed (km/h): 6km

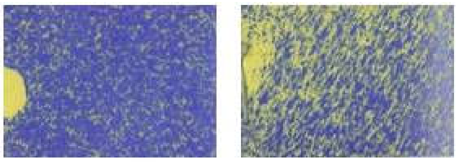
Date: 30th May 2011

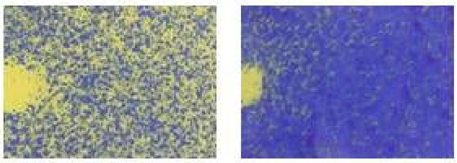
Wind speed (m/s): -
Temperature: -
Sprayer travel direction:

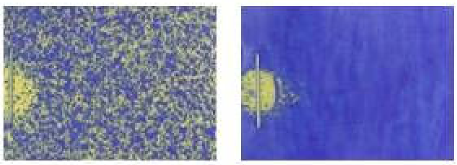


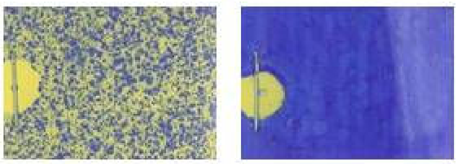
Trt: 2_400ml/ha Du-wett (0.04%)

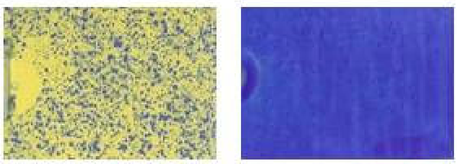
Leaf deposits	
Upper surface	Lower surface


Upper canopy, leader section

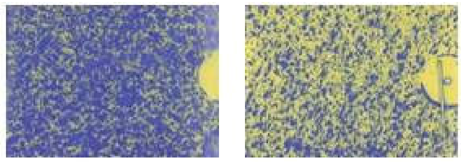

Mid canopy, leader section

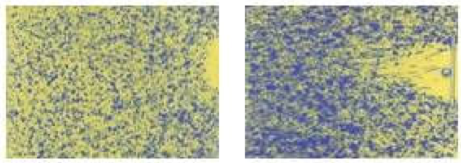

Lower canopy, leader section

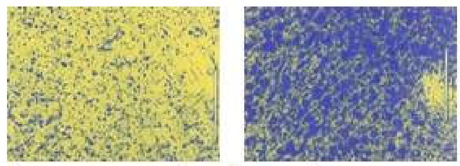

Upper canopy, centre section

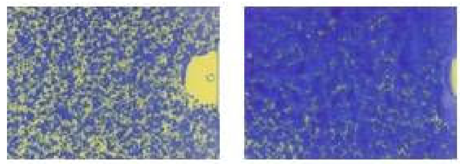

Lower canopy, centre section

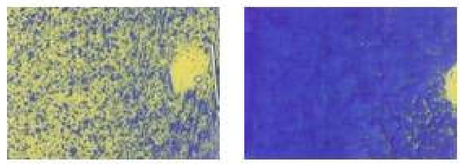
Leaf deposits	
Upper surface	Lower surface


Upper canopy, leader section


Mid canopy, leader section


Lower canopy, leader section


Upper canopy, centre section


Lower canopy, centre section

Water sensitive paper record of spraying parameters assessed in preliminary study#2.

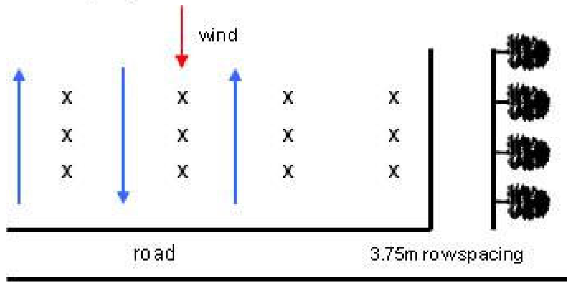
Location: 220 Maniatutu Rd, Pongakawa.
Marty Brick's Orchard.

Block: Omega (Block11)

Sprayer: Atom 2000 turbo
Nozzles: 4x Albuz ATR hollow cone (fine) nozzles. (per side)
Fan speed: 1650 rpm
Pressure: 14 bar
Water rate (L/ha): 600L
Travel speed (km/h): 6km

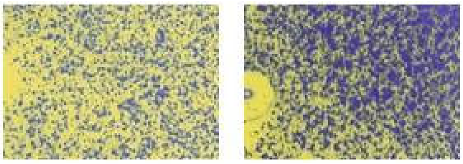
Date: 30th May 2011

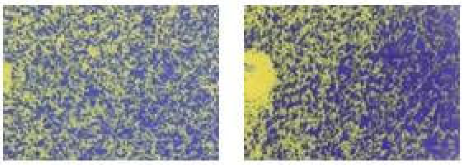
Wind speed (m/s): -
Temperature: -
Sprayer travel direction:

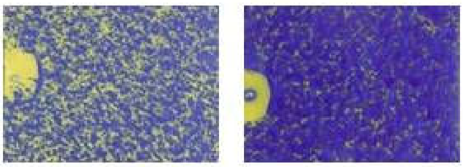


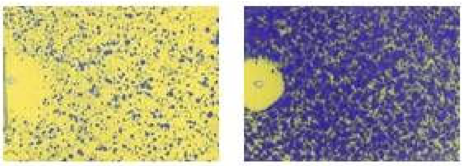
Trt: 4_400ml/ha Du-wett (0.07%)

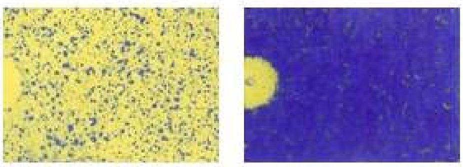
Leaf deposits
Upper surface Lower surface


Upper canopy, leader section

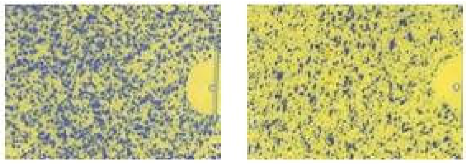

Mid canopy, leader section

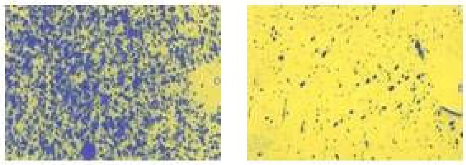

Lower canopy, leader section

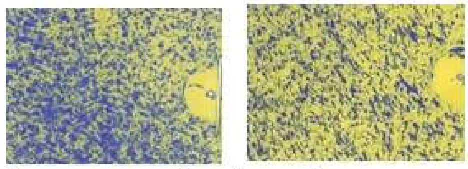

Upper canopy, centre section

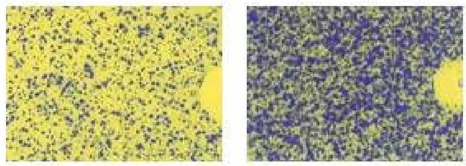

Lower canopy, centre section

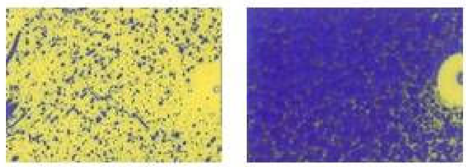
Leaf deposits
Upper surface Lower surface


Upper canopy, leader section


Mid canopy, leader section


Lower canopy, leader section


Upper canopy, centre section


Lower canopy, centre section

Water sensitive paper record of spraying parameters assessed in preliminary study#2.

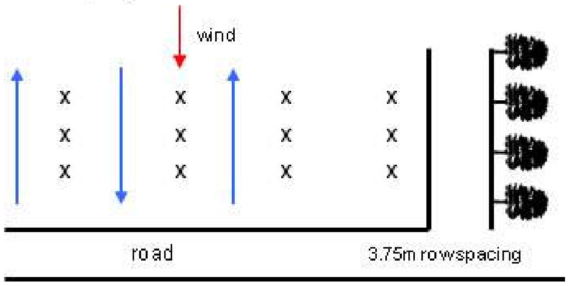
Location: 220 Maniatutu Rd, Pongakawa.
Marty Brick's Orchard.

Block: Omega (Block11)

Sprayer: Atom 2000 turbo
Nozzles: 4x Masotti Article 58 ceramic disk (pink) & stainless core nozzles. (per side)
Fan speed: 1650 rpm
Pressure: 17 bar
Water rate (L/ha): 800L
Travel speed (km/h): 6km

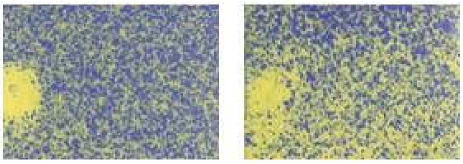
Date: 30th May 2011

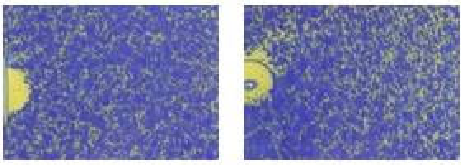
Wind speed (m/s): -
Temperature: -
Sprayer travel direction:

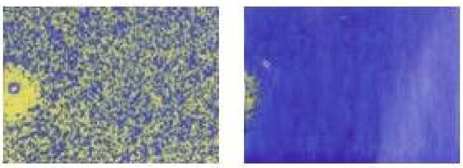


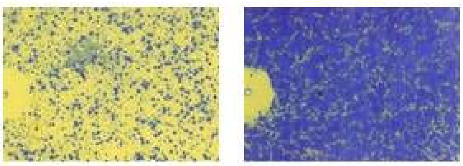
Trt: 5_400ml/ha Du-wett (0.05%)

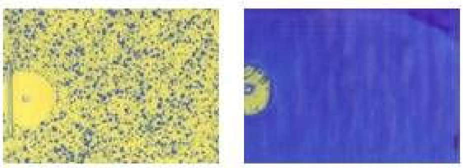
Leaf deposits
Upper surface   Lower surface


Upper canopy, leader section

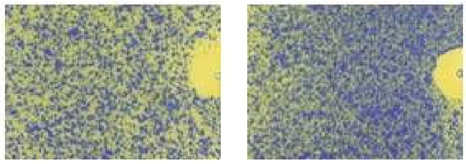

Mid canopy, leader section

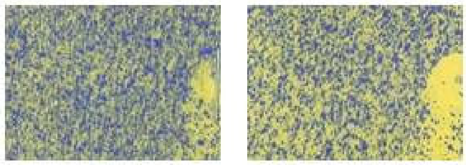

Lower canopy, leader section

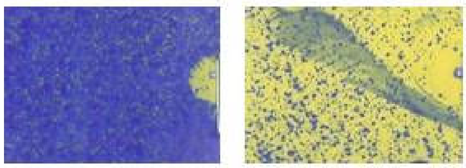

Upper canopy, centre section

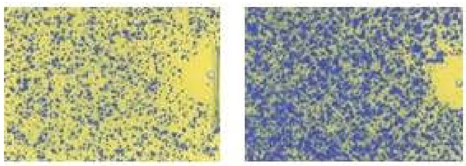

Lower canopy, centre section

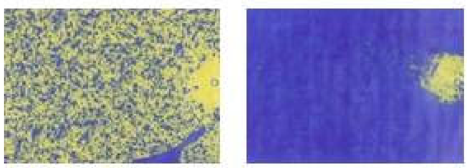
Leaf deposits
Upper surface   Lower surface


Upper canopy, leader section


Mid canopy, leader section


Lower canopy, leader section


Upper canopy, centre section


Lower canopy, centre section

Water sensitive paper record of spraying parameters assessed in preliminary study#2.

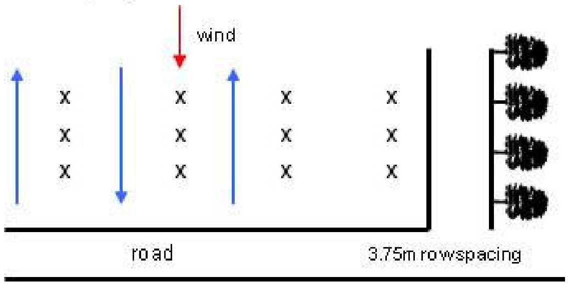
Location: 220 Maniatutu Rd, Pongakawa.
Marty Brick's Orchard.

Block: Omega (Block11)

Sprayer: Atom 2000 turbo
Nozzles: 4x Albuz ATR hollow cone (fine) nozzles. (per side)
Fan speed: 1300 rpm
Pressure: 14.5 bar
Water rate (L/ha): 400L
Travel speed (km/h): 6km

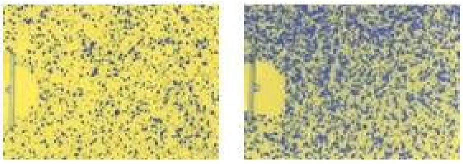
Date: 30th May 2011

Wind speed (m/s): -
Temperature: -
Sprayer travel direction:

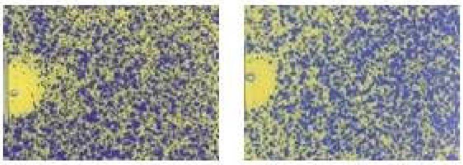


Trt: 6_400ml/ha Du-wett (0.1%)

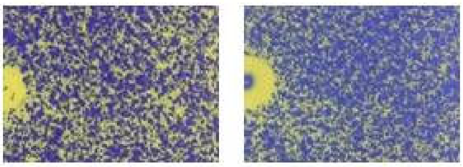
Leaf deposits
Upper surface Lower surface



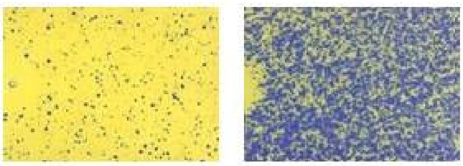
Upper canopy, leader section



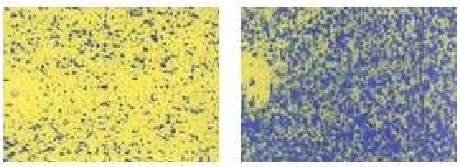
Mid canopy, leader section



Lower canopy, leader section

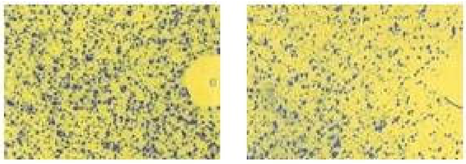


Upper canopy, centre section

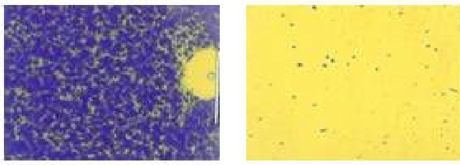


Lower canopy, centre section

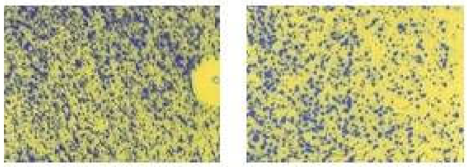
Leaf deposits
Upper surface Lower surface



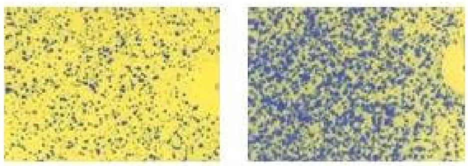
Upper canopy, leader section



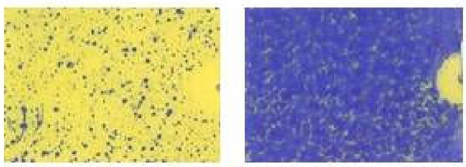
Mid canopy, leader section



Lower canopy, leader section



Upper canopy, centre section



Lower canopy, centre section

Water sensitive paper record of spraying parameters assessed in preliminary study#2.

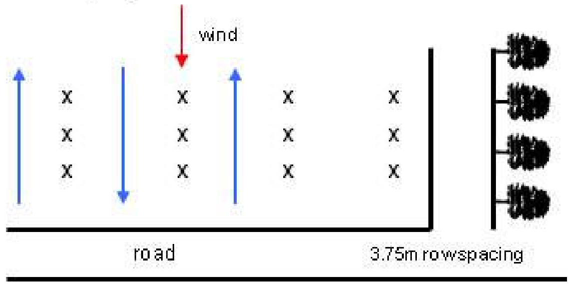
Location: 220 Maniatutu Rd, Pongakawa.
Marty Brick's Orchard.

Block: Omega (Block11)

Sprayer: Atom 2000 turbo
Nozzles: 4x Albuz ATR hollow cone (fine) nozzles. (per side)
Fan speed: 1650 rpm
Pressure: 14.5 bar
Water rate (L/ha): 400L
Travel speed (km/h): 6km

Date: 30th May 2011

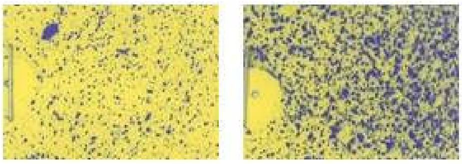
Wind speed (m/s): -
Temperature: -
Sprayer travel direction:

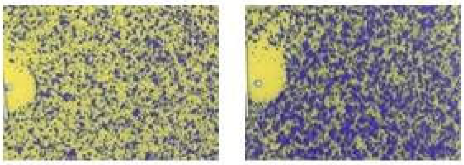


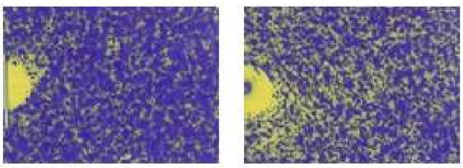
Trt: 7_400ml/ha Du-wett (0.1%)

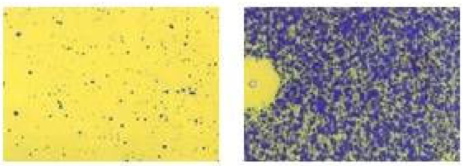
Leaf deposits

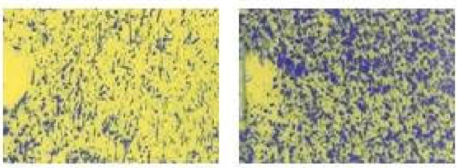
Upper surface   Lower surface


Upper canopy, leader section


Mid canopy, leader section

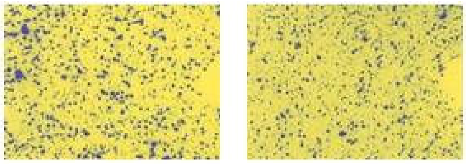

Lower canopy, leader section

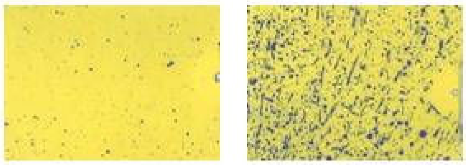

Upper canopy, centre section

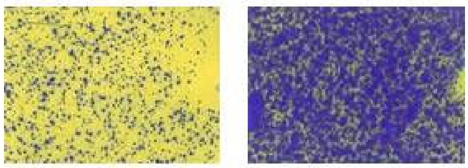

Lower canopy, centre section

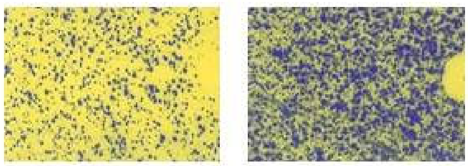
Leaf deposits

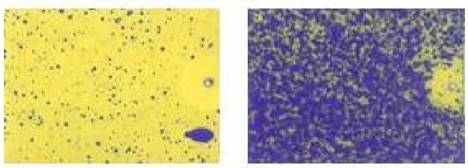
Upper surface   Lower surface


Upper canopy, leader section


Mid canopy, leader section


Lower canopy, leader section


Upper canopy, centre section


Lower canopy, centre section

Water sensitive paper record of spraying parameters assessed in preliminary study#2.

Location: 220 Maniatutu Rd, Pongakawa.
Marty Brick's Orchard.

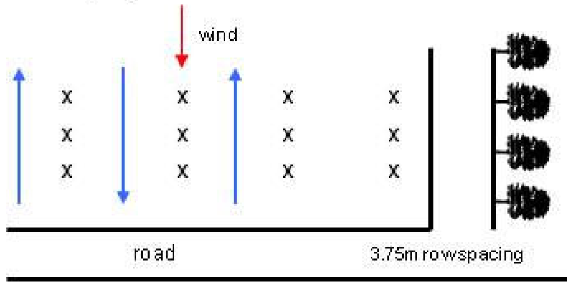
Block: Omega (Block11)

Sprayer: Atom 2000 turbo
Nozzles: 4x Albuz ATR hollow cone (fine) nozzles.
(per side)
Fan speed: 2000 rpm
Pressure: 14.5 bar
Water rate (L/ha): 400L
Travel speed (km/h): 6km

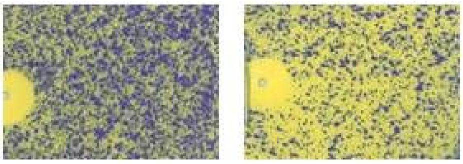
Trt: 8_400ml/ha Du-wett (0.1%)

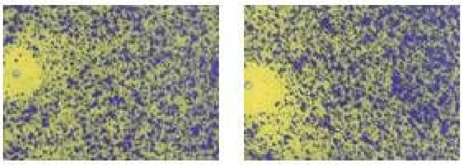
Date: 30th May 2011

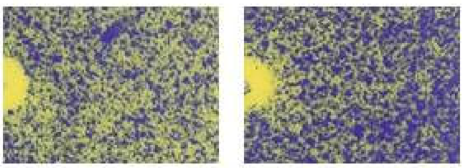
Wind speed (m/s): -
Temperature: -
Sprayer travel direction:

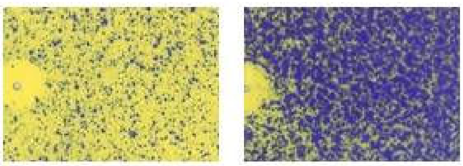


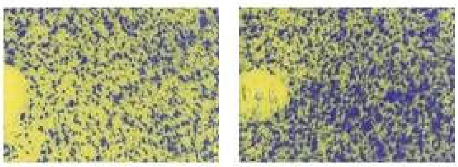
Leaf deposits
Upper surface Lower surface


Upper canopy, leader section

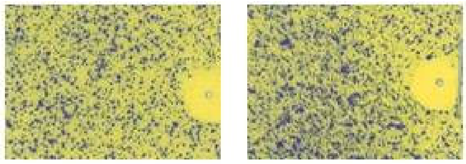

Mid canopy, leader section

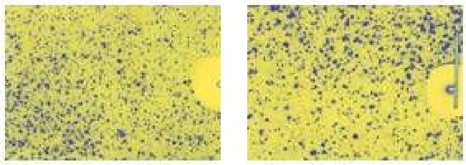

Lower canopy, leader section

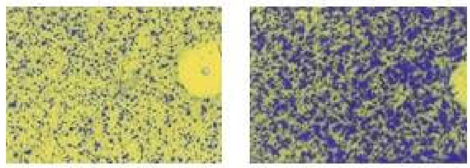

Upper canopy, centre section

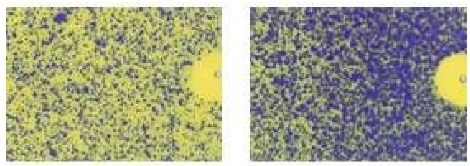

Lower canopy, centre section

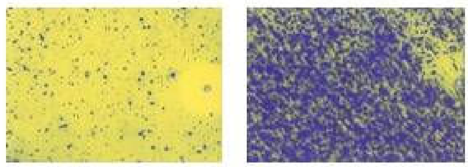
Leaf deposits
Upper surface Lower surface


Upper canopy, leader section


Mid canopy, leader section


Lower canopy, leader section


Upper canopy, centre section


Lower canopy, centre section

Water sensitive paper record of spraying parameters assessed in preliminary study#2.

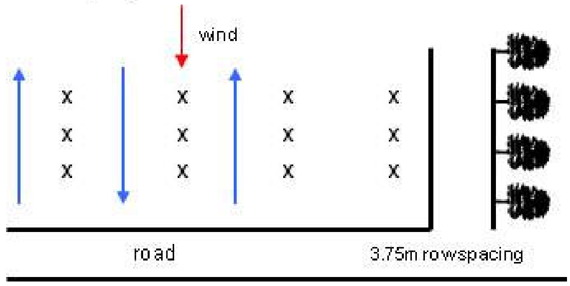
Location: 220 Maniatutu Rd, Pongakawa.
Marty Brick's Orchard.

Block: Omega (Block11)

Sprayer: Atom 2000 turbo
Nozzles: 4x Albuz ATR hollow cone (fine) nozzles. (per side)
Fan speed: 2000 rpm
Pressure: 12 bar
Water rate (L/ha): 400L
Travel speed (km/h): 7.5km

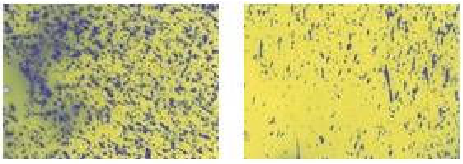
Date: 30th May 2011

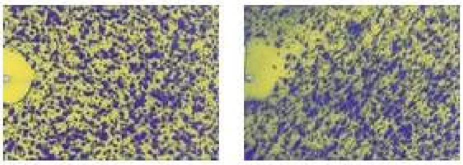
Wind speed (m/s): -
Temperature: -
Sprayer travel direction:

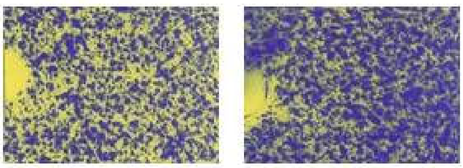


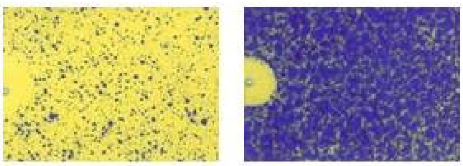
Trt: 9_400ml/ha Du-wett (0.1%)

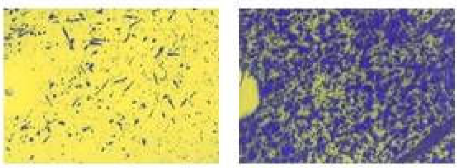
Leaf deposits
Upper surface Lower surface


Upper canopy, leader section

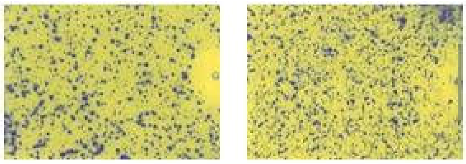

Mid canopy, leader section

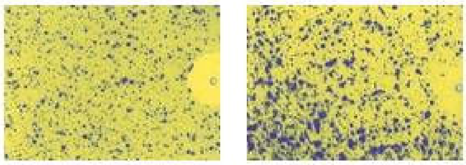

Lower canopy, leader section

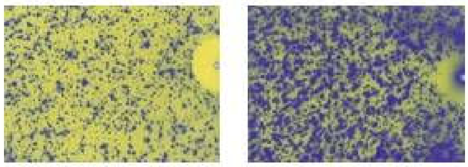

Upper canopy, centre section

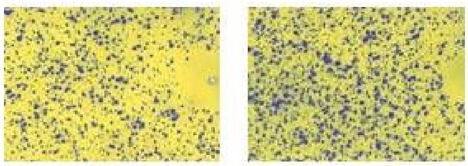

Lower canopy, centre section

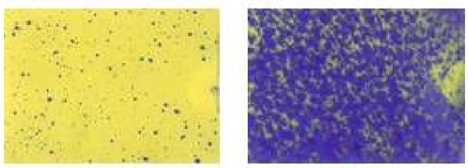
Leaf deposits
Upper surface Lower surface


Upper canopy, leader section


Mid canopy, leader section


Lower canopy, leader section


Upper canopy, centre section


Lower canopy, centre section

Water sensitive paper record of spraying parameters assessed in preliminary study#2.

Location: 220 Maniatutu Rd, Pongakawa.
Marty Brick's Orchard.

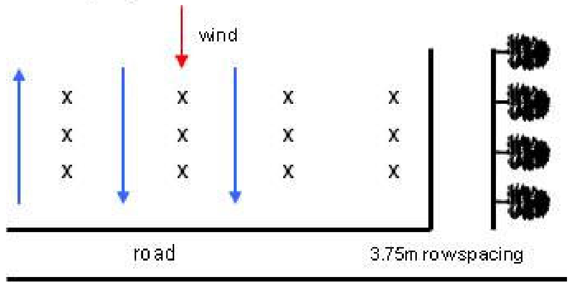
Block: Omega (Block11)

Sprayer: Atom 2000 turbo
Nozzles: 4x Billericay bubble jet AI flat fan nozzles 110° (per side)
Fan speed: 1650 rpm
Pressure: 4 bar
Water rate (L/ha): 200L
Travel speed (km/h): 6km

Trt: 10_400ml/ha Du-wett (0.2%)

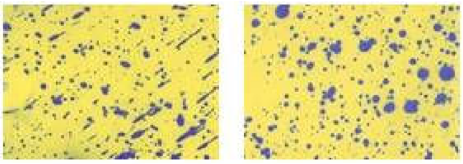
Date: 30th May 2011

Wind speed (m/s): -
Temperature: -
Sprayer travel direction:

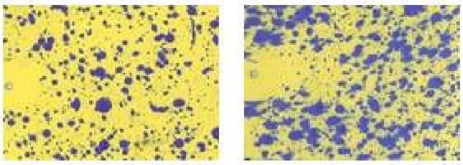


Leaf deposits

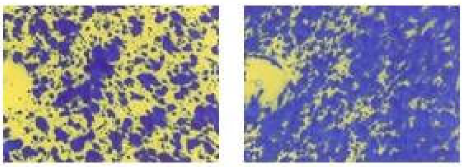
Upper surface Lower surface



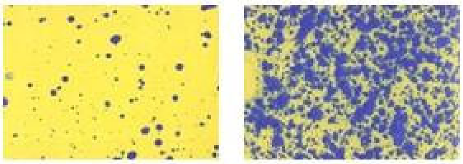
Upper canopy, leader section



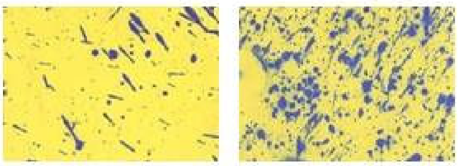
Mid canopy, leader section



Lower canopy, leader section



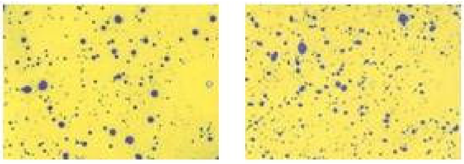
Upper canopy, centre section



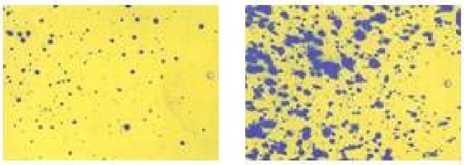
Lower canopy, centre section

Leaf deposits

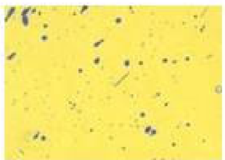
Upper surface Lower surface



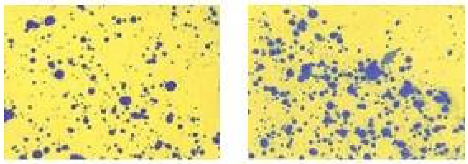
Upper canopy, leader section



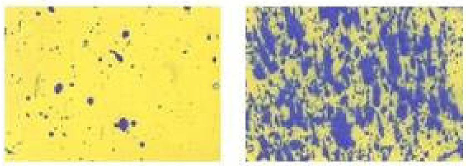
Mid canopy, leader section



Lower canopy, leader section



Upper canopy, centre section



Lower canopy, centre section

Plant Protection ChemistryNZ Ltd is an independent provider of research, advisory and extension services relating to the use and efficacy of agrichemicals.

PO Box 6282
49 Sala St
c/- Scion Campus
Rotorua 3043
New Zealand

Ph +64 7 343 5896
Fax +64 7 343 5811
Info@ppcnz.co.nz

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