Report to Zespri Group Ltd

SFF Project Number 401531
Optimising copper use for sustainable control of Psa in kiwifruit orchards

Novel technologies to deliver protectant sprays to strung canopies

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August 2016

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EXECUTIVE SUMMARY

Strung canopies that are sprayed from below using traditional airblast sprayers have shown significantly lower and more variable spray deposits than the lower pergola canopy at all of the growth stages tested. In most cases, the spray deposit levels seen on strung canopy leaves are expected to be too low to provide reliable protection against Psa at normal (canopy) spray application rates.

This study was undertaken to build on previous work to develop best practice recommendations for protective sprays for kiwifruit. In particular, it was to assess available new spray technologies to provide 'top-up' sprays to strung canopies and new growth emerging above pergola canopies and to compare these with a standard airblast application. The technologies selected for the study were:

- A single-sided spray volute that is typically used in the industry to treat shelter belts and large avocado trees. This takes the air from the lifting side of an axial fan airblast sprayer and delivers it to the upper and opposite side of the sprayer, so that all of the available air output can be used to project spray a greater distance and with more control of placement than is possible with an open air blast sprayer fan output.
- A cannon sprayer that is typically used for treating large street trees or, for example, gullies for passion vine hoppers. This type of sprayer produces a similar output to a volute, but arguably with more control of spray projection and placement.
- An unmanned helicopter (drone) that was capable of treating strung canopies from above, while operating at levels and with a degree of spray placement precision that is simply not practical with traditional helicopter application methods.

Studies were undertaken on a strung Gold3 canopy through late summer - autumn 2016. Deposits were monitored immediately below and above the pergola canopy zone, and in two strung canopy zones, at 3.5 and 5 m above ground, using water sensitive papers (WSP). Additionally, deposits on both sides of leaves in the two strung canopy zones were quantified using spray tracer dyes. In summary:

- It is not possible to protect strung vines from Psa with traditional airblast spray applications delivered from beneath the main pergola canopy.
- All three of the overhead spray delivery systems tested in these experiments could deliver higher deposits to the strung canopies than a standard airblast application, but the practical use of spray volutes or cannons is limited by the relatively narrow band of canopy that can be reliably treated using this type of technology and the high deposit variability inherent in attempting to spray across a wide swath.
- The use of small, unmanned, aerial application systems like the Yamaha RMax appear to hold great potential for effective, time- and cost-efficient, application of sprays to kiwifruit canopies from above, particularly as advances in technology continue to reduce their cost. The ability to treat young, susceptible, extension growth tissue could be very useful to protect this part of the canopy without the risk of overdosing fruit.
- Further research into unmanned aerial application systems is well worth considering, potentially in combination with electrostatic sprays. We believe that they will eventually have a useful place as a tool in spray application to kiwifruit strung canopies.

INTRODUCTION

These studies are part of a project to improve spray coverage and optimise copper use for Psa protection in kiwifruit orchards. The objective was to build on previous work to develop best practice recommendations for protective sprays for kiwifruit.

The problems of achieving effective spray deposits in overly dense kiwifruit canopies have already been identified and documented in previous spray deposit studies (Gaskin *et al*. 2011, 2012). In a reasonably open, well managed canopy, average deposits on bulked tissue samples in the most easily-sprayed canopy zones closest to the sprayer will be two to three times higher than those on more distant and difficult to spray canopy zones (typically the upper canopy and especially out at the vine leaders). As canopy density and complexity increases, the deposit variability from zone to zone increases greatly. We have measured deposits from five to twenty times lower than the most sprayed part of the canopy in overly dense male vines and in strung canopies. Deposit differences of this magnitude are unlikely to achieve effective chemical dosing in the poorly sprayed areas of the canopy and will very likely be associated with control failures of the protectant chemicals (coppers and antibiotics) used for Psa control. It is important to recognise that the high levels of deposit variability that we have reported previously (Gaskin *et al*. 2011, 2012, 2015, 2016) have largely been based on deposits measured from bulked leaf or fruit samples. Variability of deposits from organ to organ, between leaf surfaces and across tissue surfaces is usually higher than that measured from bulked tissue samples. The appropriate use of spray adjuvants is expected to help reduce deposit variability across tissue surfaces, but can do little to reduce deposit variability imposed by canopy density and structure.

The limited data on spray deposits landing on leaves in Gold3 strung (teepee) canopies suggests they cannot be protected by conventional airblast sprays (Gaskin *et al.* 2015, 2016). Deposits at mid teepee height (~3.5 m) were ≤20% of those measured in the pergola of a late summer, G3 canopy. The work reported here aimed to identify novel spray application technologies to maximise the efficiency of protectant spray delivery to mature and flushing foliage on teepee structures. After industry consultation and widespread investigation of potential spray application techniques, the technologies selected for the study were:

- A single-sided spray volute that is typically used in the industry to treat shelter belts and large avocado trees. This takes the air from the lifting side of an axial fan airblast sprayer and delivers it to the upper and opposite side of the sprayer, so that all of the available air output can be used to project spray a greater distance and with more control of placement than is possible with an open air blast sprayer fan output.

- A cannon sprayer that is typically used for treating large street trees or, for example, gullies for passion vine hoppers. This type of sprayer produces a similar output to a volute, but arguably with more control of spray projection and placement.

- An unmanned helicopter (drone) that was capable of treating strung canopies from above, while operating at levels and with a degree of spray placement precision that is simply not practical with traditional helicopter application methods.

In a lead-up to the novel application technology tests reported here, other alternative application technologies were considered and discarded. These included:

- The use of multiple, small, fixed sprinkler/nozzle delivery systems to treat the strung canopies. This method of spray delivery has been tested extensively in apples in the USA (Solid Set spray delivery systems http://www.canopydelivery.msu.edu/project-areas/horticulture/) and was tested in NZ apples in 2015-16 (Manktelow observations with AgFirst consultants Nelson). The delivery system is logistically impractical and deposits are highly variable and unreliable.

- The delivery of spray through overhead frost protection sprinkler systems. The delivery of slaked lime as a fungicide for apple wound protection from infection by the European Canker pathogen has been successfully achieved using a high volume overhead sprinkler system. This approach to the delivery of copper fungicides to the upper canopy and to strung canopies in kiwifruit would be expected to work. However, by nature this is a high volume, crude, agrichemical delivery system and would be expected to require the use of relatively large quantities of copper products. The testing of this type of spray delivery system was discarded as incompatible with the aims of minimising copper loading in the environment.

- The delivery of copper by way of emitters that deliver small doses of very fine (driftable) spray droplets to the upper kiwifruit canopy (e.g. the Robocan delivery systems for in-home insect control). This approach to spray delivery could potentially be very effective and efficient. However, it was discarded as a potential copper delivery system as there is no practical way to keep insoluble copper formulations in suspension for long periods of time for practical and reliable delivery.

- Fogging systems are an extension of the very fine droplet delivery system described above. They have the potential to achieve excellent chemical coverage on upper canopy targets using low chemical doses. However, there is no practical way to control and contain fog dispersion in an outdoor environment and this potential delivery method was discarded.

- The application of copper (or other Psa protectant chemicals) to overhead shelter net to establish a chemical reservoir, which can then redistribute chemical onto the upper canopy beneath during rain events. The potential efficacy of this type of delivery system has been proven in the past with fungicides for black spot control on apple. The extent to which overhead netting systems used in kiwifruit could contain and redistribute different copper formulations is unknown. Likewise, a system for delivering copper to the nets and any potential negative impacts of possible chemicals on the nets are all unknown. Given that only a relatively small area of NZ kiwifruit is currently netted, it was decided not to test this concept at this stage.

METHODS AND MATERIALS

<u>Volute study</u>

The study was undertaken on 09 February 2016 on Simon Cook's orchard, at Huse Lane Rangiuru. The G3 orchard is planted on 5 x 5 m row spacing, alternate strip male rows, with female vines strung on 5 m high teepees (Fig. 1). Two dilute sprays were applied, both containing Du-Wett adjuvant (40 ml/100 L) and Calcium 175™ (Grochem; approx 1.5 kg/ha) as a tracer to quantify deposits. Spray application treatments were:

(1) a standard airblast spray (1000 L/ha) applied with a calibrated Ranfurly Orchard Services Fantini Eco 2000 sprayer (Appendix 1 & 2a), driven by Simon Cook. The sprayer had an 820 mm front entry fan and was fitted with Albuz ATR hollow cone nozzles. The sprayer was driven up and down four rows as illustrated in Fig. 2 with all nozzles operating, except that row #1 was an edge row and had nozzles on the shelter side turned off (Fig. 3). Temperature was 22ºC with no wind.

(2) a volute spray consisting of a single-sided avocado volute fitted with three Masotti gun nozzles in the jetting position (Fig. 3). Nozzle pressure was 2000 kPa (45 L/min output) and travel speed was 3.0 km/h. Effective spray volume was determined as 600 L/ha at the leaf sample position, and 1000 L/ha at the block edge. The sprayer was run along the outside row of the block (Fig. 2, #1) in a single pass, to deliver spray across 15 m (three full rows). Temperature was 23ºC with no wind.

Fig. 1: G3 orchard and replacement cane development on teepees, February 2016.

Deposits were monitored with water sensitive papers (WSP) on three separate poles (A, B, C; Fig. 2). The papers were folded in half and held in place with a clip on a pole at set intervals above ground of 1.8 m (immediately below pergola canopy), 2.2 m (immediately above pergola canopy), 3.6 m (half-way up strings) and 5 m (at top of teepee). WSP were positioned horizontally and vertically, with the vertical papers mounted parallel to the drive path of the sprayer.

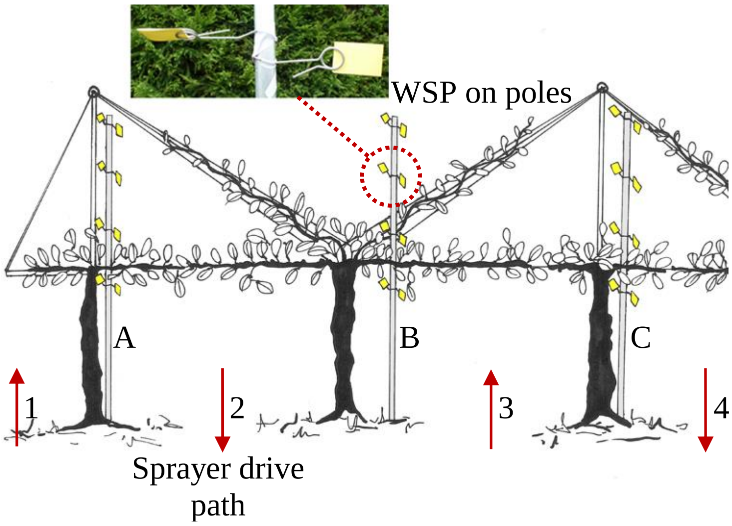

Fig. 2: Schematic of treatment block pole setup and driving pattern. Line 1 is the block edge

Calcium was used to quantify deposits on the basis of ion conductivity of sample washings (Gaskin *et al.* 2010). Immediately after spray treatments had dried, leaf samples (five reps) were collected from two canopy zones in the teepee in Row 3 (~12-15 m from sprayer; Fig. 2): at mid-height (3.6 m) and tops (5 m above ground). These leaves were washed individually on each side with varying (recorded) volumes of wash solution (containing 0.025% Du-Wett), depending on their size, to determine spray deposits on the adaxial and abaxial leaf surfaces.

Deposits were calculated as dose (µg/cm^2) and were normalised to an equivalent spray application rate of 1 kg a.i. per ha in each treatment (to allow meaningful direct comparisons of deposits between treatments). The deposit data are presented as micrograms of tracer per square centimetre of one-sided leaf area. Results were statistically analysed using ANOVA to determine the significance of treatment on spray deposits retained on leaves in different zones.

Fig. 3: Standard airblast (LHS) and volute (RHS) spray applications

Cannon study

The study was undertaken on 06 April 2016 at the same site (Simon Cook's orchard, Huse Lane Rangiuru; Fig. 4). Three dilute sprays were applied, all containing Du-Wett adjuvant (40 ml/100 L) and Calcium 175™ (Grochem; approx 1.5 kg/ha) as a tracer to quantify deposits. Spray application treatments were:

(1) a standard airblast spray (1000 L/ha) applied with a calibrated Ranfurly Orchard Services Atom 2000 Modena sprayer (Appendix 2b), driven by Simon Cook. The sprayer was fitted with Albuz ATR hollow cone nozzles and had twin rings operating. Temperature was 23.7ºC with < 0.5 m/sec wind.

(2) a ute mounted cannon sprayer fitted with 5x Orange Albuz ATR 80 degree hollow cone nozzles (Fig. 5). Nozzle pressure was 2040 kPa, delivering 170 L/ha at a travel speed of 2.3 km/h. The sprayer was run along the outside row of the block (#1, Fig. 2) in a single pass, to deliver spray across a nominal 15 m swath (three full rows). Temperature was 24ºC with an average wind speed of 0.70 m/sec blowing across rows into the block.

(3) The cannon sprayer as above, but this time with electrostatic charging of the spray droplets in operation. Temperature was 25ºC with an average wind speed of 0.38 m/sec blowing down rows into the block.

Fig. 4: G3 orchard and replacement cane development on teepees, 06 April 2016.

Fig. 5: Sonic cannon sprayer and nozzles

Deposits were monitored with water sensitive papers (WSP) on three separate poles as described previously (A, B, C; Fig. 2). Immediately after spray treatments had dried, leaf samples (five reps) were collected from two canopy zones in the teepee in Row 3 (Fig. 2): at mid-height (3.6 m) and tops (5 m above ground). Additional leaves were sampled for the cannon spray applications, from tops (5 m high) of the teepees in rows 5 and 7 into the block (~30 & 40 m, respectively, from the sprayer). Leaves were processed and deposits calculated as before.

Unmanned helicopter (Drone) study

The study was undertaken on 27 April 2016 at the same site (Simon Cook's orchard, Huse Lane Rangiuru; Fig. 6). Three dilute sprays were applied, all containing Du-Wett adjuvant (40 ml/100 L) and tartrazine dye (5 g/L) as a tracer to quantify deposits. Spray application treatments were:

(1) a standard airblast spray (1000 L/ha) applied with a calibrated Ranfurly Orchard Services Atom 2000 Modena sprayer (Appendix 2c), driven by Simon Cook. The sprayer was fitted with Albuz ATR hollow cone nozzles and had twin rings operating. Temperature was 21ºC with no wind.

(2) Yamaha RMax 3 passes at a nominal 180 L/ha. Temperature was 25ºC with a mean wind speed of <0.5 m/s. Sprays were applied with the drone flying along teepee/pergola rows.

(3) Yamaha RMax 1 pass at a nominal 60 L/ha. Temperature was 22ºC with a mean wind speed of 1.24 m/s. Sprays were applied with the drone flying across teepee/pergola rows.

Fig. 6: G3 Canopy development on teepees, 27 April 2016

The Yamaha RMax helicopter drone sprayer (Fig. 7) was calibrated prior to spray application (Appendix 2c; Runs 1&2). The RMax was fitted with a pair of Yamaho SR5 flat fan, air inclusion nozzles (see figures in Appendix 1). In this case the sprayer was operated with a fixed nozzle output of 1.08 L/min at ca. 250 kPa pressure (advanced versions of the RMax feature a speed linked nozzle output rate controller). The RMax literature suggested that in this twin nozzle configuration, the sprayer should treat a 7.5 m effective swath width when the sprayer is operated at ca. 3 m above the target canopy. However, trial output pattern runs over sets of water sensitive papers laid out on the ground, at right angles to the sprayer travel direction at a height of 3.4 m above the ground (the anticipated spraying height above strung canopy structures), indicated that the effective swath was only ca. 3.5 m (Appendix 2a).

The spraying travel speed of the RMax unit was tested in a series of timed flights along a flight track of known length. The pilot was able to maintain a reasonably constant travel speed in these test runs of between 4.6 and 5.1 km/h.

The Air Inclusion nozzles fitted to this sprayer delivered the coarsest spray droplets of any of the sprayers used in these deposit studies. While this was entirely appropriate for spray drift risk mitigation from aerial sprays, based on the relative droplet sizes this sprayer would have been expected to give relatively uneven deposits on the upper and lower sides of leaves.

Figure 7: The Yamaha RMax helicopter drone during speed and output swath calibration prior to canopy treatments.

Deposits were monitored with water sensitive papers (WSP) mounted on poles and at heights as described previously in the volute study. In Treatment 2 (RMax, 180 L/ha), sprays were applied with the drone flying <u>along</u> the teepee/pergola rows. Poles were placed and foliage samples were taken as described in Fig. 8. In Treatment 3 (RMax, 60 L/ha), sprays were applied with the drone flying <u>across</u> the teepee/pergola rows. Poles were placed and foliage samples were taken as illustrated in Fig. 9.

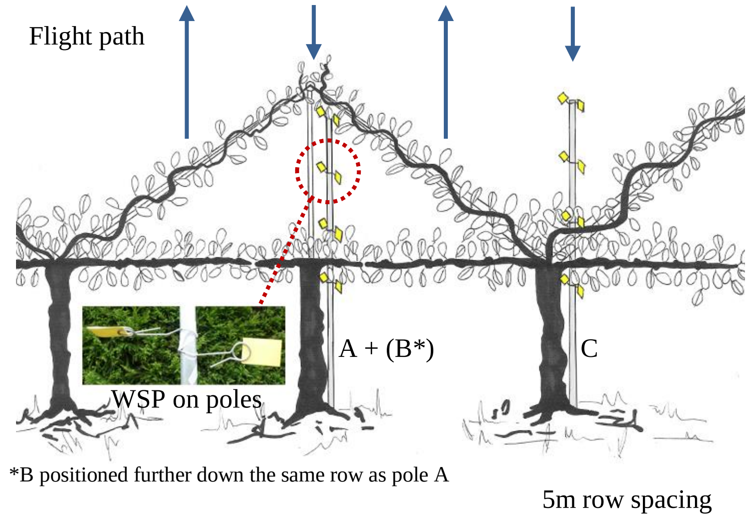

Fig. 8: WSP pole setup and flight path (along rows) for RMax 180 L/ha spray
Foliage deposits sampled from medium and top zones adjacent to poles A&B.

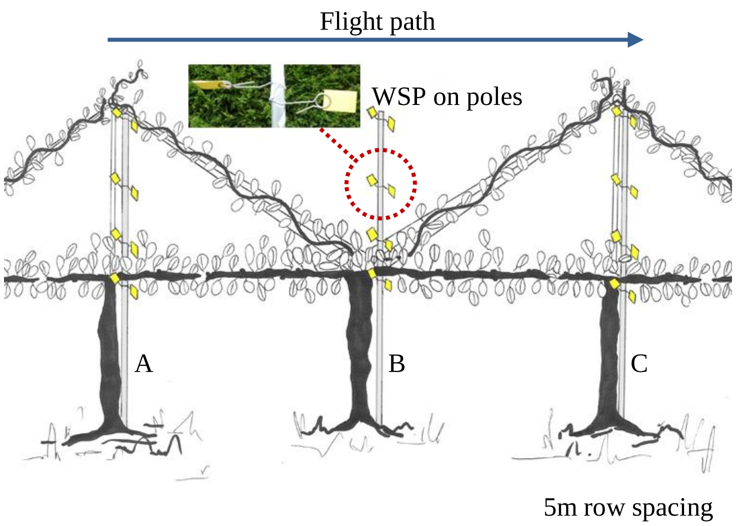

Fig. 9: WSP pole setup and flight path (across rows) for RMax 60 L/ha spray
Foliage deposits sampled from medium and top zones adjacent to poles A&C.

RESULTS and DISCUSSION

Volute study

The standard airblast treatment deposits on teepee foliage (Table 1) were similar to bulk deposits measured on a G3 strung canopy (at medium height) in an earlier study (ca 0.2 µg/cm^2; Gaskin *et al*, 2015). In the current study there were no statistical differences between airblast deposits on adaxial (top) and abaxial (bottom) surfaces of strung canopy leaves, but the adaxial surface deposits tended to be higher. This suggested that a greater proportion of the spray deposit was achieved by droplets falling out onto the upper leaf surfaces. The spray deposits normally measured on kiwifruit leaves in fully developed pergola canopies are in the order of 1-2 µg/cm^2 (per kilogram of chemical applied per hectare) (Gaskin *et al*. 2010, 2011, 2012, 2015). The deposit levels achieved by the airblast sprayer were unlikely to be adequate to cover teepee foliage. The WSP (Appendix 2a) confirmed that airblast spray delivery to teepees within the block were often inadequate at the medium teepee height, where growth of the strung shoots terminated. Airblast sprays atomised from beneath the summer (February) pergola canopy could not be delivered to the tops of teepees.

The Masotti volute (1000 L/ha) deposits on strung canopies were higher than for the airblast spray but followed a similar pattern (Table 1). Deposits were consistently higher on the adaxial leaf surface and tended to decrease with height. The WSPs (Appendix 2a) confirmed that volute delivery to all teepee foliage was generally adequate up to 10 m distance from the sprayer, but declined rapidly after that. As expected, coverage of foliage within the pergola canopy was generally poor. While potentially delivering adequate deposits to strung canopies, the logistics of covering a complete kiwifruit pergola block with a volute sprayer are challenging; it would require above-pergola access at every second or third row throughout the canopy.

Table 1: Mean deposits (µg/cm^2, normalised at 1 kg/ha) on upper & lower surfaces of leaves sampled from medium height (~3.6 m) and tops (~5 m) of teepee strings

Tmt	Spray vol. (L/ha)	Medium height		Teepee tops		**Whole leaf deposit**	
		Adaxial surface	Abaxial surface	Adaxial surface	Abaxial surface	**Med. ht**	**Teepee top**
airblast	1000	0.18 b	0.02 b	0.06 b	0.05 b	**0.20 B**	**0.11 B**
volute (Masotti)	1000	1.22 a	0.28 b	0.89 a	0.04 b	**1.50 A**	**0.93 A**

Means sharing common lower- or upper-case postscripts are not significantly different (LSD, P=0.05).

Cannon study

The airblast treatment deposits were similar to the volute study in that there were no differences between adaxial and abaxial leaf surfaces, although the former tended to be higher (Table 2). There were also no differences between deposits at medium height and on teepee tops. WSPs indicated spray deposits ranging from runoff volumes to no spray coverage in these zones (Appendix 2b).

The cannon sprayer (Treatment 2) could deliver up to five-fold higher deposits on strung foliage than the airblast (Table 2), but the deposits were low overall (< 1µg/cm^2) and the two treatments were not significantly different (P=0.05) because of the high variability in cannon deposits. The WSP confirmed this, with deposits ranging from runoff to nil (Appendix 2b). The wind was moderately gusty during this treatment application, and carried spray further into the block (Table 3) than would have occurred under light wind conditions. The cannon sprayer was marginal with respect to delivering an adequate dose to teepee foliage, and there was effectively no spray deposited in the pergola canopy zone (Appendix 2b).

With an electrostatic charge applied to the cannon (Treatment 3), spray deposits were increased, particularly on teepee tops (P=0.05). WSPs also confirmed this. A previous attempt to measure improvements in spray deposition in pergola kiwifruit canopies from the use of electrostatic charging of spray droplets did not show any improvement over standard airblast spraying (Gaskin *et al.* 2012). If the droplets are small enough (ideally less than 100 microns in diameter, as would have been expected from this sprayer), the addition of an appropriate charge will result in their attraction to the crop canopy which carries the opposite charge. The strung canopy structures are in many ways ideal targets for charged droplets and the higher deposit levels achieved by the cannon with charged droplets was an exciting result that may warrant further study. Spray drift is always a risk when application requires that spray is projected high into the air and at relatively long distances from the sprayer. The higher deposits seen from the cannon treatment with electrostatics operating effectively represents less chemical potentially available to drift.

Deposit samples taken at 30 and 40 m from the sprayer (Table 3) suggest that the cannon sprayer delivered similar deposits at this distance to the standard airblast sprayer, but again, these were arguably too low to adequately protect teepee foliage without requiring significantly higher chemical application rates – with all of the environmental and crop contamination issues that that might cause.

Table 2: Mean deposits (µg/cm^2, normalised at 1 kg/ha) on upper & lower surfaces of leaves sampled from medium height (~3.6 m) and tops (~5 m) of teepee strings

Tmt	Spray vol.	Medium height		Teepee tops		**Whole leaf deposit**	
	(L/ha)	Adaxial surface	Abaxial surface	Adaxial surface	Abaxial surface	**Med. ht**	**Teepee top**
airblast	1000	0.17 bc	0.07 c	0.29 bc	0.09 c	**0.24 B**	**0.38 B**
cannon	170	0.85 bc	0.12 c	0.73 bc	0.17 bc	**0.97 B**	**0.90 B**
cannon+electrostatic	170	1.20 ab	0.27 bc	2.17 a	2.09 a	**1.47 B**	**4.26 A**

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

Table 3: Mean deposits (µg/cm^2, normalised at 1 kg/ha) on upper & lower surfaces of leaves sampled from tops (~5 m) of teepee strings at ~30 m and ~40 m from sprayer

Tmt	Spray	30 m		40 m	
	vol. (L/ha)	Adaxial surface	Abaxial surface	Adaxial surface	Abaxial surface
airblast	1000	-	-	-	-
cannon	170	0.34	0.13	-	-
cannon+electrostatic	170	0.27	0.12	0.18	0.11

<u>Drone study</u>

This study took place nearly three months after the initial study that used the avocado volute and the strung and pergola canopies were at their most dense by this stage. The airblast treatment deposit levels were similar to the previous studies (Table 1 vs Table 4) in that there were no differences between adaxial and abaxial leaf surfaces, nor between deposits at medium height and teepee tops. All deposits were well below levels required to adequately protect foliage. WSPs generally confirmed this (Appendix 2c).

The higher volume multi-pass RMax treatment (180 L/ha) flying along the rows delivered higher deposits in the strung canopy than the airblast sprayer (P<0.001) and these were well distributed on both leaf surfaces at both teepee sampling heights (Table 4). WSPs did not reflect the high measured deposits on both sides of leaves in this case (Appendix 2c). The difference between the deposits seen on water sensitive papers and those measured on leaves reflects the rigid mounting of the papers, while leaves would have been free to move in the air downwash from the RMax rotor and so pick up a higher deposit than the papers displayed. The large droplets from the RMax air inclusion nozzles would almost certainly not have given such good coverage on abaxial leaf surfaces if the leaves had been unable to move in the spray plume. This is an illustration of how misleading spray coverage interpretations can be when relying on WSP alone!

The lower volume RMax spray (60 L/ha) flying across rows delivered very high deposits to both adaxial and abaxial leaf surfaces, approx. 3-4 times more than the application along rows (Table 4). Again, the WSP did not always reflect this but it must be considered that the volume applied to these papers was <10% of that delivered by the airblast sprayer, so coverage intensity on the WSP will naturally be lower.

Table 4: Mean deposits (μg/cm^2, normalised at 1 kg/ha) on upper & lower surfaces of leaves sampled from medium height (~3.6 m) and tops (~5 m) of teepee strings

Tmt	Spray vol. (L/ha)	Medium height		Teepee tops		**Whole leaf deposit**	
		Adaxial surface	Abaxial surface	Adaxial surface	Abaxial surface	**Med Ht**	**Teepee top**
airblast	1000	0.08 e	0.05 e	0.11 e	0.15 e	**0.13 C**	**0.26 C**
RMax[1]	180	2.79 cde	1.82 de	3.08 cde	1.55 de	**4.61 B**	**4.63 B**
RMax[1]	60	11.50 a	6.38 bc	8.78 ab	4.83 bcd	**17.88 A**	**13.61 A**

Means sharing common postscripts are not significantly different (LSD, P=0.05).
[1]Note that the RMax 180 L/ha treatment was applied flying along teepee/pergola rows (Fig. 8), while the 60 L/ha treatment was applied flying across these rows (Fig. 9).

The large differences in the spray deposit levels between the two different RMax spray application patterns require some explanation and can be largely attributed to the orientation of the strung canopy relative to the line of flight of the RMax. The single pass 60 L/ha treatment was made along the line of the strings towards the teepee and a much greater proportion of the applied spray volume was therefore likely to have deposited on the strung canopy. The amount of strung canopy in the total area traversed by the RMax in the other flying direction was significantly lower (at least 50%), so a greater proportion of the applied spray would have landed on the pergola canopy below in this case.

These results suggest that drone application may be a highly efficient method to deliver top-up sprays to teepees and may allow copper rates to be reduced accordingly. In addition, such low volume applications are likely to limit off-target spray drift. Flying across rows, rather than along them, may maximise spray delivery to and coverage of foliage.

General discussion

The air assistance profiles from the four different sprayers used in these tests were very different. The airblast sprayer delivered the most controlled and easily managed spray output profile. However, this failed to adequately treat any of the strung canopies tested because of the obstruction presented by the main pergola canopy. A typical axial fan airblast sprayer of the type used in these trials will output 40,000-60,000 cubic metres of air per hour. The addition of a volute to take all of the air output to one side of the sprayer will allow significantly more air (and spray droplets) to be directed with reasonable control above a pergola canopy. The gun nozzles on this type of sprayer will deliver a relatively coarse spray plume. The cannon sprayer in contrast, produced less than half of the air volume of that from the volute, but it delivered this in an initially very narrow band of higher speed air and made use of fine spray droplets. The net result of this difference was a less even spray delivery from the cannon across a significantly wider, but less controlled, band of canopy.

The air assistance delivered by the RMax came by way of rotor downwash and appears to have provided enough turbulence to move the canopy sufficiently to achieve better coverage on both leaf surfaces than was observed on the fixed target water sensitive paper lower surfaces. The downwash air volumes and profile from drones is a function of the mass of the drone (heavier = more air displacement required to keep it flying) and the nature of the propellers that keep it airborne. The RMax is a relatively large drone with a single main rotor. The downwash effect from smaller multi-rotor drones would be substantially different and their spray coverage performance cannot be predicted from the work with the RMax in this trial. Additionally, the cost of the RMax at this point in time is possibly prohibitive, along with the requirement for multiple operators. This limits its practicality for growers until advances in technology address this. Spray application by smaller multi-rotor drones warrants further investigation.

The spray deposit data in this report have all been normalised to reflect an equivalent chemical application rate of one kg per hectare regardless of application volume. It should be recognised that the spray application volumes from each of the three overhead spray delivery systems tested in these experiments are an estimate of the actual volumes that would have been applied to the sample areas. The volute and cannon sprayer delivered a single sided and variable application rate per hectare across the swath width. In the case of the RMax helicopter, variations in travel speed, flying height and swath overlap could have caused variations in the actual application rates. Because the cannon and RMax sprayers delivered the lowest spray volumes, a relatively small change in the actual volume applied would have the largest impact on the actual amount of chemical delivered. These potential variations are always going to be a feature of this type of spray delivery system and this needs to be factored into any recommendations for chemical application rates if this type of spraying of strung canopies is to become common practice in the industry.

We would recommend that application rates of Psa protectants to target strung canopies should be higher than those accepted for spraying the main pergola canopy. Exactly how much higher, and exactly when such sprays may be required, really needs to be determined by further tests that include measurement of Psa control efficacy.

CONCLUSIONS

Strung canopies that are sprayed from below using traditional airblast sprayers have shown significantly lower and more variable spray deposits than the lower pergola canopy at all of the growth stages tested. In all cases, the spray deposit levels seen on strung canopy leaves would be expected to be too low to provide reliable protection against Psa at normal (canopy) spray application rates. At this time, it is not possible to protect strung vines from Psa with traditional airblast spray applications delivered from beneath the main pergola canopy.

All three of the overhead spray delivery systems tested in these experiments could deliver higher deposits than a traditional airblast sprayer to the strung canopies. However, the practical use of spray volutes or cannons will be limited by the relatively narrow band of canopy that can be reliably treated using this type of technology and the high deposit variability inherent in attempting to spray across a wide swath.

The use of an aerial application system is an obvious option for treating the upper canopy and strung canopy foliage. However, because of drift concerns, traditional large helicopters are usually forced to apply very large spray droplets that compromise deposits. The use of small, unmanned, aerial application systems like the Yamaha RMax appear to hold great potential for effective, time- and cost-efficient, application of sprays to kiwifruit canopies from above. The ability to treat young, susceptible, extension growth tissue could be very useful to protect this part of the canopy without the risk of overdosing fruit.

Further research into unmanned aerial application systems is well worth considering, potentially in combination with electrostatic sprays. We believe that they will eventually have a useful place as a tool in spray application to kiwifruit strung canopies.

ACKNOWLEDGEMENTS

Thanks to Simon and Bob Cook, for the use of their orchard and sprayer. The volute was supplied by Ranfurly Orchard Services. The cannon sprayer was supplied by Sonic Contracting. The Yamaha RMax was supplied by Yamaha Motor NZ Ltd with assistance provided by Greg Quinn, Cameron Baker and Geoff Lamb. Technical assistance was provided by Kevin Steele, and Justin Nairn. Clinton Heard (Spray-Tec Consultants) assisted with the RMax calibration. Etec Crop Solutions and Grochem provided chemicals. Funding was provided by ZESPRI/KVH and the MPI Sustainable Farming Fund.

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APPENDIX 1
Sprayer setup and calibration notes for deposit studies

<u>Standard Airblast Sprayer –reference for traditional spray delivery from below the pergola canopy.</u>

Trailed twin nozzle ring Fantini with an 820 mm diameter front entry fan. Towed by a Trac Atom tractor. Applied at 1000 L/ha using a twin set of nozzle rings, 6.5 km/h to 5 m rows. Nozzling as described below.

TARGET APPLICATION VOLUME & SPEED		
Target Volume	**1000**	l/ha
	50.0	l/100m row
Target speed	**6.5**	km/hr
Row spacing	**5**	metres
Output required	**54.2**	**l/min total**
Note output below =	*54.2*	*l/min*
TracAtom front entry fan sprayer		
Double ring of nozzles used in upper strung canopy deposit test 9/2/16		
Nozzle pressure	**1590**	**kPa**
Gauge pressure		**kPa**

Description		Nozzle name	Predicted output	%	Cum%
Front ring top	**1**	ATR Red 80	2.39	8.8%	9%
	2	ATR Green 80	3.07	11.3%	20%
	3	ATR Black 60	3.46	12.8%	33%
	4	ATR Blue 60	4.24	15.7%	49%
	5	AD3-35	2.49	9.2%	58%
Back ring top	**1**	ATR Orange 80	1.73	6.4%	64%
	2	ATR Orange 80	1.73	6.4%	71%
	3	ATR Red 60	2.39	8.8%	79%
	4	ATR Green 60	3.07	11.3%	91%
	5	AD3-35	2.49	9.2%	100%
Output from one side (l/min)			**27.08**		
Total output (l/min)			**54.15**		

<u>Volute on a standard Airblast Sprayer – The volute was used to deliver spray to the upper and strung canopy from one side of the block to cover a ca. 15 m swath.</u>

Trailed twin nozzle ring Fantini with an 820 mm diameter front entry fan. Towed by a Trac Atom tractor fitted with a single side avocado volute with three Masotti gun nozzles located in the volute and operated in the jetting position. The delivery volume was 45 L/min at 3 km per hour to treat a swath of ca 15 m. The sprayer was run just along the outside row of the block to spray across ca. 15 m of row (three full rows). The nozzles were operated at ca. 2000 kPa and the resulting droplet size was possibly a little too large (higher pressures would have generated finer droplet sizes). The measured sprayer output was 45 L/min and the travel speed was 3.0 km/h (slow in order to give the spray time to be carried a reasonable distance across the top of the block canopy). Assuming that the effective sprayed swath was 15 m, the effective spray application volume in this treatment was 600 L/ha. Note that the distribution across the swath will not be perfectly even, so is likely to have varied from around 1000 L/ha close to the sprayer down to ca. 400 L/ha or less between 15-20 m from the sprayer.

TARGET APPLICATION VOLUME & SPEED		
Target Volume	600	l/ha
	90.0	l/100m row
Target speed	3	km/hr
Row spacing	15	metres
Output required	45.0	l/min total
Note output below =	*45.1*	*l/min*

TracAtom front rentry fan sprayer
Double ring of nozzles used in upper strung canopy deposit test 9/2/16

Nozzle pressure	2050	kPa
Gauge pressure		kPa

Description		Nozzle name	Predicted output	%	Cum%
Volute top	1	MSGun_3.5	17.63	39.1%	39%
	2	MSGun_3.0	15.36	34.0%	73%
	3	MSGun_2.5	12.12	26.9%	100%
	4	Off	0.00	0.0%	100%
	5	Off	0.00	0.0%	100%
Back ring top	1	Off	0.00	0.0%	100%
	2	Off	0.00	0.0%	100%
	3	Off	0.00	0.0%	100%
	4	Off	0.00	0.0%	100%
	5	Off	0.00	0.0%	100%
		Output from one side (l/min)	**45.11**		
		Total output (l/min)	**45.11**		

Cannon sprayer

The cannon nozzle outputs and expected application volumes assuming a 15 m effective sprayed swath at a travel speed of 2.3 km/h should have delivered ca. 170 L/ha. In practice the speed control on a ute mounted sprayer is not precise and travel speed varied during application by ca. 0.2 km/h or approximately plus or minus 10%. The fine droplets produced by the nozzles in this sprayer are ideal for achieving excellent potential spray coverage at low application volumes. However, they are easily carried relatively long distances on even a light breeze and some spray droplets were seen to carry >100 m downwind across the block. As with the volute application there will have been an application volume gradient across the sprayed swath. As the spray plume from the cannon was narrower initially than that from the volute is was expected that the peak deposition and potential coverage will have occurred further out from the cannon than with the volute. Visually peak plume deposition appeared to occur at ca. 10 m out from the sprayer and would have declined rapidly beyond there.

TARGET APPLICATION VOLUME & SPEED		
Target Volume	170	l/ha
	25.5	l/100m row
Target speed	2.3	km/hr
Row spacing	15	metres
Output required	9.8	l/min total
Note output below =	*9.8*	*l/min*

Truck mounted cannon sprayer

Nozzle pressure	2040	kPa
Gauge pressure		kPa

Description		Nozzle name	Predicted output	%	Cum%
Cannon	1	ATR Orange 80	1.96	20.0%	20%
	2	ATR Orange 80	1.96	20.0%	40%
	3	ATR Orange 80	1.96	20.0%	60%
	4	ATR Orange 80	1.96	20.0%	80%
	5	ATR Orange 80	1.96	20.0%	100%
Output from one side (l/min)			9.79		
Total output (l/min)			9.79		

Drone sprayer

Based on the nominal swath width, nozzle output rate and travel speeds measured for this sprayer it should in theory have delivered a spray application volume of ca. 75 L/ha from a single spray pass to the kiwifruit canopy. Based on timed observations of the sprayer working to treat strung canopy areas, it was estimated that the single swath pass at 90 degrees to the row orientation will have delivered ca. 60 L/ha. However, it is important to recognise the difficulty of accurately defining the applied volume in this type of test and the actual application rate could have been higher than that estimated.

The multiple pass run along the row orientation featured significant swath overlap on each pass. Because of uncertainty as to the exact swath overlap and travel speeds across the multiple runs, it was even more difficult to accurately estimate the actual spray volume delivered to the treatment area in this test. The nominal application rate estimated was 180 L/ha.

TARGET APPLICATION VOLUME & SPEED

Target Volume	**75**	l/ha
	2.6	l/100m row
Target speed	**5**	km/hr
Row spacing	**3.5**	metres
Output required	**2.2**	**l/min total**
Note output below =	*2.2*	*l/min*

Yamaha Rmax helicopter drone sprayer

Nozzle pressure	**250**	**kPa**
Gauge pressure		**kPa**

Description		Nozzle name	Predicted output	%	Cum%
Rmax boom	1	Red 04	1.08	50.0%	50%
	2	Red 04	1.08	50.0%	100%
	Total output (l/min)		**2.16**		

RMax literature links:
http://www.cdpr.ca.gov/docs/license/apcac/minutes/2016/yamaha_helicopter_review.pdf
http://rmax.yamaha-motor.com.au/sites/rmax/files/pdf/RMAX_Brochure.pdf

2x Yamaho SR5 flat fan AI nozzles

APPENDIX 2a: WSPs for Volute study, 09/02/16

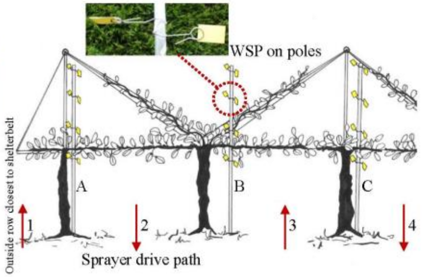
SFF_targeting spray at Gold3 strung canopies using water sensitive papers

Location: Huse Lane, Rangiuru
Simon Cook

Date: 9th Feb 2016

Sprayer: Fantini Eco 2000 sprayer, front entry fan with twin nozzle rings.

Wind speed (m/s): 0.1 m/s (max)
Temperature: 21.8 °C



Nozzles: Albuz ATR hollow cone nozzles. Twin rings operating.

Fan speed:

Nozzle pressure: 1590 kpa

Water rate (L/ha): 1000 L/ha

Travel speed (km/h): 6.5 km/hr

5m row spacing

Airblast sprayer: Water + 40 ml/100 L Du-Wett

Water sensitive papers were folded in half and held in place with a clip on a pole at set intervals. WSPs were positioned horizontally & vertically & parallel to the drive path of the sprayer.

POLE A

Horizontal papers at the *high tepee* — Upper, Lower

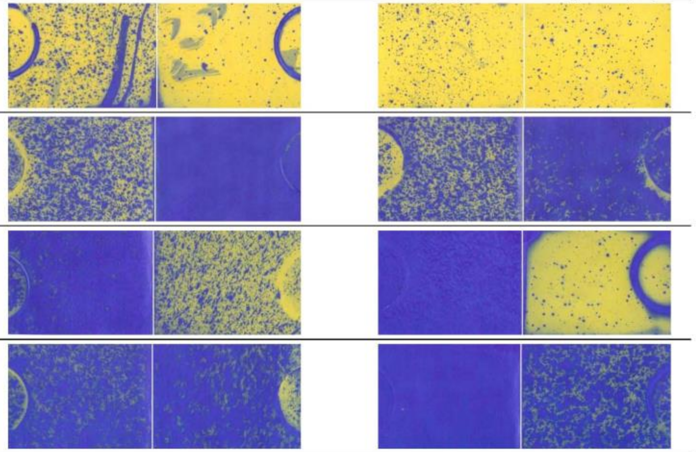
Vertical papers at the *high tepee* — To sprayer, Away from sprayer

5m from ground

3.6m from ground

2.2m from ground

1.8m from ground



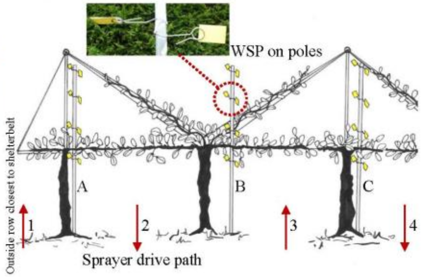
SFF_targeting spray at Gold3 strung canopies using water sensitive papers

Location: Huse Lane, Rangiuru
Simon Cook

Date: 9th Feb 2016

Sprayer: Fantini Eco 2000 sprayer, front entry fan with twin nozzle rings.

Wind speed (m/s): 0.1 m/s (max)
Temperature: 21.8 °C



Nozzles: Albuz ATR hollow cone nozzles. Twin rings operating.

Fan speed:

Nozzle pressure: 1590 kpa

Water rate (L/ha): 1000 L/ha

Travel speed (km/h): 6.5 km/hr

5m row spacing

Airblast sprayer: Water + 40 ml/100 L Du-Wett

Water sensitive papers were folded in half and held in place with a clip on a pole at set intervals. WSPs were positioned horizontally & vertically & parallel to the drive path of the sprayer.

POLE B

Horizontal papers at the *low tepee* — Upper, Lower

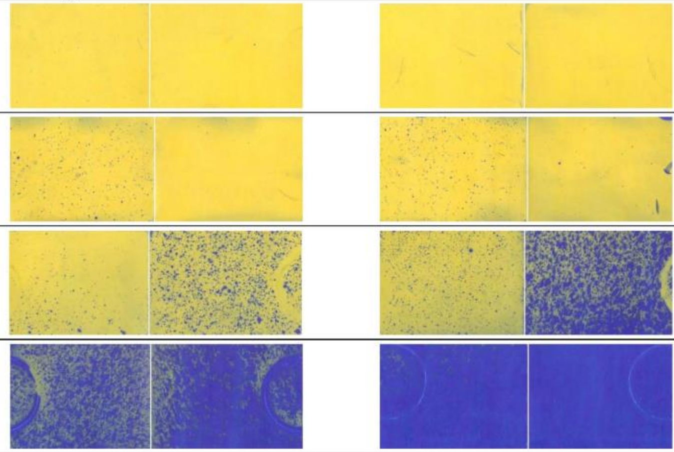
Vertical papers at the *low tepee*

5m from ground

3.6m from ground

2.2m from ground

1.8m from ground



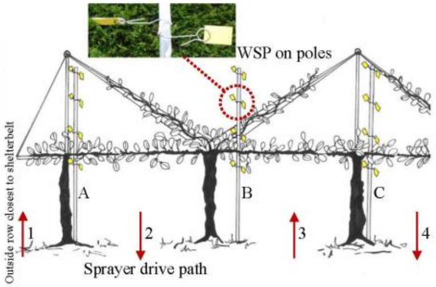
SFF_targeting spray at Gold3 strung canopies using water sensitive papers

Location: Huse Lane, Rangiuru
Simon Cook

Date: 9th Feb 2016

Sprayer: Fantini Eco 2000 sprayer, front entry fan with twin nozzle rings.

Wind speed (m/s): 0.1 m/s (max)
Temperature: 21.8 °C



Nozzles: Albuz ATR hollow cone nozzles. Twin rings operating.

Fan speed:

Nozzle pressure: 1590 kpa

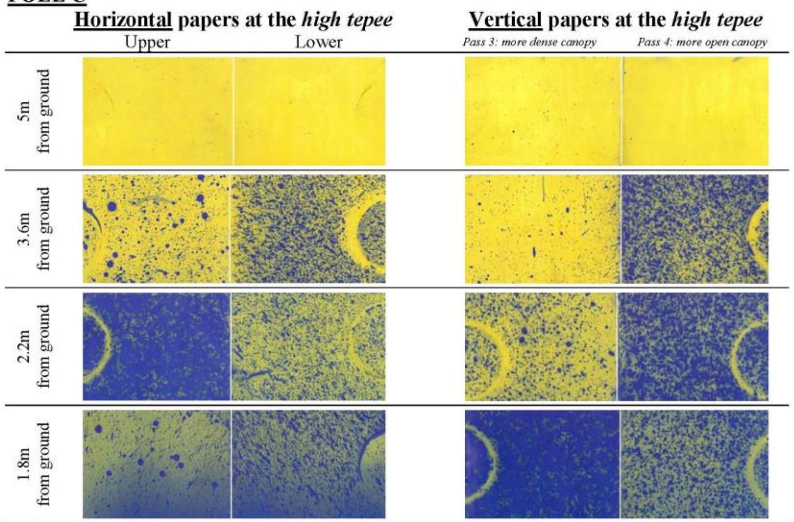
Water rate (L/ha): 1000 L/ha

Travel speed (km/h): 6.5 km/hr

Airblast sprayer: Water + 40 ml/100 L Du-Wett

Water sensitive papers were folded in half and held in place with a clip on a pole at set intervals. WSPs were positioned horizontally & vertically & parallel to the drive path of the sprayer.

POLE C



Any large droplets on the paper are from rain drops

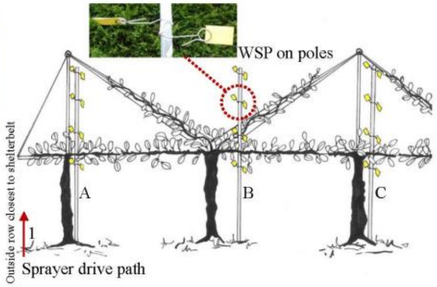
SFF_targeting spray at Gold3 strung canopies using water sensitive papers

Location: Huse Lane, Rangiuru
Simon Cook

Date: 9th Feb 2016

Sprayer: Fantini Eco 2000 sprayer, front entry fan with twin nozzle rings & volute setup.

Wind speed (m/s): 0.27 m/s (max) 0 m/s (min)
Temperature: 23 °C



Nozzles: Single sided volute fitted with 3x Masotti gun nozzles in the jetting position. No other nozzles were used.

Fan speed:

Nozzle pressure: 2700 kpa

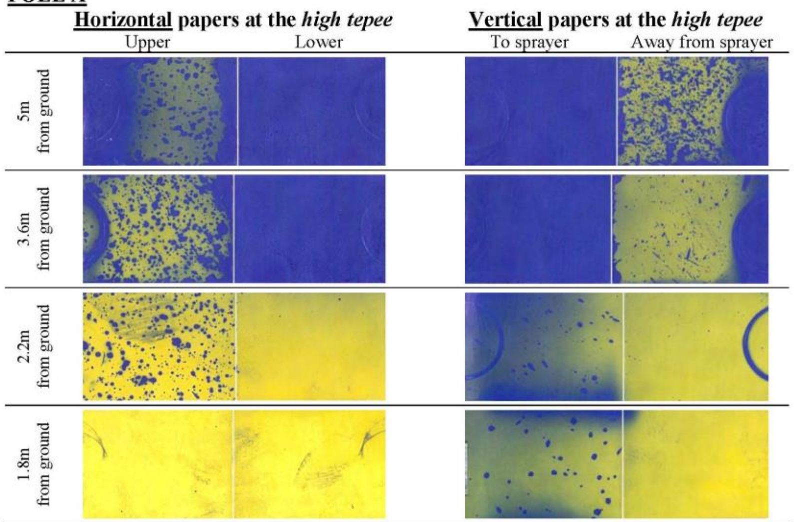
Water rate (L/ha): 600 L/ha

Travel speed (km/h): 6.5 km/hr

Airblast sprayer with volute setup:
Water + 40 ml/100 L Du-Wett

Water sensitive papers were folded in half and held in place with a clip on a pole at set intervals. WSPs were positioned horizontally & vertically & parallel to the drive path of the sprayer.

POLE A



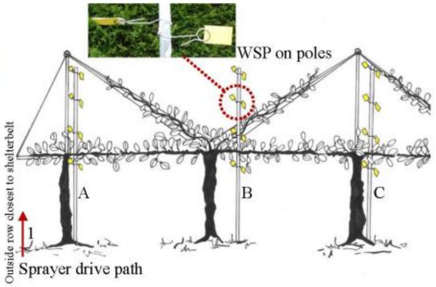
SFF_targeting spray at Gold3 strung canopies using water sensitive papers

Location: Huse Lane, Rangiuru
Simon Cook

Date: 9th Feb 2016

Sprayer: Fantini Eco 2000 sprayer, front entry fan with twin nozzle rings & volute setup.

Wind speed (m/s): 0.27 m/s (max) 0 m/s (min)
Temperature: 23 °C



Nozzles: Single sided volute fitted with 3x Masotti gun nozzles in the jetting position. No other nozzles were used.

Fan speed:

Nozzle pressure: 2700 kpa

Water rate (L/ha): 600 L/ha

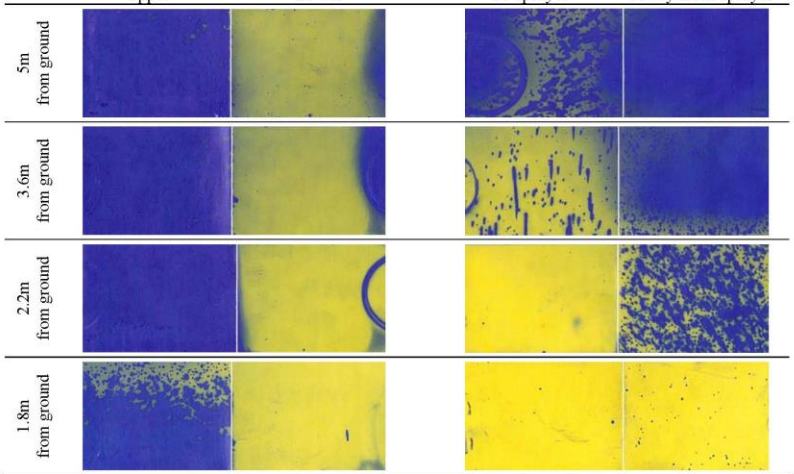
Travel speed (km/h): 6.5 km/hr

Water sensitive papers were folded in half and held in place with a clip on a pole at set intervals. WSPs were positioned horizontally & vertically & parallel to the drive path of the sprayer.

Airblast sprayer with volute setup:
Water + 40 ml/100 L Du-Wett

POLE B

Horizontal papers at the *low tepee* — Upper, Lower
Vertical papers at the *low tepee* — To sprayer, Away from sprayer



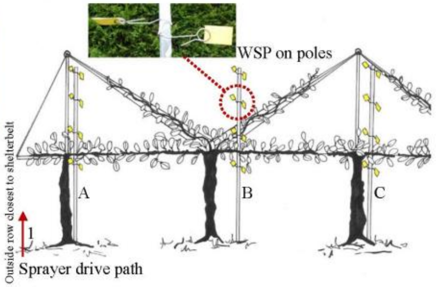
SFF_targeting spray at Gold3 strung canopies using water sensitive papers

Location: Huse Lane, Rangiuru
Simon Cook

Date: 9th Feb 2016

Sprayer: Fantini Eco 2000 sprayer, front entry fan with twin nozzle rings & volute setup.

Wind speed (m/s): 0.27 m/s (max) 0 m/s (min)
Temperature: 23 °C



Nozzles: Single sided volute fitted with 3x Masotti gun nozzles in the jetting position. No other nozzles were used.

Fan speed:

Nozzle pressure: 2700 kpa

Water rate (L/ha): 600 L/ha

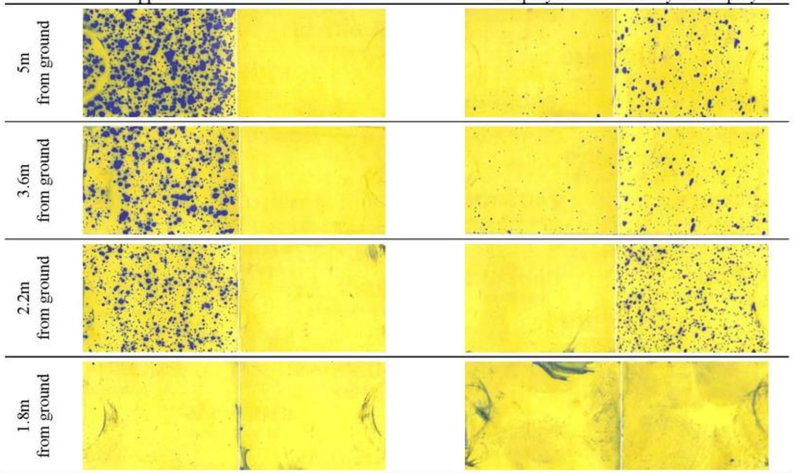
Travel speed (km/h): 6.5 km/hr

Water sensitive papers were folded in half and held in place with a clip on a pole at set intervals. WSPs were positioned horizontally & vertically & parallel to the drive path of the sprayer.

Airblast sprayer with volute setup:
Water + 40 ml/100 L Du-Wett

POLE C

Horizontal papers at the *high tepee* — Upper, Lower
Vertical papers at the *high tepee* — To sprayer, Away from sprayer



APPENDIX 2b: WSPs for Cannon study, 06/04/16

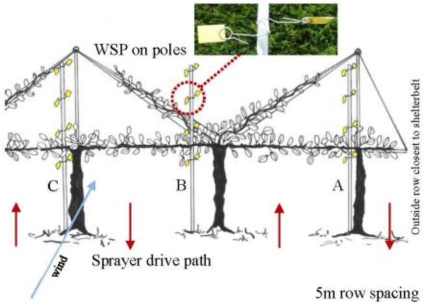
SFF_targeting spray at Gold3 strung canopies using water sensitive papers

Location: Huse Lane, Rangiuru
Simon Cook

Date: 6th April 2016

Sprayer: Atom 2000 Modena with twin nozzle rings.

Wind speed (m/s): < 0.5 m/s (average)
Temperature: 23.7 °C



Nozzles: Albuz ATR hollow cone nozzles.
Twin rings operating.

Fan speed:

Pressure:

Water rate (L/ha): 1000 L/ha

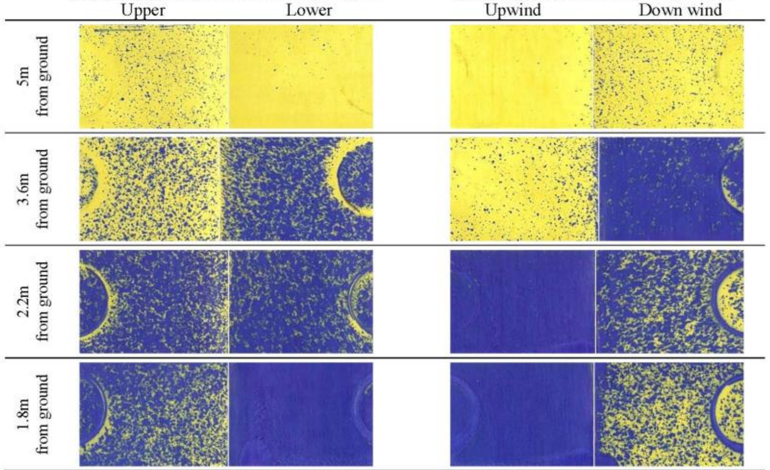
Travel speed (km/h): 6.5 km/hr

Airblast sprayer: Water + 40 ml/100 L Du-Wett

Water sensitive papers were folded in half and held in place with a clip on a pole at set intervals. WSPs were positioned horizontally & vertically & parallel to the drive path of the sprayer.

POLE A

Horizontal papers at the *high tepee* — Upper, Lower
Vertical papers at the *high tepee* — Upwind, Down wind



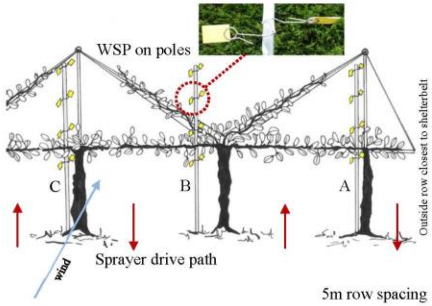
SFF_targeting spray at Gold3 strung canopies using water sensitive papers

Location: Huse Lane, Rangiuru
Simon Cook

Date: 6th April 2016

Sprayer: Atom 2000 Modena with twin nozzle rings.

Wind speed (m/s): < 0.5 m/s (average)
Temperature: 23.7 °C



Nozzles: Albuz ATR hollow cone nozzles.
Twin rings operating.

Fan speed:

Pressure:

Water rate (L/ha): 1000 L/ha

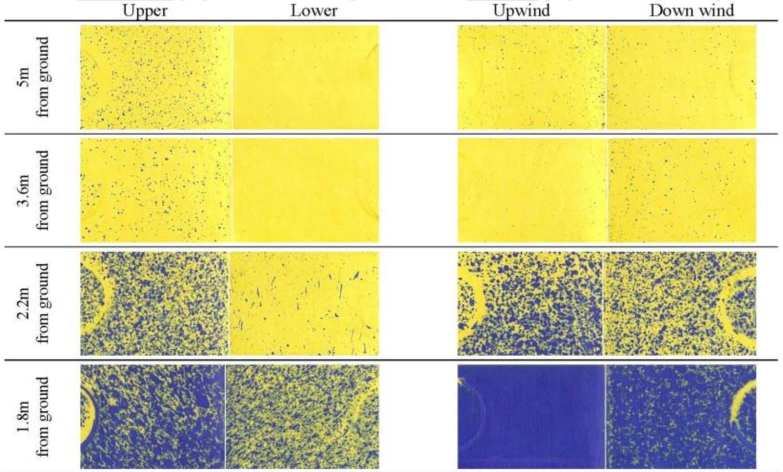
Travel speed (km/h): 6.5 km/hr

Airblast sprayer: Water + 40 ml/100 L Du-Wett

Water sensitive papers were folded in half and held in place with a clip on a pole at set intervals. WSPs were positioned horizontally & vertically & parallel to the drive path of the sprayer.

POLE B

Horizontal papers at the *low tepee* — Upper, Lower
Vertical papers at the *low tepee* — Upwind, Down wind



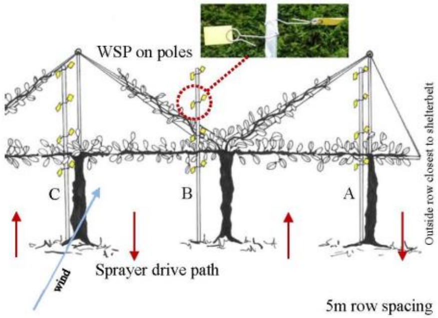
SFF_targeting spray at Gold3 strung canopies using water sensitive papers

Location: Huse Lane, Rangiuru
Simon Cook

Date: 6th April 2016

Sprayer: Atom 2000 Modena with twin nozzle rings.

Wind speed (m/s): < 0.5 m/s (average)
Temperature: 23.7 °C



Nozzles: Albuz ATR hollow cone nozzles. Twin rings operating.

Fan speed:

Pressure:

Water rate (L/ha): 1000 L/ha

Travel speed (km/h): 6.5 km/hr

Airblast sprayer: Water + 40 ml/100 L Du-Wett

Water sensitive papers were folded in half and held in place with a clip on a pole at set intervals. WSPs were positioned horizontally & vertically & parallel to the drive path of the sprayer.

POLE C

Horizontal papers at the ***high tepee*** — Upper, Lower

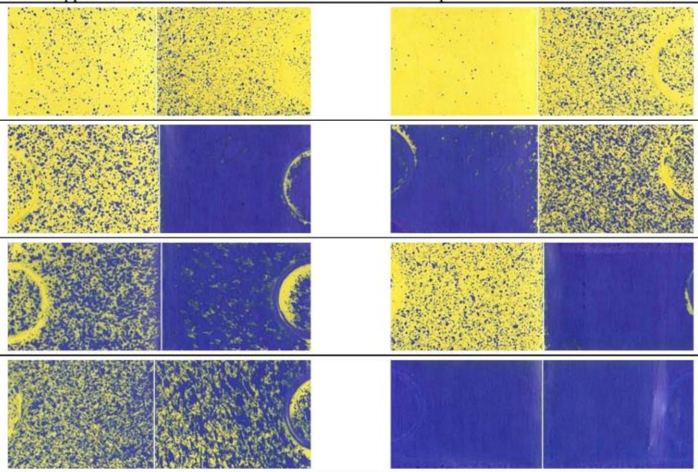
Vertical papers at the ***high tepee*** — Upwind, Down wind

5m from ground

3.6m from ground

2.2m from ground

1.8m from ground



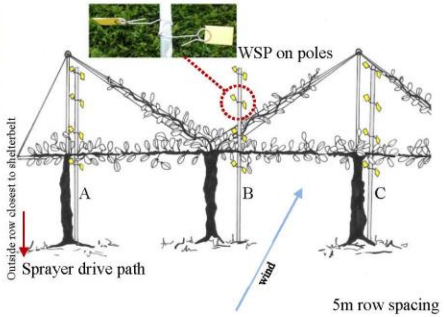
SFF_targeting spray at Gold3 strung canopies using water sensitive papers

Location: Huse Lane, Rangiuru
Simon Cook

Date: 6th April 2016

Sprayer: Sonic canon
.

Wind speed (m/s): < 1 m/s (average)
Temperature: 24.1 °C



Nozzles: 5x Albuz ATR hollow cone nozzles

Fan speed:

Pressure: 2000 kpa

Water rate (L/ha): ~ 170 L/ha

Travel speed (km/h): 2.3 km/hr average

Sonic canon: Water + 40 ml/100 L Du-Wett

Water sensitive papers were folded in half and held in place with a clip on a pole at set intervals. WSPs were positioned horizontally & vertically & parallel to the drive path of the sprayer.

POLE A

Horizontal papers at the ***high tepee*** — Upper, Lower

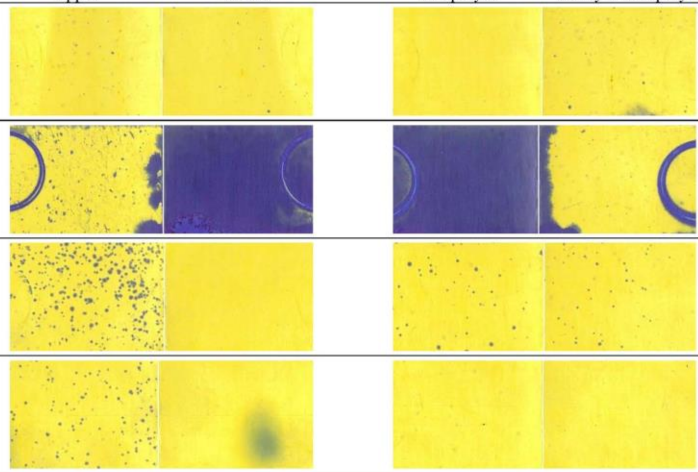
Vertical papers at the ***high tepee*** — To sprayer, Away from sprayer

5m from ground

3.6m from ground

2.2m from ground

1.8m from ground



SFF_targeting spray at Gold3 strung canopies using water sensitive papers

Location: Huse Lane, Rangiuru
Simon Cook

Sprayer: Sonic canon
.

Date: 6th April 2016

Wind speed (m/s): < 1 m/s (average)
Temperature: 24.1 °C

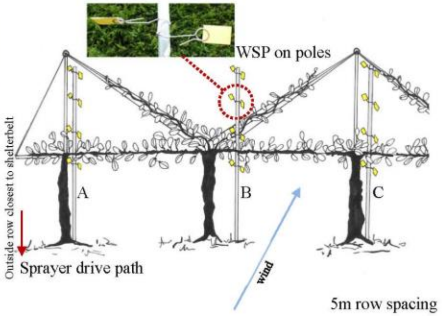
Nozzles: 5x Albuz ATR hollow cone nozzles

Fan speed:

Pressure: 2000 kpa

Water rate (L/ha): ~ 170 L/ha

Travel speed (km/h): 2.3 km/hr average

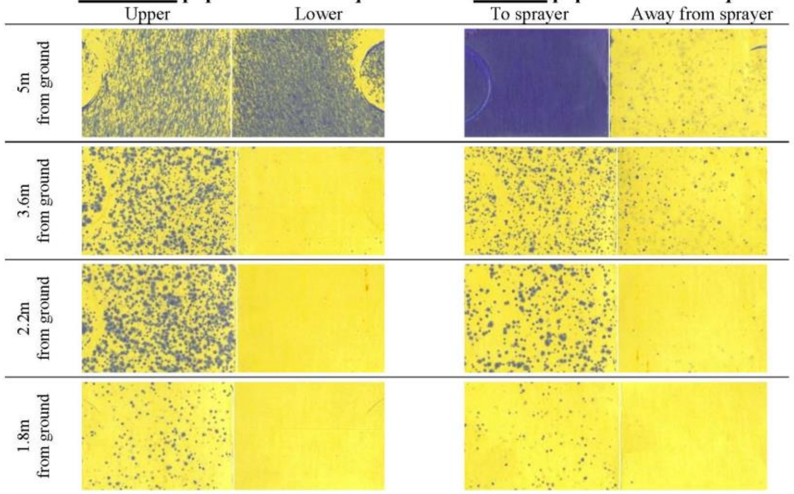


Water sensitive papers were folded in half and held in place with a clip on a pole at set intervals. WSPs were positioned horizontally & vertically & parallel to the drive path of the sprayer.

Sonic canon: Water + 40 ml/100 L Du-Wett

POLE B

Horizontal papers at the *low tepee* | **Vertical papers at the *low tepee***



SFF_targeting spray at Gold3 strung canopies using water sensitive papers

Location: Huse Lane, Rangiuru
Simon Cook

Sprayer: Sonic canon
.

Date: 6th April 2016

Wind speed (m/s): < 1 m/s (average)
Temperature: 24.1 °C

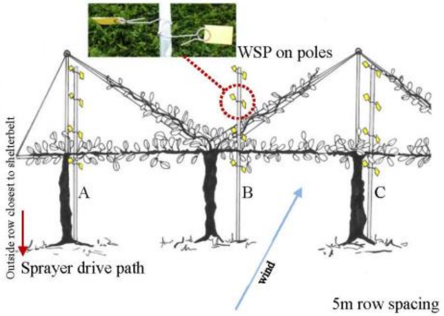
Nozzles: 5x Albuz ATR hollow cone nozzles

Fan speed:

Pressure: 2000 kpa

Water rate (L/ha): ~ 170 L/ha

Travel speed (km/h): 2.3 km/hr average

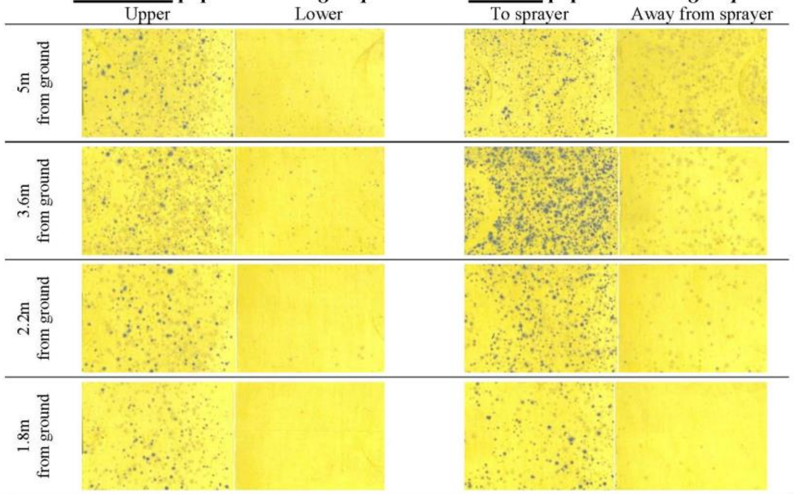


Water sensitive papers were folded in half and held in place with a clip on a pole at set intervals. WSPs were positioned horizontally & vertically & parallel to the drive path of the sprayer.

Sonic canon: Water + 40 ml/100 L Du-Wett

POLE C

Horizontal papers at the *high tepee* | **Vertical papers at the *high tepee***



SFF_targeting spray at Gold3 strung canopies using water sensitive papers

Location: Huse Lane, Rangiuru
Simon Cook

Sprayer: Sonic canon + electro static

.

Date: 6th April 2016

Wind speed (m/s): < 0.5 m/s (average)
Temperature: 25.2 °C

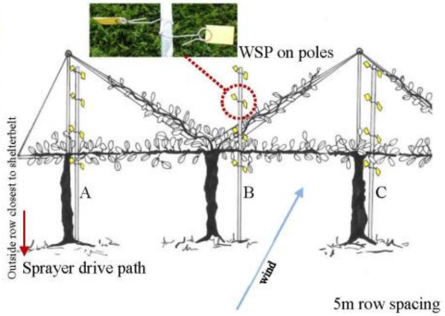
Nozzles: 5x Albuz ATR hollow cone nozzles

Fan speed:

Pressure: 2000 kpa

Water rate (L/ha): ~ 170 L/ha

Travel speed (km/h): 2.3 km/hr average

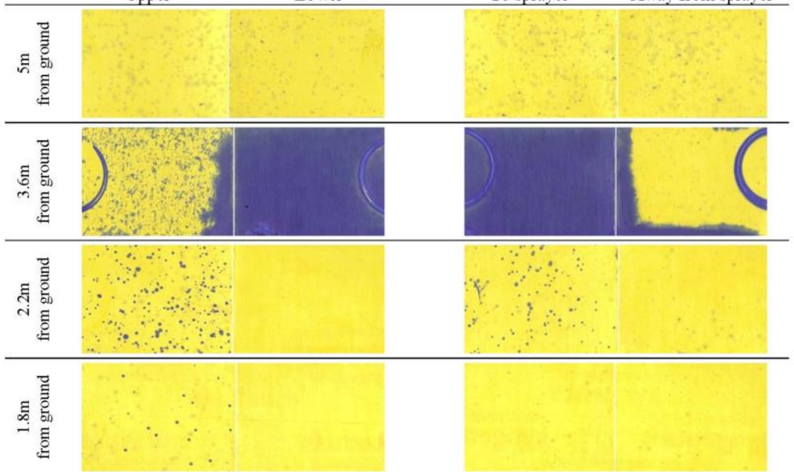


Water sensitive papers were folded in half and held in place with a clip on a pole at set intervals. WSPs were positioned horizontally & vertically & parallel to the drive path of the sprayer.

Sonic canon + electro static:
Water + 40 ml/100 L Du-Wett

POLE A

Horizontal papers at the *high tepee* — Upper, Lower
Vertical papers at the *high tepee* — To sprayer, Away from sprayer



SFF_targeting spray at Gold3 strung canopies using water sensitive papers

Location: Huse Lane, Rangiuru
Simon Cook

Sprayer: Sonic canon + electro static

.

Date: 6th April 2016

Wind speed (m/s): < 0.5 m/s (average)
Temperature: 25.2 °C

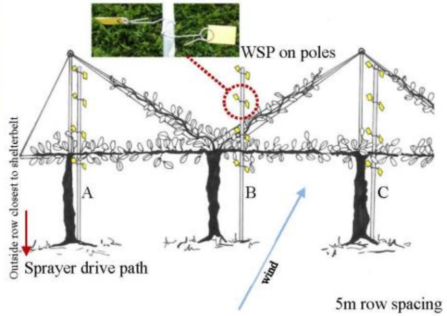
Nozzles: 5x Albuz ATR hollow cone nozzles

Fan speed:

Pressure: 2000 kpa

Water rate (L/ha): ~ 170 L/ha

Travel speed (km/h): 2.3 km/hr average

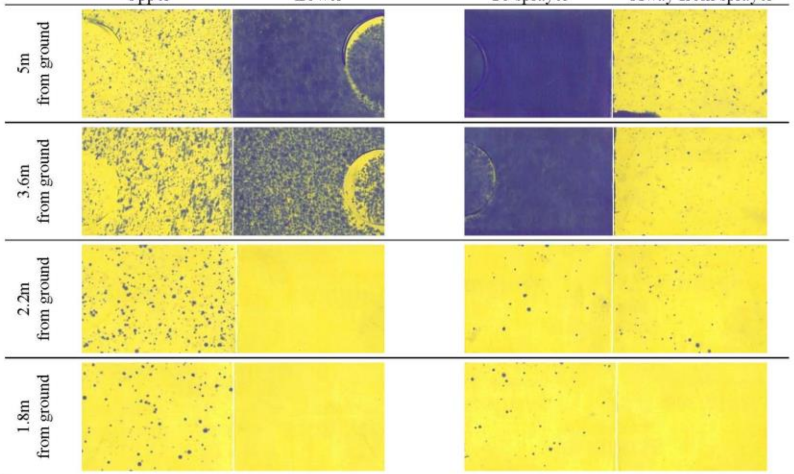


Water sensitive papers were folded in half and held in place with a clip on a pole at set intervals. WSPs were positioned horizontally & vertically & parallel to the drive path of the sprayer.

Sonic canon + electro static:
Water + 40 ml/100 L Du-Wett

POLE B

Horizontal papers at the *low tepee* — Upper, Lower
Vertical papers at the *low tepee* — To sprayer, Away from sprayer



SFF_targeting spray at Gold3 strung canopies using water sensitive papers

Location: Huse Lane, Rangiuru
Simon Cook

Date: 6th April 2016

Sprayer: Sonic canon + electro static
.

Wind speed (m/s): < 0.5 m/s (average)
Temperature: 25.2 °C

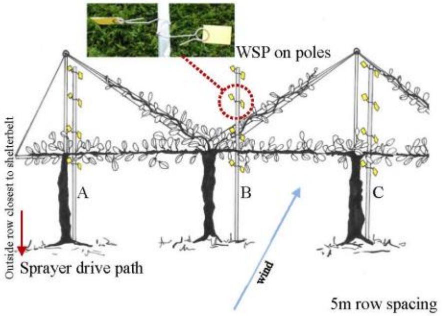
Nozzles: 5x Albuz ATR hollow cone nozzles

Fan speed:

Pressure: 2000 kpa

Water rate (L/ha): ~ 170 L/ha

Travel speed (km/h): 2.3 km/hr average



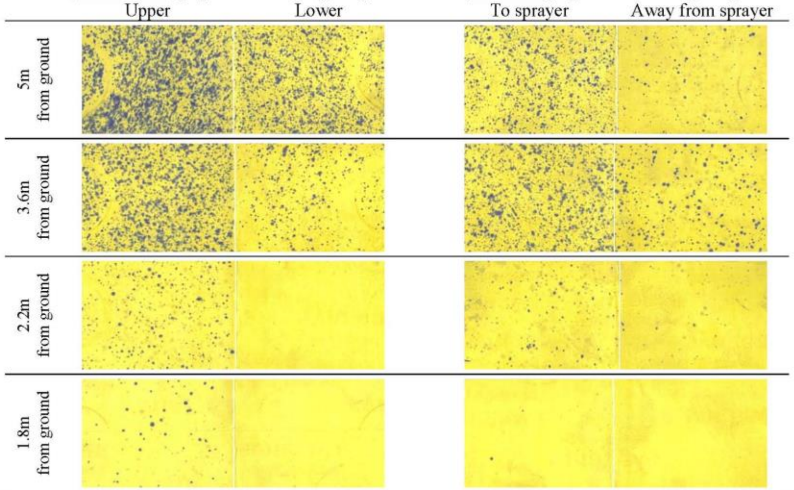
Water sensitive papers were folded in half and held in place with a clip on a pole at set intervals. WSPs were positioned horizontally & vertically & parallel to the drive path of the sprayer.

Sonic canon + Electro Static:
Water + 40 ml/100 L Du-Wett

<u>POLE C</u>

<u>Horizontal</u> papers at the *high tepee* — Upper, Lower

<u>Vertical</u> papers at the *high tepee* — To sprayer, Away from sprayer



APPENDIX 2c: WSPs for Drone study, 27/04/16

SFF_targeting spray at Gold3 strung canopies using water sensitive papers

Location: Huse Lane, Rangiuru
Simon Cook

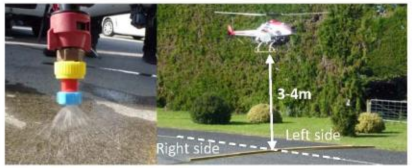
Date: 27th April 2016

Sprayer: Yamaha RMAX 0118 remote controlled helicopter

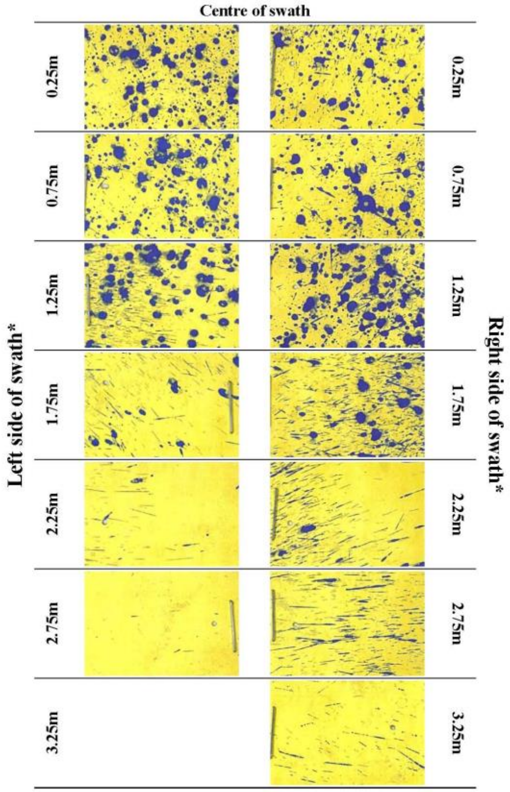
Nozzles: 2x Yamaha red flat fan AI nozzles

Travel speed (km/hr): ~5 km/hr

*From operator (tail end) perspective



Run 1



SFF_targeting spray at Gold3 strung canopies using water sensitive papers

Location: Huse Lane, Rangiuru
Simon Cook

Date: 27th April 2016

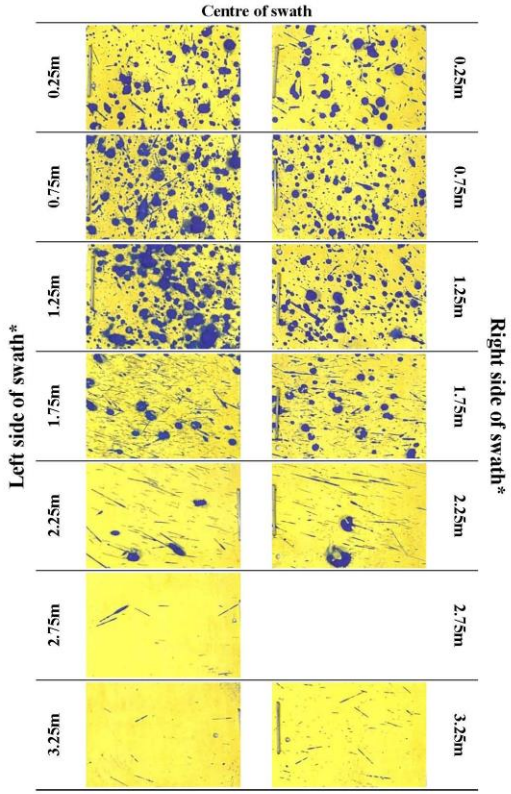
Sprayer: Yamaha RMAX 0118 remote controlled helicopter

Nozzles: 2x Yamaha red flat fan AI nozzles

Travel speed (km/hr): ~5 km/hr

*From operator (tail end) perspective

Run 2



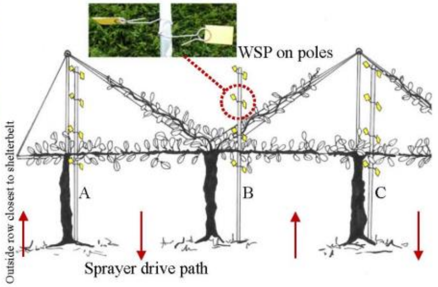
SFF_targeting spray at Gold3 strung canopies using water sensitive papers

Location: Huse Lane, Rangiuru
Simon Cook

Date: 27th April 2016

Sprayer: Atom 2000 Modena, with twin nozzle rings.

Wind speed (m/s): 0 m/s
Temperature: 21 °C



5m row spacing

Nozzles: Albuz ATR hollow cone nozzles.
Twin rings operating.

Fan speed:

Pressure:

Water rate (L/ha): 1000 L/ha

Travel speed (km/h): 6.5 km/hr

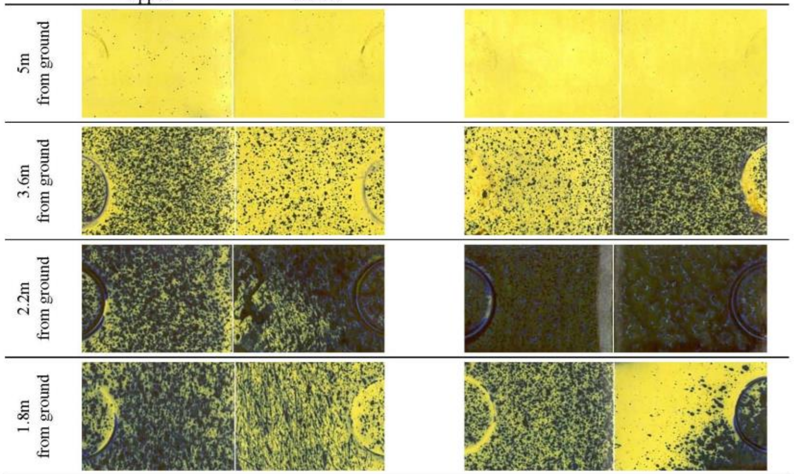
Airblast sprayer: Water + 40 ml/100 L Du-Wett

Water sensitive papers were folded in half and held in place with a clip on a pole at set intervals. WSPs were positioned horizontally & vertically & parallel to the drive path of the sprayer.

POLE A

Horizontal papers at the *high tepee* — Upper, Lower

Vertical papers at the *high tepee*



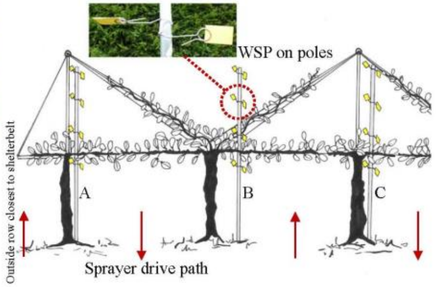
SFF_targeting spray at Gold3 strung canopies using water sensitive papers

Location: Huse Lane, Rangiuru
Simon Cook

Date: 27th April 2016

Sprayer: Atom 2000 Modena, with twin nozzle rings.

Wind speed (m/s): 0 m/s
Temperature: 21 °C



5m row spacing

Nozzles: Albuz ATR hollow cone nozzles.
Twin rings operating.

Fan speed:

Pressure:

Water rate (L/ha): 1000 L/ha

Travel speed (km/h): 6.5 km/hr

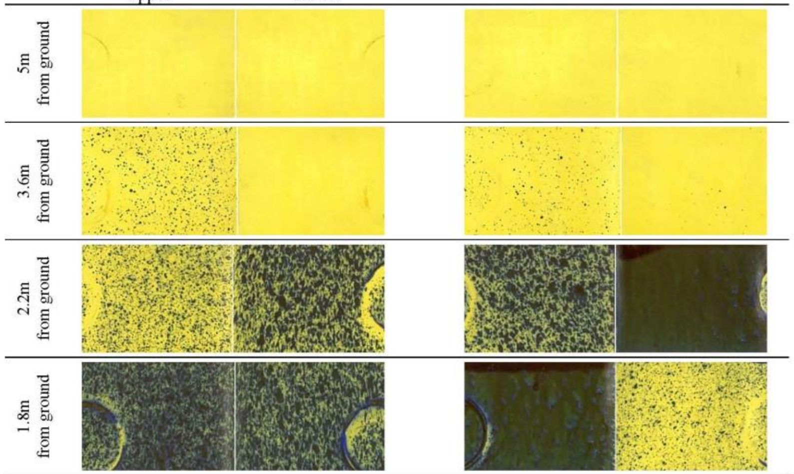
Airblast sprayer: Water + 40 ml/100 L Du-Wett

Water sensitive papers were folded in half and held in place with a clip on a pole at set intervals. WSPs were positioned horizontally & vertically & parallel to the drive path of the sprayer.

POLE B

Horizontal papers at the *low tepee* — Upper, Lower

Vertical papers at the *low tepee*



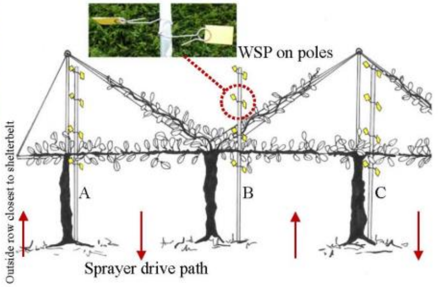
SFF_targeting spray at Gold3 strung canopies using water sensitive papers

Location: Huse Lane, Rangiuru
Simon Cook

Date: 27th April 2016

Sprayer: Atom 2000 Modena, with twin nozzle rings.

Wind speed (m/s): 0 m/s
Temperature: 21 °C



5m row spacing

Nozzles: Albuz ATR hollow cone nozzles. Twin rings operating.

Fan speed:

Pressure:

Water rate (L/ha): 1000 L/ha

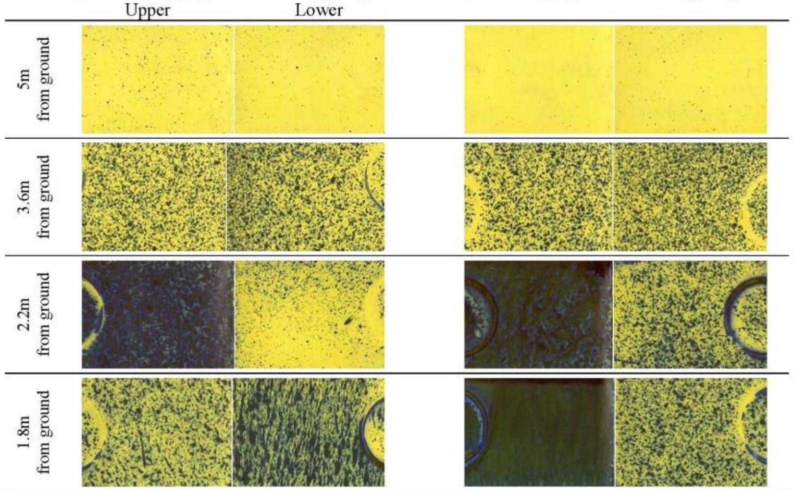
Travel speed (km/h): 6.5 km/hr

Airblast sprayer: Water + 40 ml/100 L Du-Wett

Water sensitive papers were folded in half and held in place with a clip on a pole at set intervals. WSPs were positioned horizontally & vertically & parallel to the drive path of the sprayer.

POLE C

Horizontal papers at the *high tepee* (Upper, Lower) — **Vertical papers at the *high tepee***



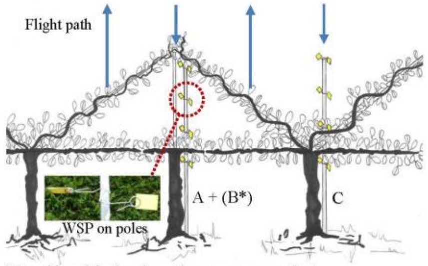
SFF_targeting spray at Gold3 strung canopies using water sensitive papers

Location: Huse Lane, Rangiuru
Simon Cook

Date: 27th April 2016

Sprayer: Yamaha RMAX 0118 remote controlled helicopter.

Wind speed (m/s): 0.6 m/s (average)
Temperature: 25 °C



*B positioned further down the same row as pole A

5m row spacing

Nozzles: 2x Yamaho SR5 flat fan AI nozzles.

Fan speed: n/a

Pressure: n/a

Water rate (L/ha): 180 L/ha

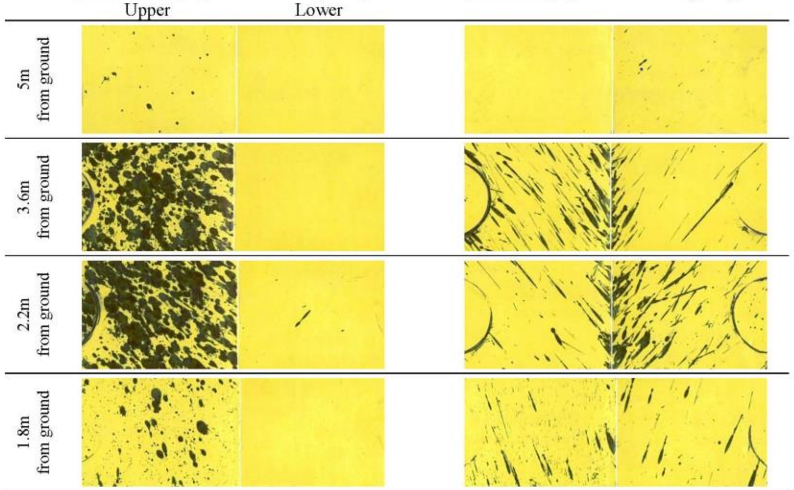
Travel speed (km/h): ~ 4 km/hr

Yamaha RMAX 0118 helicopter:
Water + 250 ml/100 L Du-Wett

Water sensitive papers were folded in half and held in place with a clip on a pole at set intervals. WSPs were positioned horizontally & vertically & parallel to the fly path of the sprayer.

POLE A

Horizontal papers at the *high tepee* (Upper, Lower) — **Vertical papers at the *high tepee***



SFF_targeting spray at Gold3 strung canopies using water sensitive papers

Location: Huse Lane, Rangiuru
Simon Cook

Sprayer: Yamaha RMAX 0118 remote controlled helicopter.

Nozzles: 2x Yamaho SR5 flat fan AI nozzles.

Fan speed: n/a

Pressure: n/a

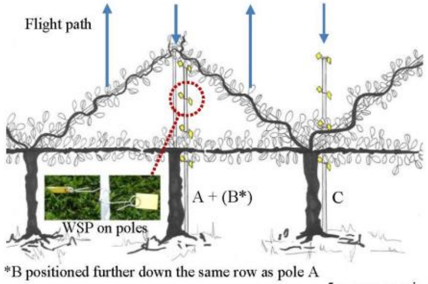
Water rate (L/ha): 180 L/ha

Travel speed (km/h): ~ 4 km/hr

Yamaha RMAX 0118 helicopter:
Water + 250 ml/100 L Du-Wett

Date: 27th April 2016

Wind speed (m/s): 0.6 m/s (average)
Temperature: 25 °C



*B positioned further down the same row as pole A

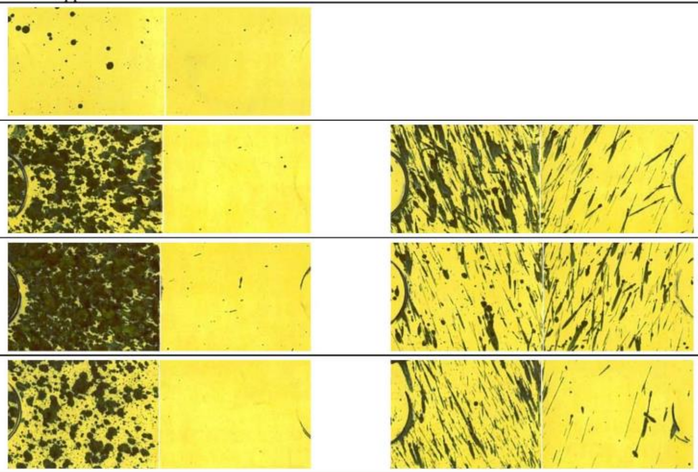
5m row spacing

Water sensitive papers were folded in half and held in place with a clip on a pole at set intervals. WSPs were positioned horizontally & vertically & parallel to the fly path of the sprayer.

POLE B

Horizontal papers at the *high tepee* (Upper, Lower) — **Vertical papers at the *high tepee***

5m from ground; 3.6m from ground; 2.2m from ground; 1.8m from ground



SFF_targeting spray at Gold3 strung canopies using water sensitive papers

Location: Huse Lane, Rangiuru
Simon Cook

Sprayer: Yamaha RMAX 0118 remote controlled helicopter.

Nozzles: 2x Yamaho SR5 flat fan AI nozzles.

Fan speed: n/a

Pressure: n/a

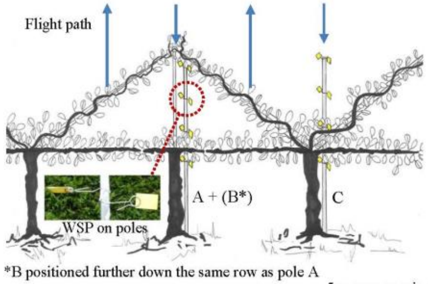
Water rate (L/ha): 180 L/ha

Travel speed (km/h): ~ 4 km/hr

Yamaha RMAX 0118 helicopter:
Water + 250 ml/100 L Du-Wett

Date: 27th April 2016

Wind speed (m/s): 0.6 m/s (average)
Temperature: 25 °C



*B positioned further down the same row as pole A

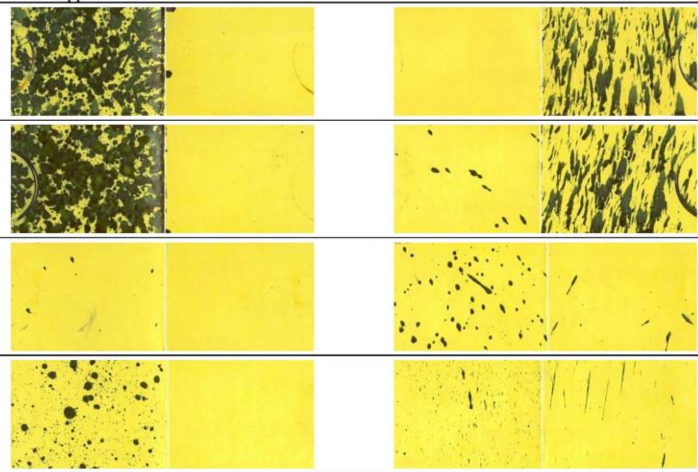
5m row spacing

Water sensitive papers were folded in half and held in place with a clip on a pole at set intervals. WSPs were positioned horizontally & vertically & parallel to the fly path of the sprayer.

POLE C

Horizontal papers at the *low tepee* (Upper, Lower) — **Vertical papers at the *low tepee***

5m from ground; 3.6m from ground; 2.2m from ground; 1.8m from ground



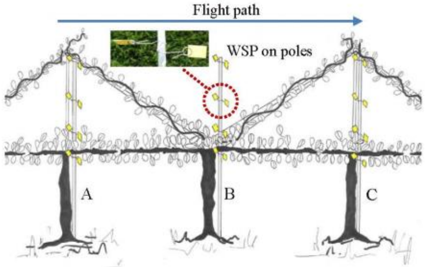
SFF_targeting spray at Gold3 strung canopies using water sensitive papers

Location: Huse Lane, Rangiuru
Simon Cook

Date: 27th April 2016

Sprayer: Yamaha RMAX 0118 remote controlled helicopter.

Wind speed (m/s): 1.24 m/s (average)
Temperature: 22 °C



5m row spacing

Nozzles: 2x Yamaho SR5 flat fan AI nozzles.

Fan speed: n/a

Pressure: n/a

Water rate (L/ha): ~ 60 L/ha

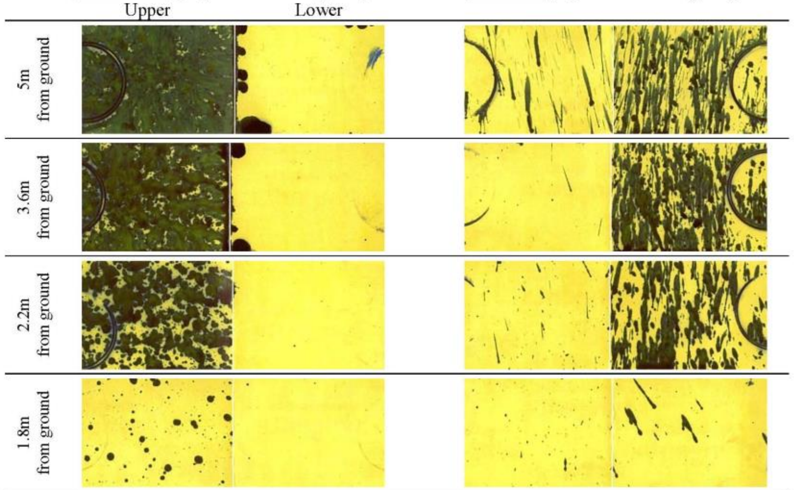
Travel speed (km/h): ~ 2-3 km/hr

Yamaha RMAX 0118 helicopter:
Water + 250 ml/100 L Du-Wett

Water sensitive papers were folded in half and held in place with a clip on a pole at set intervals. WSPs were positioned horizontally & vertically & parallel to the fly path of the sprayer.

POLE A

Horizontal papers at the *high tepee* | **Vertical papers at the *high tepee***



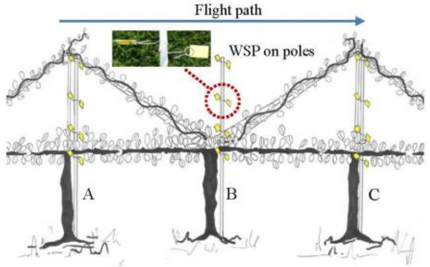
SFF_targeting spray at Gold3 strung canopies using water sensitive papers

Location: Huse Lane, Rangiuru
Simon Cook

Date: 27th April 2016

Sprayer: Yamaha RMAX 0118 remote controlled helicopter.

Wind speed (m/s): 1.24 m/s (average)
Temperature: 22 °C



5m row spacing

Nozzles: 2x Yamaho SR5 flat fan AI nozzles.

Fan speed: n/a

Pressure: n/a

Water rate (L/ha): ~ 60 L/ha

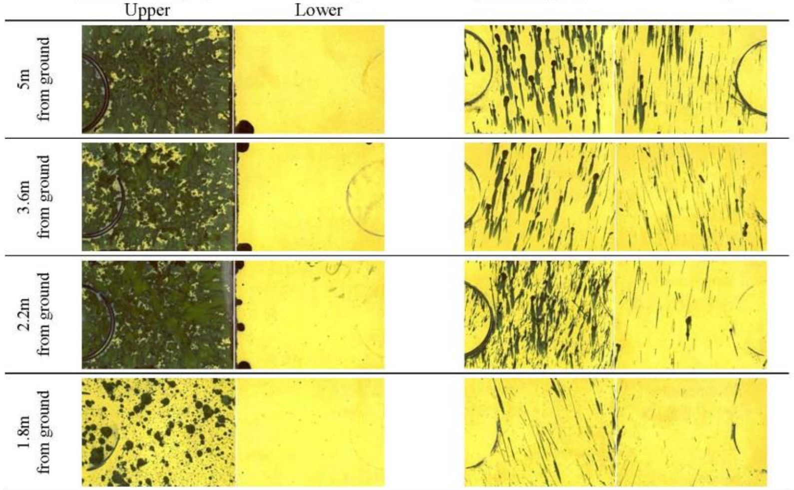
Travel speed (km/h): ~ 2-3 km/hr

Yamaha RMAX 0118 helicopter:
Water + 250 ml/100 L Du-Wett

Water sensitive papers were folded in half and held in place with a clip on a pole at set intervals. WSPs were positioned horizontally & vertically & parallel to the fly path of the sprayer.

POLE B

Horizontal papers at the *low tepee* | **Vertical papers at the *low tepee***



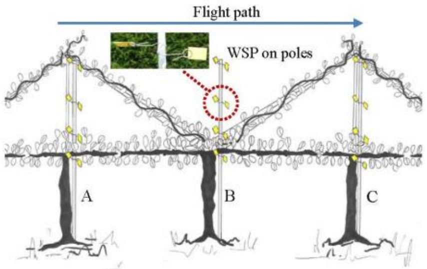
SFF_targeting spray at Gold3 strung canopies using water sensitive papers

Location: Huse Lane, Rangiuru
Simon Cook

Date: 27th April 2016

Sprayer: Yamaha RMAX 0118 remote controlled helicopter.

Wind speed (m/s): 1.24 m/s (average)
Temperature: 22 °C



Nozzles: 2x Yamaho SR5 flat fan AI nozzles.

Fan speed: n/a

Pressure: n/a

Water rate (L/ha): ~ 60 L/ha

Travel speed (km/h): ~ 2-3 km/hr

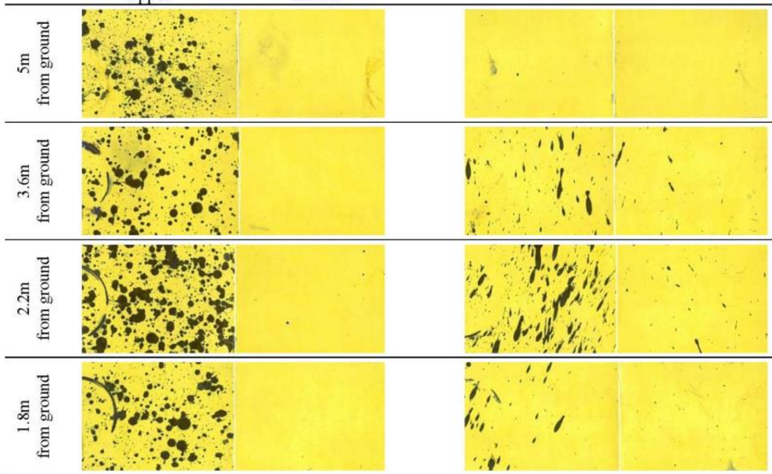
Yamaha RMAX 0118 helicopter:
Water + 250 ml/100 L Du-Wett

Water sensitive papers were folded in half and held in place with a clip on a pole at set intervals. WSPs were positioned horizontally & vertically & parallel to the fly path of the sprayer.

POLE C

Horizontal papers at the *high tepee* — **Vertical papers at the *high tepee***

Upper — Lower



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