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Report to Zespri Group Ltd

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Optimising copper use for sustainable control of Psa in kiwifruit orchards

Best Practice for protectant spray coverage of spring and summer kiwifruit canopies

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EXECUTIVE SUMMARY

This study was undertaken to build on previous work to develop best practice recommendations for protective sprays for kiwifruit. In particular, it was to determine (1) for how long low-drift air inclusion (AI) nozzles could efficiently deliver protectant sprays to expanding spring canopies, and (2) to maximise the efficiency of spray delivery to flowering Hayward and fully expanded Gold3 canopies on wide row spacings.

Studies were undertaken on Hayward and Gold3 canopies through the 2014/15 season, from budbreak through to pre-harvest in March. Deposits were monitored throughout canopy zones, on foliage, buds and flowers, with tracers in the spray tanks and extensive use of water sensitive papers. In summary:

<u>On spring canopies:</u>

- AI nozzles performed equally as well as conventional fine droplet ATR nozzles in delivering protectant sprays to pergola canopies, from budburst through to pre-flowering.

- AI nozzles visibly reduced off-target drift compared to fine droplet ATR nozzles, in sprays applied to expanding spring canopies.

- AI sprays targeting expanding shoots should contain Driftstop adjuvant, at a suggested rate of 200 ml/100 L (0.2%), to maximise spray deposits and ensure surface coverage (spreading) of large droplets.

- AI sprays delivered at 800 L/ha targeted foliage equally as well as, or better than, AI sprays delivered at 1000 L/ha.

- AI sprays targeting flower buds may benefit from the preferential use of a better superspreader adjuvant (e.g. Du-Wett at 40 ml/100 L {0.04%}), rather than Driftstop.

- It is probable that AI nozzles will not deliver adequate deposits to protect open flowers and flowering canopies, due to the increased canopy density. More conventional fine droplet nozzles are recommended at this stage; coverage of target surfaces will benefit from use of a very good superspreading adjuvant (e.g. Du-Wett, 40 ml/100 L).

<u>On Gold3 summer/pre-harvest canopies:</u>

- 2x concentrate volume (1000 L/ha), with the addition of Du-Wett (400 ml/ha), performed equally to dilute volume (2000 L/ha) in delivering protectant sprays to all canopy zones.

- Both dilute and concentrate protectant sprays can provide equivalent good deposits on lower canopy zone foliage.

- Both dilute and concentrate protectant sprays can provide equivalent adequate deposits on foliage in upper canopy zones, dependent on canopy density.

- Both dilute and concentrate protectant sprays failed to provide adequate deposits on foliage of vines strung above the main canopy.

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.

Large droplet Air Inclusion (AI) nozzles have been adopted by the NZ kiwifruit industry to help minimise potential off target losses of hydrogen cyanamide dormancy breaking sprays. An extensive experimental programme has compared spray deposits and efficacy from fine (spray droplets typically <200 microns) and coarse (spray droplets typically >300 microns) hydrogen cyanamide applications. As droplet size increases the number of droplets produced for a given volume of spray decreases. For each doubling of droplet diameter the number of droplets produced reduces by a factor of eight. The numbers of spray droplets from a typical kiwifruit AI nozzle setup for hydrogen cyanamide application is expected to be between 8-64 times lower than the number of droplets from an equivalent fine droplet setup. Spray deposits seen on water sensitive papers (WSPs) are markedly different between the two nozzle types, with large droplet AI nozzles showing fewer large deposit points, with more defined gaps in coverage between droplets. The addition of suitable adjuvants can assist in the initial retention of large droplets and their subsequent spreading on target surfaces.

Deposit measurements and efficacy studies have confirmed that large droplet, low drift hydrogen cyanamide sprays through AI nozzles, with appropriate adjuvant additions, achieve equivalent efficacy to traditional fine droplet sprays, while greatly reducing potential off-target losses. The drift reduction potential of AI nozzles is well established, but there is a risk that spray deposits from large droplet sprays will be compromised as the target canopy develops, gets denser and more complex. Spray deposit failure is expected to manifest in two main ways; (1) that overall deposits reduce as the canopy density increases and (2) that deposit variability will increase unacceptably as leaves (or other structures such as flowers or fruit) expand and become more complex to spray.

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*. 2012). Basically we expect to see a two- to three-fold variation in average deposits from the most easily sprayed canopy zones closest to the sprayer, and the more difficult distant and upper canopy zones. Deposits in overly dense (typically male) canopy zones can be only 20% (or less) of the deposits in acceptably sprayed zones, and much more variable. This is expected to be associated with control failures of the protectant chemicals (coppers and antibiotics) used for Psa control.

The industry has no experience or data on how long large droplet AI nozzle deposits can be expected to achieve acceptable coverage in developing spring canopies. The work reported here aimed to determine for how long low drift, large droplet AI nozzles could efficiently deliver protectant sprays to expanding spring canopies. The other aim was to maximise the efficiency of protectant spray delivery to flowering canopies and on fully expanded Gold3 canopies on wide row spacings. While extensive deposit studies have been undertaken on Hayward and Hort 16A varieties in recent years, none have yet been conducted on the Gold3 variety.

METHODS AND MATERIALS

<u>Spring deposit studies</u>
The spring deposit studies were undertaken between 25th September and 20th November 2014 on Bob Cook's orchard, at 48 Huse Lane Rangiuru. The Hayward orchard is planted on 5 x 5 m row spacing, with males comprising every third vine in every row. Treatment blocks comprised 3 rows x 3 bays and all monitoring was undertaken in the centre row/bay. Sprays were applied with a calibrated (Appendix 1) Ranfurly Orchard Services Fantini Eco 2000 sprayer (Fig. 1), driven by Simon Cook. The sprayer has a front entry fan with twin nozzle rings, fitted with both Albuz ATR hollow cone nozzles and AI nozzles (Fig. 1). Treatment blocks were sprayed with all nozzles operating at all times.

Fig. 1: Sprayer and AI nozzle setup

Study 1: 25th September 2014
Bud break had just occurred and leaf emergence varied from 1-5 leaves (Fig. 2). No leaf length measurements were taken because leaves were too small and were fully exposed to sprays. Deposits were monitored with water sensitive papers (WSP) placed in varying positions. WSPs were attached to leaves by folding in half (one half on each side of the leaf) and securing with a paper clip (Fig. 2). Folded WSPs were attached to the leaves of very small leaf buds with double sided adhesive tape.

Male leaf shoots in the leader zone (within one wire either side of the vine) had WSP placed on the youngest, second and third oldest leaves on a single shoot, on both top and bottom surfaces of these leaves. Shoots were randomly selected (10 replicate shoots) in each treatment, throughout the male vines.

Female leaf shoots were less expanded than males. They were monitored at both the leader and row centre (within two centre row wires) zones, with WSP placed on the second oldest leaf, on both top and bottom surfaces. Ten replicate shoots were selected within each zone.

Leaf buds (10 replicate shoots) were monitored in the centre zone only.

WSP were assessed visually as adequate deposits, inadequate deposits or run-off, taking into account that WSPs indicate spray reaching the papers, but do not accurately reflect droplet adhesion or spray coverage (droplet spreading) on target plant surfaces.

Fig. 2: Budbreak stage of male buds in Study 1

Standard dilute (1000 L/ha) and lower volume concentrated (800 L/ha) spray treatments, as applied by Ranfurly Orchard Services, were utilised in the study (Table 1). Driftstop™ (Nufarm Ltd) is a recommended adjuvant for use when applying sprays with large droplet AI nozzles to dormant canes. Du-Wett® (Etec Crop Solutions Ltd) is a recommended adjuvant for applying protectant sprays through conventional hollow cone nozzles to spring canopies. No copper was included in the spray mixes because it has no effect, at the product rates used in kiwifruit, on the physical properties of the adjuvant sprays.

Table 1: Study 1 treatments

Tmt	Spray volume L/ha	Adjuvant (L/ha)	Travel speed (km/h)	Nozzles[1]	Pressure (bar)	Temp °C	Mean wind (m/s)[2]
1	1000	Du-Wett (0.40)	6.5	ATR 2 rings	15	21	1.0
2	800	Driftstop (1.6)	6.5	AI 1 ring	27	24	1.5

[1] see Appendix 1 for calibration details; [2] 1 m/s = 3.6 km/h

Study 2: 10th October 2014

Two weeks later, shoots had expanded substantially (Fig. 3). The average length of shoots and mean number of leaves on each were determined by measuring 20 random shoots in each sample zone (Table 2).

Table 2: Mean shoot lengths (cm) and mean leaf numbers per shoot

	Male Leader	Female leader	Female centre
Shoot length	14.9	20.6	20.1
Leaf numbers	8.7	8.6	9.4

WSPs were placed on male leaves as described in Study 1, except the leaves used were the youngest, intermediate and oldest on each shoot. On female shoots, WSPs were attached to the three youngest leaves. Five replicate shoots were selected in each zone. No unexpanded leaf buds were present.

The same sprays were applied as in Study 1 (Table 1). Treatment 1 (dilute) was applied in a mean wind speed of 0.31 m/s (1.03 m/s max.) and 17.5°C. Treatment 2 was applied in a mean wind speed of 1.45 m/s (3.17 m/s max) and 18.5°.

Fig. 3: Canopy development in Study 2

Study 3: 31st October 2014

By this time, the canopy was well developed and flower buds were present on vines (Fig. 4). WSPs were placed on male leaves at the leader zone, in both the upper and lower canopy. For each treatment, five random leaves were selected in each zone and WSPs were attached (using drawing pins through the leaf mid rib/stem) to both top and bottom leaf surfaces. On less dense female vines, WSPs were similarly attached to ten random leaves in the canopies of both the leader and centre row zones.

Because of the greater canopy density, an additional AI nozzle treatment was included, to determine if increasing spray volume through these nozzles could increase deposits (Table 3).

Fig. 4: Canopy development in Study 3

Table 3: Study 3 treatments

Tmt	Spray volume L/ha	Adjuvant (L/ha)	Travel speed (km/h)	Nozzles[1]	Pressure (bar)	Temp °C	Mean wind (m/s)
1	1000	Du-Wett (0.4)	6.5	ATR 2 rings	15	17	0.7
2	800	Driftstop (1.6)	6.5	AI 1 ring	27	21	0.4
3	1000	Driftstop (2.0)	6.5	AI 2 rings	18	17	0.7

[1] see Appendix 1 for calibration details

Study 4: 4th November 2014 (pre-bloom)
Because of the rapid canopy development (Fig. 5), a quantitative deposit study was undertaken four days later. Included in the study was the comparison of AI nozzles delivering two volumes, plus the use of adjuvants (Driftstop or Du-Wett) with AI nozzles (Table 4). All treatments contained tartrazine dye at 5g/L, to quantify spray deposits.

Fig. 5: Female pre-bloom canopy in Study 4

Measurements were made of cane density, canopy depth (cm) and leaf layers on all treatment blocks (Table 5). WSPs were placed in male and female leader and centre row zones, pinned to both top and bottom surfaces of three random leaves in each treatment replicate block.

Table 4: Study 4 treatments (see Appendix 1 for calibration details)

Tmt	Spray volume L/ha	Adjuvant (L/ha)	Travel speed (km/h)	Nozzles	Pressure (bar)	Temp °C	Mean wind (m/s)
1	800	Driftstop (1.6)	6.5	AI 1 ring	27	21	0.24
2	1000	Driftstop (2.0)	6.5	AI 2 rings	18	22	0.25
3	1000	Du-Wett (0.4)	6.5	AI 2 rings	18	21	0.34
4	1000	Du-Wett (0.4)	6.5	ATR 2 rings	15	21	0.29

Table 5: Study 4 canopy characterisation

Tmt-rep	Cane density (per bay)	Mean canopy depth (cm)			Mean leaf layers		
		centre	female leader	male leader	centre	female leader	male leader
1-1	23	32	66	82	2.2	5.6	8.6
1-2	20	21	57	58	2.2	2.6	5.8
2-1	22	27	51	71	3.2	3.2	8
2-2	22	31	51	66	3.6	2.8	6.8
3-1	24	26	62	78	3.0	4.2	8.8
3-2	24	36	64	63	4.4	4.8	7.6
4-1	26	34	51	67	3.2	3.6	7.4
4-2	21	36	58	62	3.8	4.0	7.6

Spray deposit assessment: After spray treatments had dried, leaf samples were collected from eight different canopy zones: upper (leaves in top of canopy shielded from sprayer) and lower (exposed to sprayer) positions at the row centre, female leader zone (within one wire either side of the vine) and male leader zone (ditto), and randomly from flower buds in the centre row and at the male vine leader. Three replicate samples of five random leaves (or buds) were collected in each zone from each replicate block, placed in resealable plastic bags and kept out of direct sunlight. Samples were processed as previously described (Gaskin *et al*, 2010) to quantify bulk leaf deposits.

Additionally, five single leaves were sampled in one replicate block for each treatment, from four canopy zones: male leader upper and lower canopy positions, and female centre row upper and lower canopy positions. These leaves were washed individually on each side (50 ml wash solution) to determine spray deposits on the adaxial (top) and abaxial (bottom) leaf surfaces.

Deposits were calculated as dose ($\mu g/cm^2$) 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 bulk deposit data are presented as micrograms of tracer per square centimetre of the two leaf surface areas added together to allow direct comparison with single leaf wash offs. Previous reports have followed the convention of presenting average deposit per square centimetre of projected leaf area (i.e. deposits on both leaf surfaces have been expressed per square centimetre of one side of the leaf). Results were statistically analysed using ANOVA to determine the significance of treatment on spray deposits retained on leaves in different zones.

Study 5: 20th November 2014 (flowering)

Two weeks later flowering was well progressed (Fig. 6). Two treatments were applied (Table 6) containing Sardi fluorescent dye (0.5%), to enable visualisation of leaf and flower spray coverage. In an effort to improve AI nozzle performance on the moderately dense canopy (Fig. 6), the AI application volume was increased from 800 to 1000 L/ha and the superior superspreader adjuvant, Du-Wett, was substituted for Driftstop.

Fig. 6: Female flowering canopy in Study 5

Table 6: Study 5 treatments

Tmt	Spray volume L/ha	Adjuvant (L/ha)	Travel speed (km/h)	Nozzles[1]	Pressure (bar)	Temp °C	Mean wind (m/s)
1	1000	Du-Wett (0.4)	6.5	ATR 2 rings	15	19	0.67
2	1000	Du-Wett (0.4)	6.5	AI 2 rings	18	19	1.15

[1] see Appendix 1 for calibration details

Measurements were made of cane density, canopy depth (cm) and leaf layers on both treatment blocks (Table 7). WSPs were placed in female leader and centre row zones, and in the upper and lower canopies of the male leader vines. The WSPs were pinned to both top and bottom surfaces of five random leaves in each zone.

Once sprays had dried, leaf and flower samples were collected. Leaves were sampled from centre row, female leader zones and male vines, in both the upper and lower canopy positions, and placed individually into separate paper bags. Open flowers were sampled from centre row, female leader zones and male vines and placed into egg cartons (one flower per egg holder). Leaves and flowers were kept cool and transported immediately to the lab where they were visualised under UV light and photographed within 6 h (flowers) or 24 h (leaves) after sampling. Spray coverage on both open flowers and the calyx was photographed, and on both adaxial and abaxial leaf surfaces.

Table 7: Study 5 canopy characterisation

Tmt	Cane density (per bay)	Mean canopy depth(cm)			Mean leaf layers		
		centre	female leader	male leader	centre	female leader	male leader
1	22	32	64	82	4.9	5.1	8.9
2	25	35	61	74	4.0	5.3	7.9

<u>Summer deposit study</u> (pre-harvest)
This pre-harvest deposit study was undertaken on 25th March 2015 on Murray and Deborah Holmes G3 orchard at 41 Mark Rd, Te Puke (Fig. 7). This orchard is planted on 4.5 m rows, with the replacement canes strung to tepees (Fig. 8). Sprays were applied with the grower's Atom 200 EVO sprayer, calibrated (Appendix 2) and driven by Bill May. Two treatments (two reps of each) were applied, through conventional ATR hollow cone plus Article 58 nozzles, a dilute (2000 L/ha) and a 2x concentrate (1000 L/ha) spray (Table 8). Calcium 175™ (Grochem) was added to all treatments (approx 1.5 kg/ha) as a tracer to quantify deposits on the basis of ion conductivity of sample washings (Gaskin *et al.* 2010).

WSPs were placed in leader and centre row zones. They were pinned to both top and bottom surfaces of five random leaves in each zone.

Fig. 7: Typical leader canopy (left) and centre row canopy (right) in G3 study

Table 8: G3 summer treatments

Tmt	Spray volume L/ha	Adjuvant (L/ha)	Travel speed (km/h)	Nozzles[1]	Pressure (bar)	Temp °C	Mean wind (m/s)
1	2000	nil	6.0	Art. 58 2 rings	16	24	0.30
2	1000	Du-Wett (0.4)	6.0	Art. 58 2 rings	16	28	0.34

[1] see Appendix 2 for calibration details

After spray treatments had dried, leaf samples were collected from five different canopy zones: upper (leaves in top of canopy shielded from sprayer) and lower (exposed to sprayer) positions at the row centre and leader zones, and from strings at 3.5-4 m above ground. Three replicate samples of five random leaves each were collected in each zone from each replicate block, placed in resealable plastic bags and processed immediately as previously described (Gaskin *et al*, 2010) to quantify bulk leaf deposits.

Additionally, five single leaves were sampled in one replicate block for each treatment, from four canopy zones: leader upper and lower canopy positions, and centre row upper and lower canopy positions. These leaves were washed individually on each side (50 ml wash solution) 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 two-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. 8: G3 strung canopy

RESULTS and DISCUSSION

Spring deposit studies

Study 1
The standard practice by the grower on this orchard, was to add Du-Wett (400 ml/ha) to spring sprays applied through conventional hollow cone (ATR) nozzles. Du-Wett has superspreader properties that improve spray deposition and target coverage, and also has some beneficial drift-reducing properties. Thus, it is likely to improve on-target deposits. The spray through AI nozzles (+ Driftstop) was applied in slightly higher winds than the ATR spray (1.5 m/s vs 1.0 m/s mean wind speed), but production of fine droplets and off-target drift was visibly less in the AI nozzle treatment. The AI spray was observed to “fall out” much faster than the ATR spray (Fig. 9).

Generally good spray coverage of emerging shoots by the conventional ATR treatment was confirmed by WSPs (Fig. 10). Some shading with visibly reduced deposits was apparent on leaves in expanding shoots on the more advanced male vines, but this was minimal. Leaves, both top and bottom surfaces, on female vines were well contacted by sprays, with evidence of run-off on both surfaces. Coverage of expanding leaf buds was considered acceptable in all cases (Fig. 10).

Coverage assessments on WSPs indicated that the large droplet AI nozzles (Fig. 11) performed equally to the fine droplet ATR nozzles, with less evidence of run-off and potentially more even spray distribution on WSPs in all canopy zones. It should be noted that WSPs do not accurately reflect spreading on target leaf surfaces, and that chemical (on a per ha basis) was more concentrated in the 800 L/ha AI spray than in the 1000 L/ha application with ATR nozzles.

Fig. 9a: Study 1, dilute ATR nozzle spray **Fig. 9b: AI nozzle spray**

Study 2
The conventional ATR spray was applied in very still conditions (mean 0.3 m/s; max. 1.0 m/s), while the AI spray was applied in higher winds (mean 1.45 m/s; max. 3.2 m/s). Regardless of this, the AI spray was observed to drift less than the ATR spray (Fig. 12). Deposits from the ATR spray on WSP were excellent on female vines (Fig. 13) and just a little less consistent on the younger leaves (longer shoots) on male vines.

Deposits on WSPs in the AI spray were slightly less consistent than for the ATR sprays (Fig. 14), but leaves were judged to be adequately covered by AI spray in the higher wind speeds. Both leaf surfaces were well contacted by both sprays in all zones.

Fig. 12a: Dilute ATR nozzle spray

Fig. 12b: AI nozzle spray

Study 3

Winds were similar and light for all treatments in this study (Table 3) and the effect of AI nozzles on reducing drift was readily apparent (Fig. 15).

WSPs mounted in the female vines (leader and centre zones) were generally well contacted by spray in all treatments (Figs 16-18); WSPs in the more dense male vines (see Table 5) were less so. This was most apparent in the upper canopy of male vines, where WSP coverage from the AI nozzle treatments was visually slightly poorer than from the ATR nozzles. There was no evidence that increasing the volume of spray through the AI nozzles, from 800 to 1000 L/ha, improved spray distribution through the canopy at this growth stage. There was limited evidence of run-off in all treatments, but more so in the ATR spray (Fig. 16).

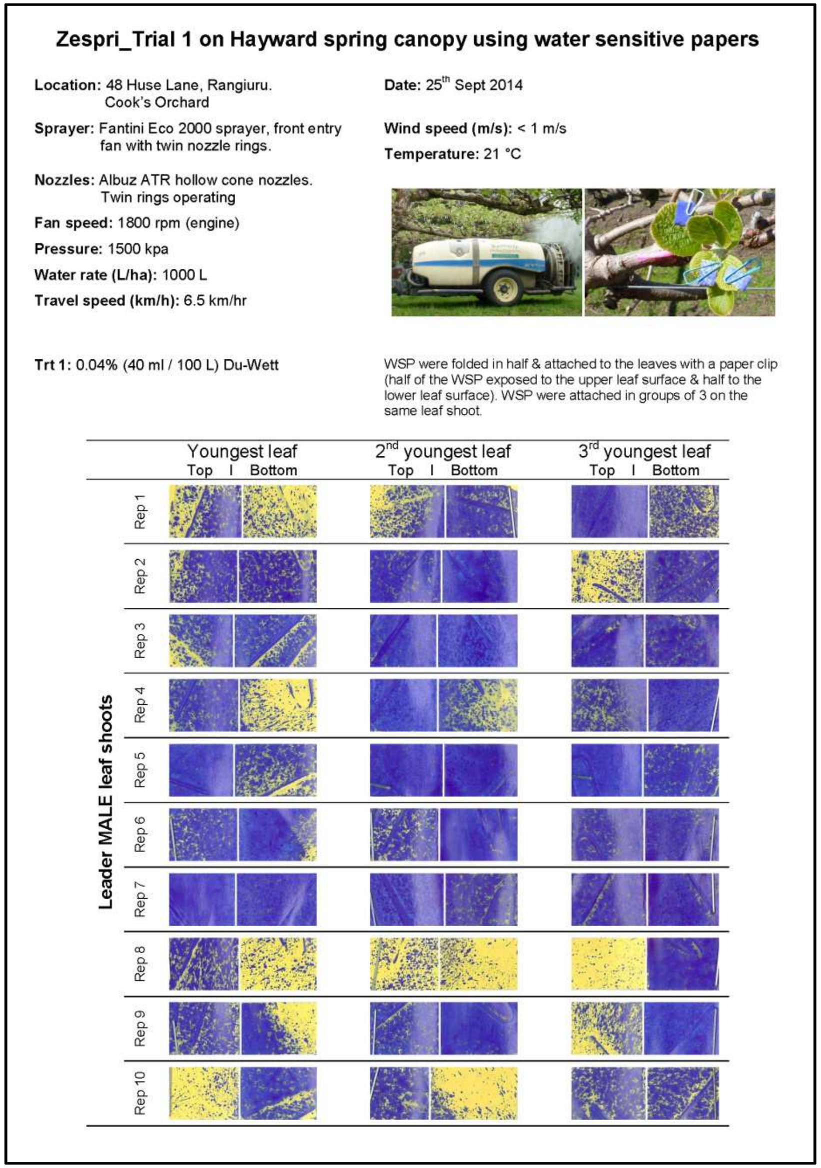
Visual comparison of coverage on WSPs indicated that deposits from the AI nozzles were similar to those from ATR nozzles at this stage of spring canopy development. However, visual coverage comparisons only provide a crude relative estimate of chemical dose and the dye deposit trial, undertaken four days later, aimed to quantitatively confirm spray deposits from the different treatments.

Fig. 15a: Dilute ATR nozzle spray, 1000 L/ha + Du-Wett

Fig. 15b: AI nozzle spray, 800 L/ha + Driftstop

Fig. 15c: AI nozzle spray, 1000 L/ha + Driftstop

Fig. 10: WSPs for Study 1, Treatment 1 - conventional ATR nozzles, 1000 L/ha



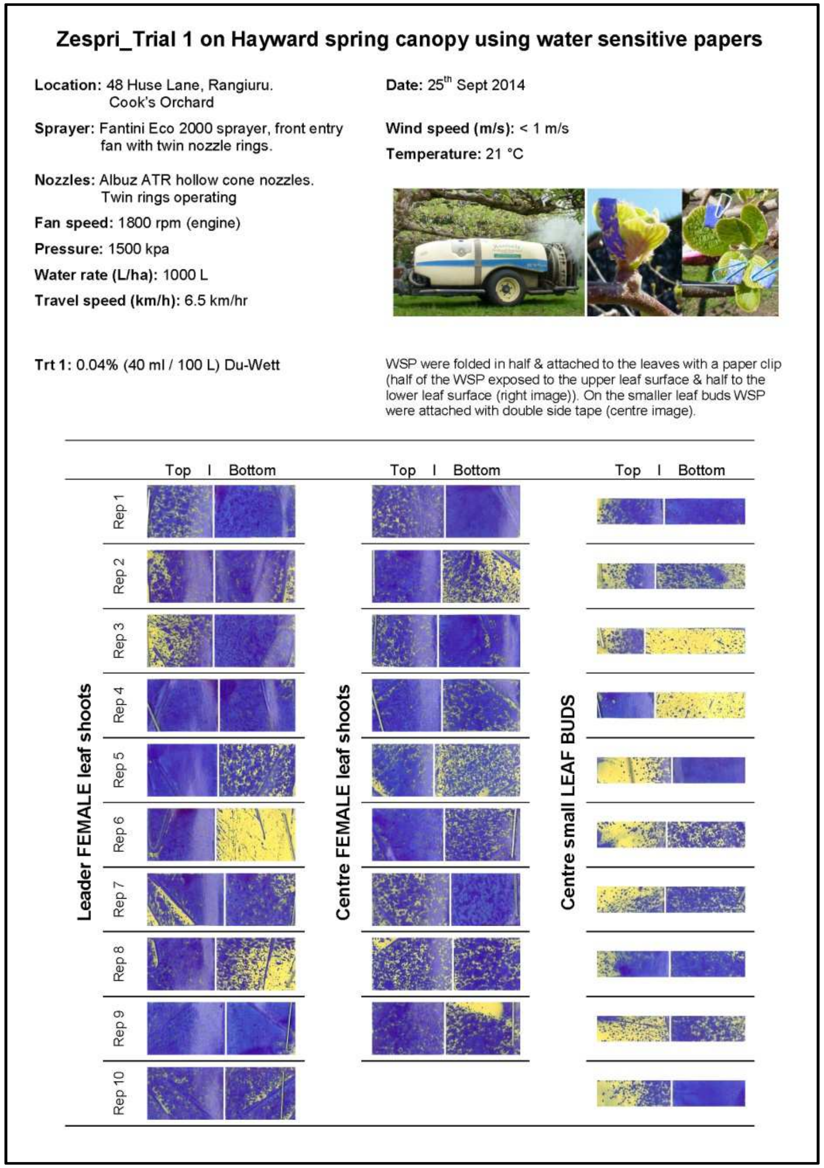
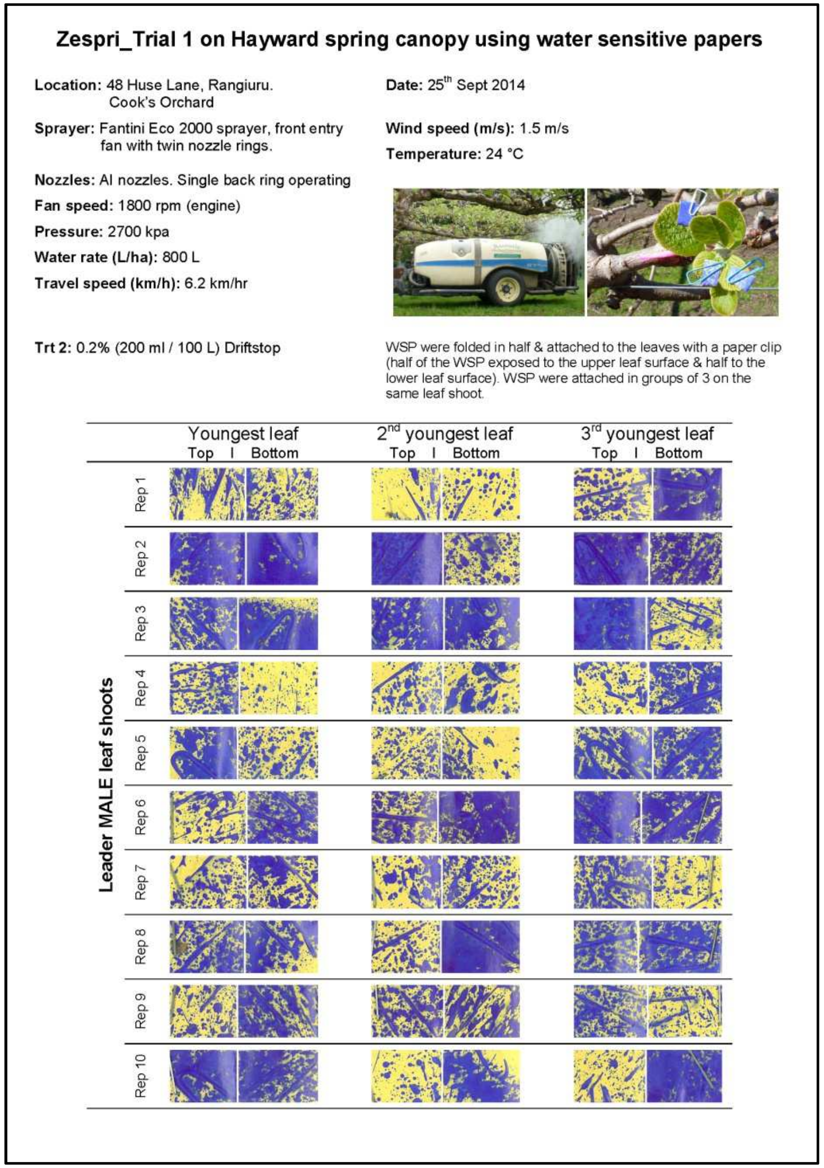


Fig. 11: WSPs for Study 1, Treatment 2 – AI nozzles, 800 L/ha



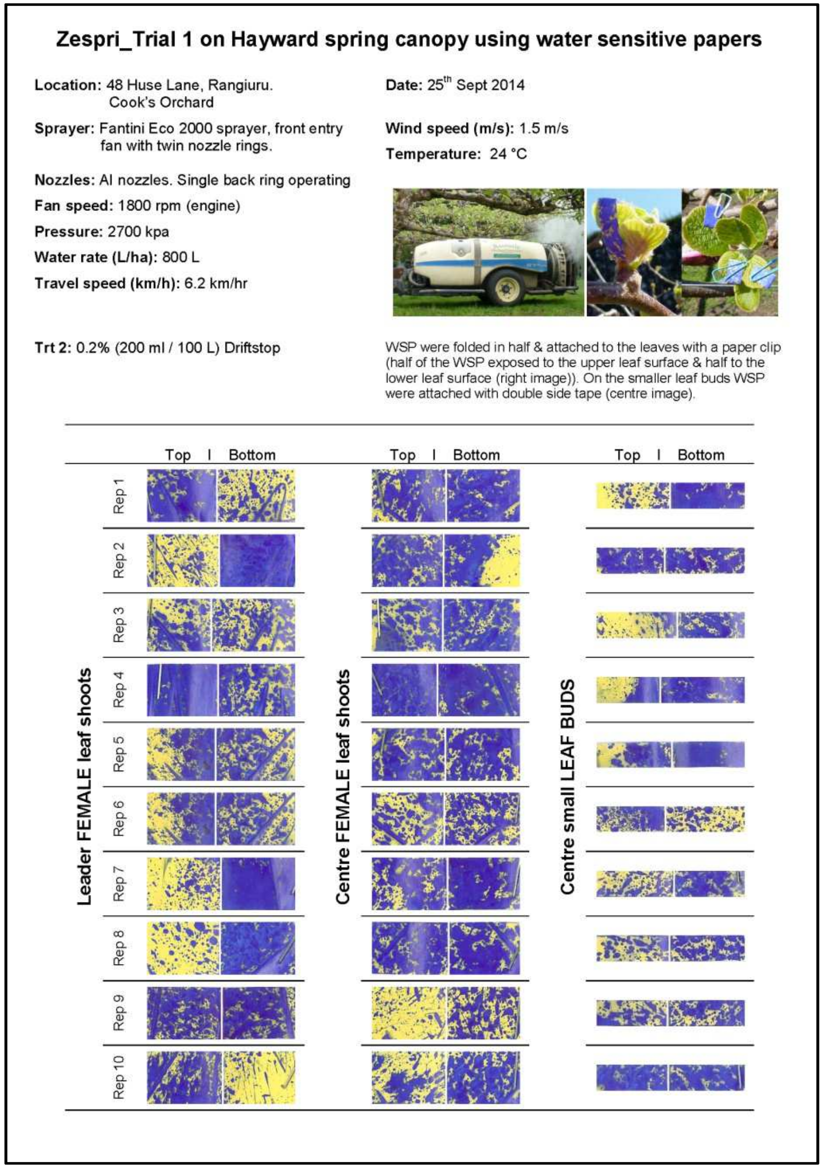
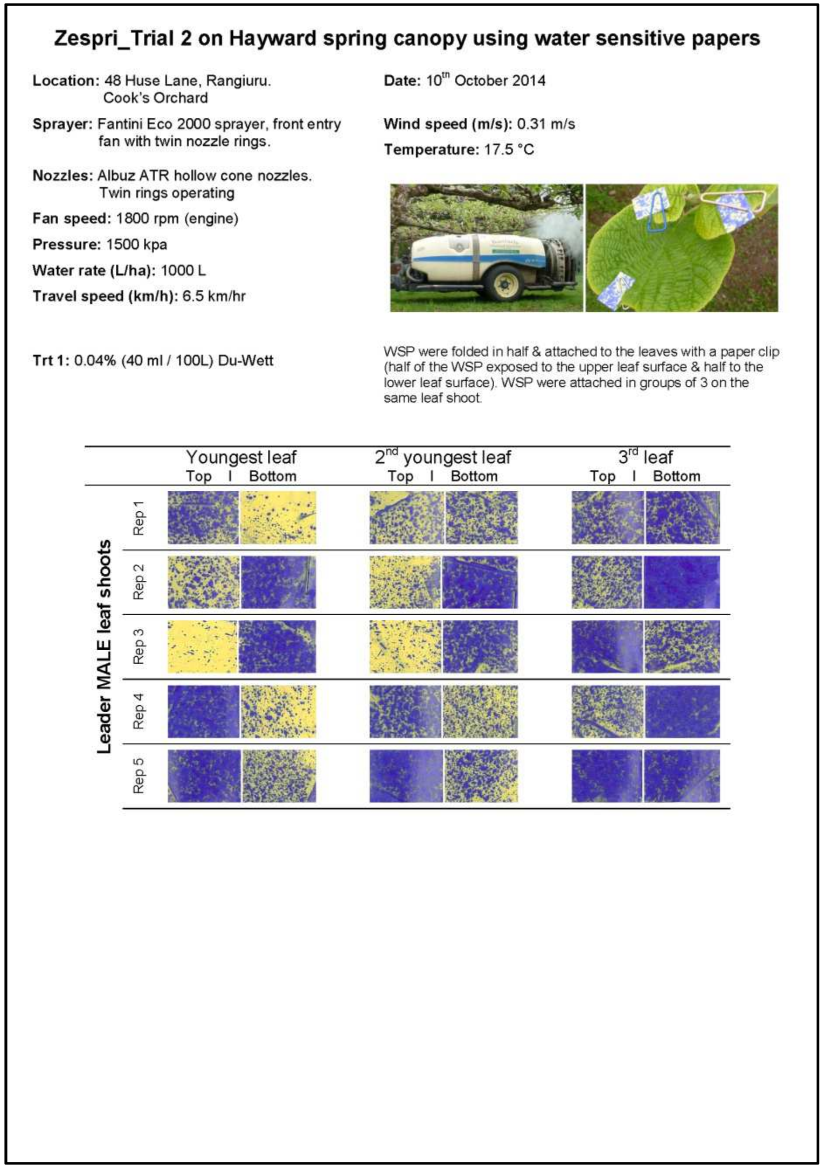


Fig. 13: WSPs for Study 2, Treatment 1 – conventional ATR nozzles, 1000 L/ha



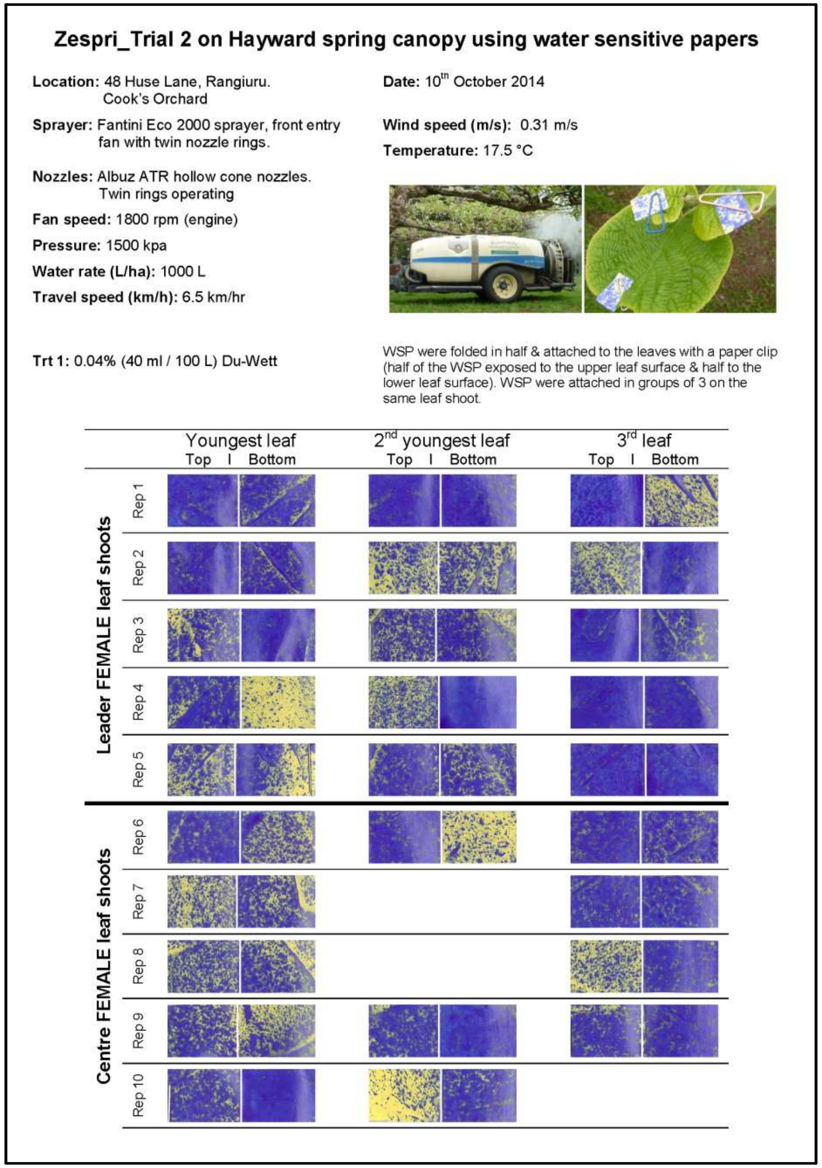
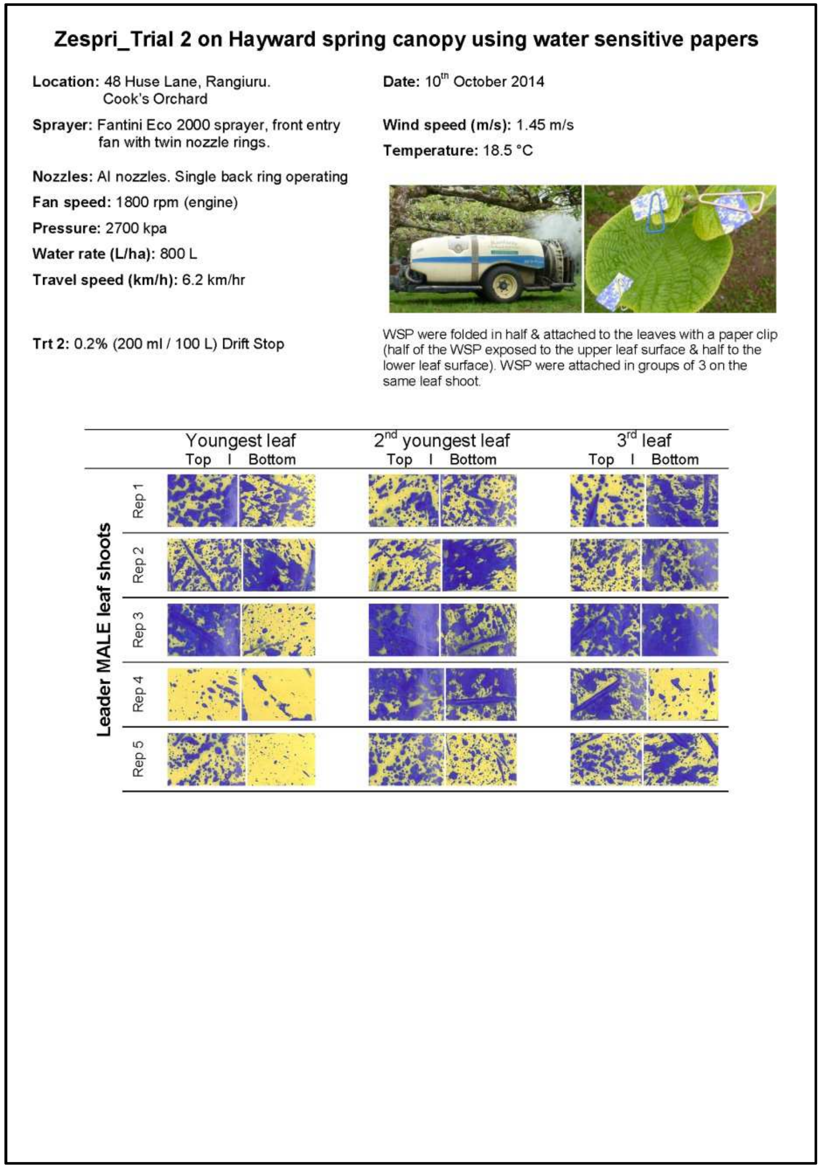


Fig. 14: WSPs for Study 2, Treatment 2 – AI nozzles, 800 L/ha



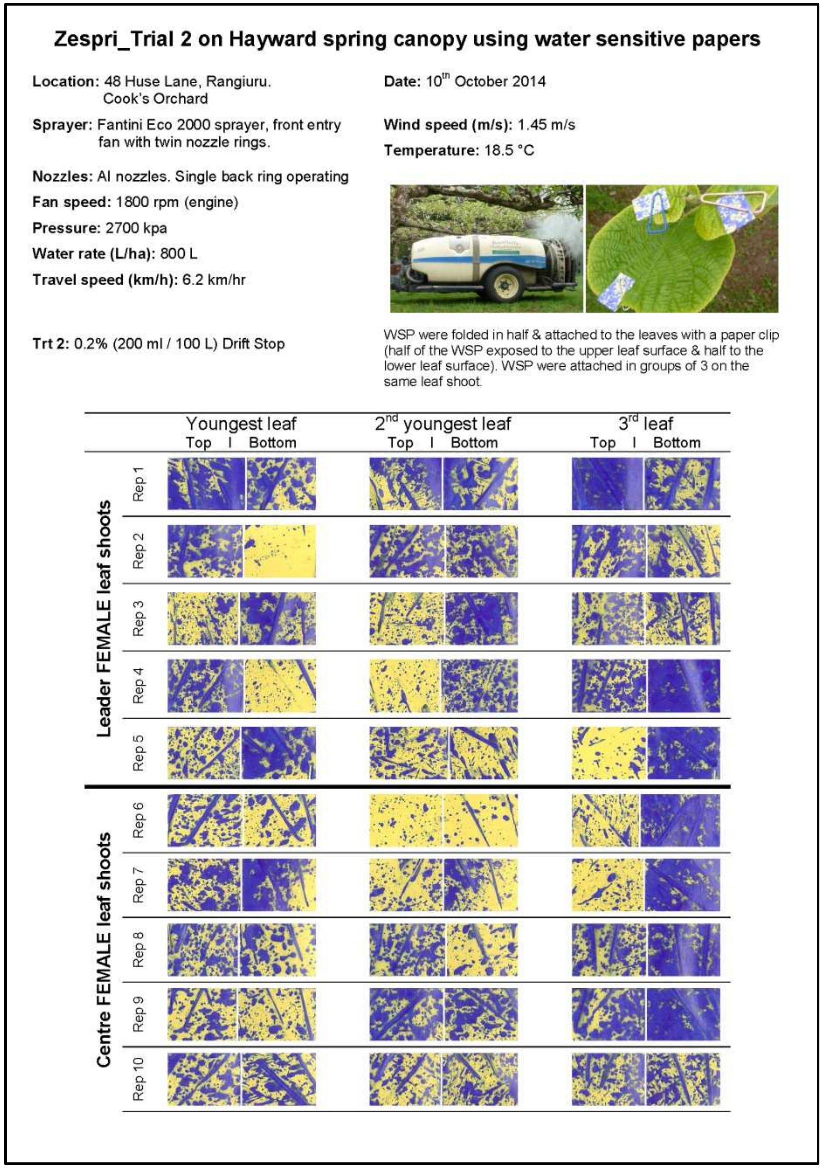
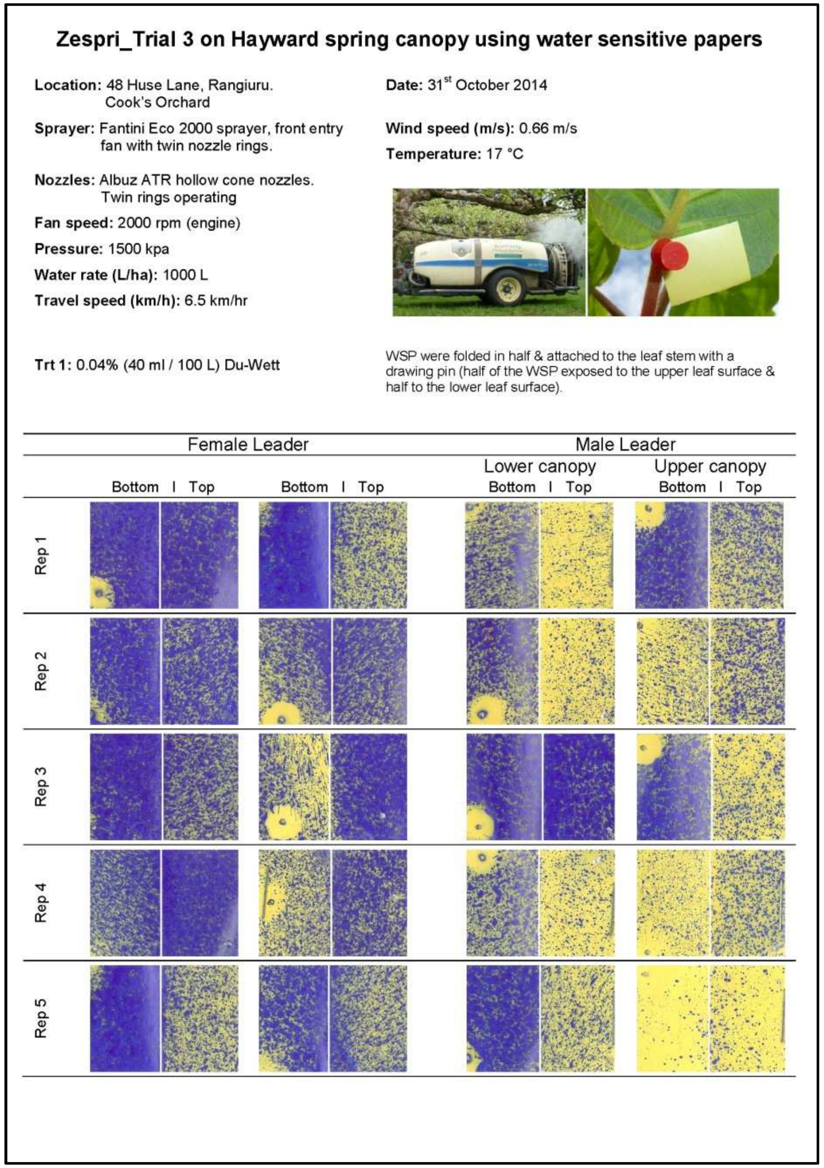


Fig. 16: WSPs for Study 3, Treatment 1 – conventional ATR nozzles, 1000 L/ha



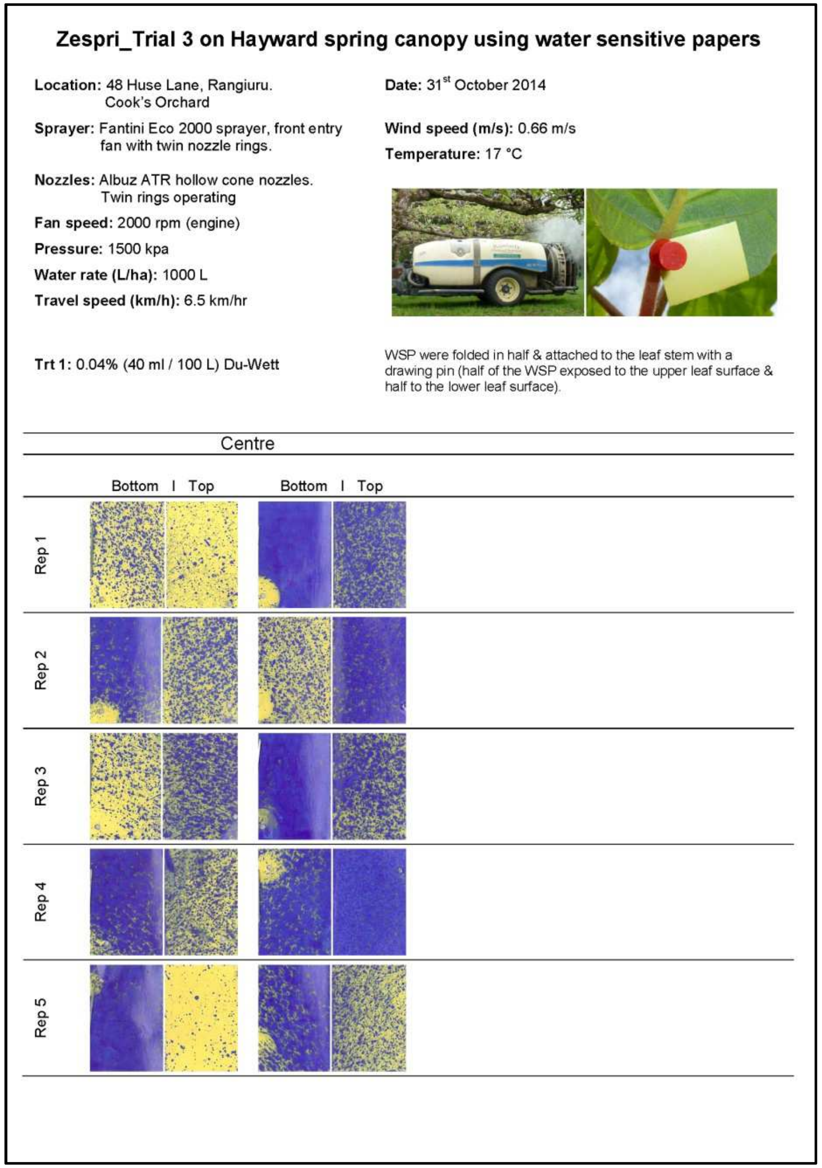
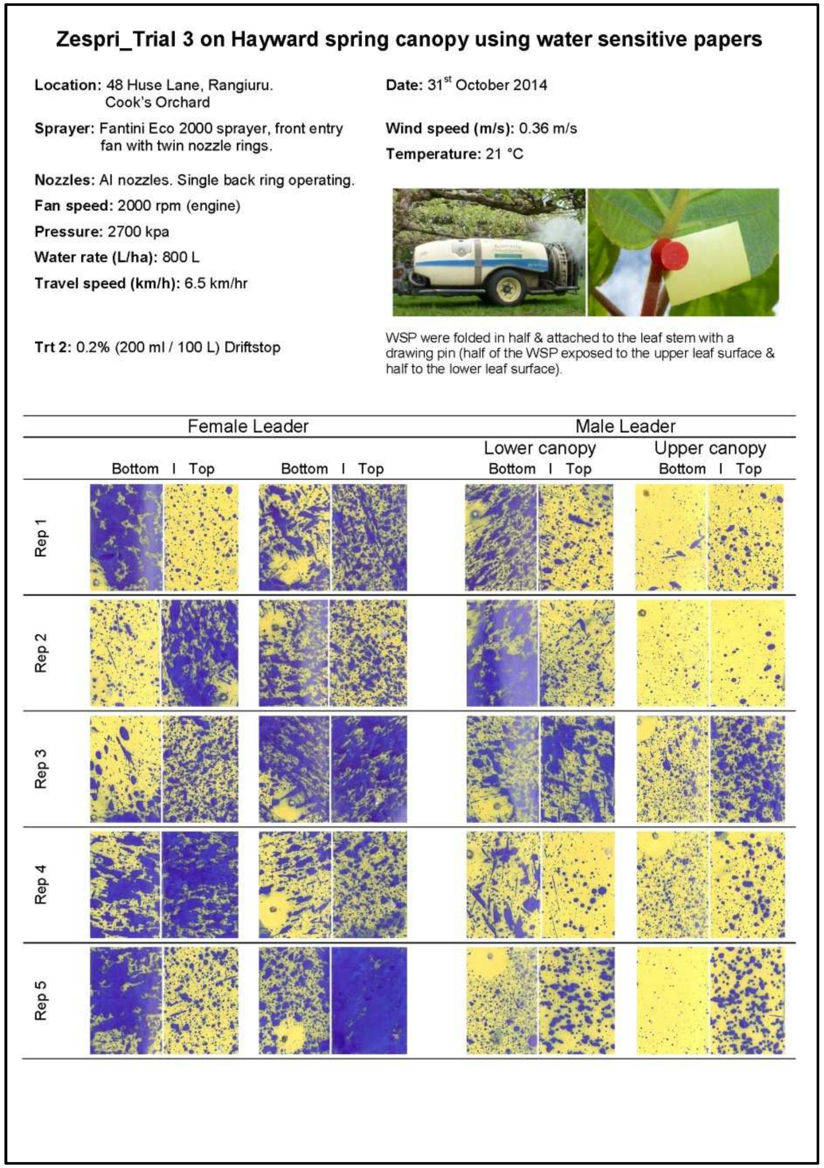


Fig. 17: WSPs for Study 3, Treatment 2 – AI nozzles, 800 L/ha, Driftstop adjuvant



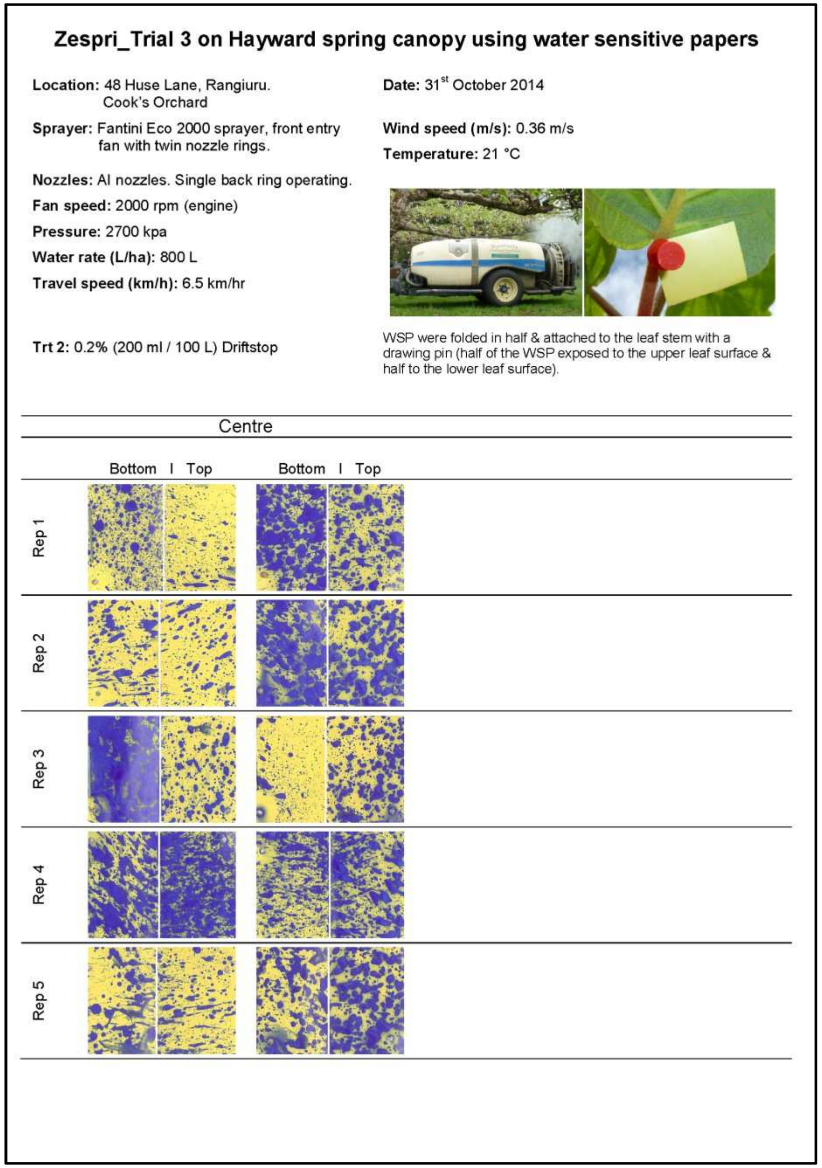
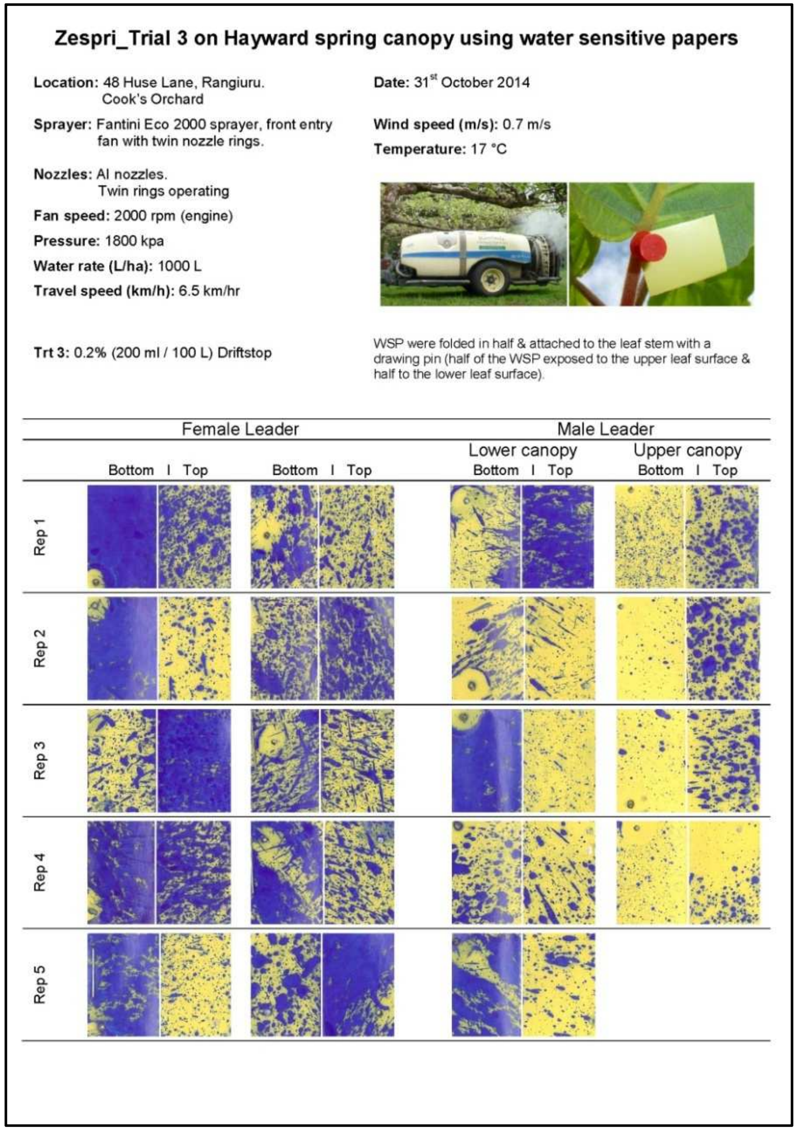
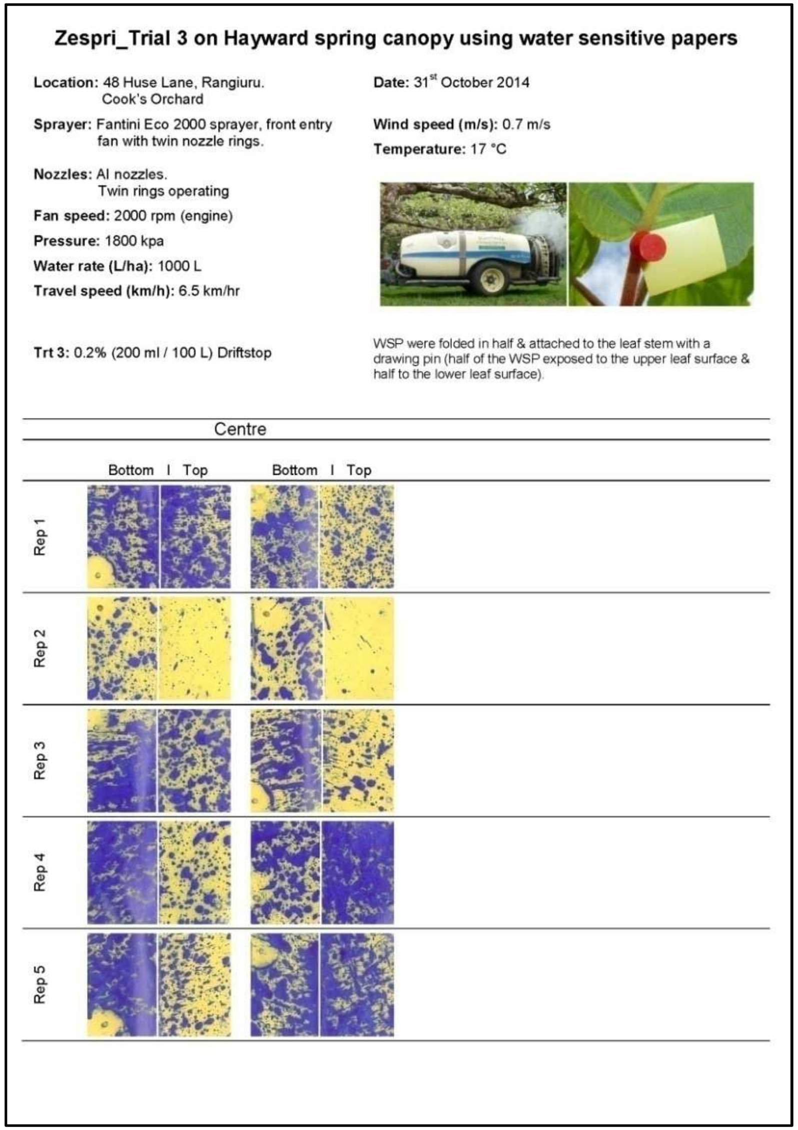


Fig. 18: WSPs for Study 3, Treatment 3 – AI nozzles, 1000 L/ha, Driftstop adjuvant





Study 4

Average treatment deposits provide limited information on spray distribution within canopies, but they are useful to show gross trends. When the more dense male vines were included in the analysis, then the low volume AI (800 L/ha + Driftstop) treatment gave highest mean deposit overall (Table 9), followed by the AI 1000 L/ha (+ Driftstop). The AI and ATR sprays containing Du-Wett gave similar mean deposits. All sprays covered leaves in the centre and leader female zones adequately (Fig. 19), and AI nozzle treatments were always equivalent to or better than the conventional ATR nozzle treatment (Table 9). In particular, Driftstop adjuvant appeared to be a better choice than Du-Wett for sprays on this canopy stage, and the lower spray volume through AI nozzles tended to perform better.

The failing of all sprays was in adequately covering leaves in the upper canopy position of the male leader zone (Fig. 19), but the AI + Driftstop sprays performed best in this regard, and better than the conventional ATR nozzles. The WSPs corroborated these results (Figs 23 & 24).

Table 9: Mean deposits (µg/cm^2, normalised to a 1 kg/ha application of dye) on bulk leaves in all zones and canopy positions

Tmt	Spray vol. (L/ha)	Male vines		Female vines				**Tmt mean**
		Leader upper	Leader lower	Leader upper	Leader lower	Centre upper	Centre lower	
AI + DStop	800	0.67 j	1.45 bc	1.54 ab	1.45 bc	1.14 def	1.44 bc	**1.28 *A***
AI + DStop	1000	0.84 hij	0.87 ghij	1.70 a	1.33 bcd	0.91 fghij	1.25 cd	**1.15 *B***
AI + DWett	1000	0.38 k	0.99 efghi	1.11 defg	1.16 de	0.88 ghij	1.27 cd	**0.97 *C***
ATR + DWett	1000	0.34 k	0.82 ij	1.29 bcd	1.09 defgh	0.92 efghij	1.29 cd	**0.96 *C***
mean		**0.56 D**	**1.03 C**	**1.41 A**	**1.26 B**	**0.96 C**	**1.31 AB**	

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

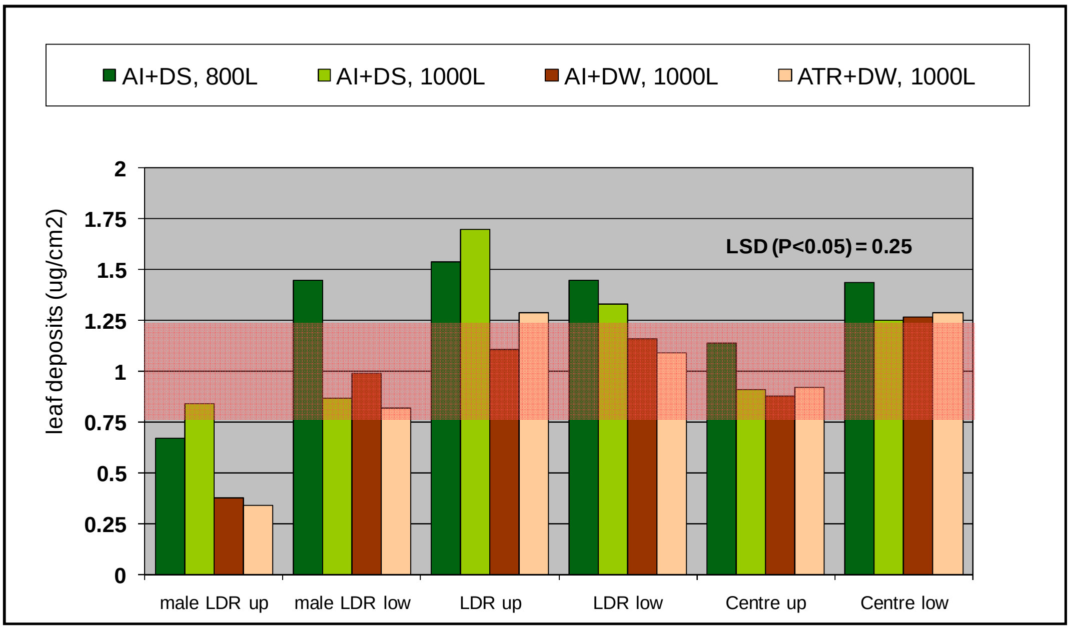


Fig. 19: Mean deposits on bulk leaves in all zones and canopy positions (Red shading band denotes "acceptable" mean deposit levels)

When male vines were excluded from the analysis, deposits confirmed the performance of the AI nozzles. They were very efficient at delivering spray to the leader zone, particularly to the upper canopy position in this zone. The fine (driftable) droplet production by the ATR nozzles, relative to the ATR nozzles, was exceedingly obvious in this study (Fig. 20). Beneath the canopy, the ATR spray drift could be readily felt more than four rows downwind (in light winds), whereas the AI nozzle sprays fell out within two rows.

Fig. 20a: ATR (+ Du-Wett) nozzle spray

Fig. 20b: AI (+ Du-Wett) nozzle spray

The opposite trend to spray deposits on foliage was observed on flower buds (Table 10). Highest mean deposits were obtained with conventional ATR spray nozzles and with addition of Du-Wett adjuvant, but these were no different to the AI spray with Du-Wett. Du-Wett is a better superspreader than Driftstop; this suggests that unopened flower buds are a more difficult-to-wet target than foliage. The deposits on flower buds from the AI (+ Driftstop) sprays were up to 26% lower than the conventional ATR nozzle deposits and spray volume had no effect on this (Table 10).

There was no difference in deposits on buds in the two zones sampled, confirming good, even delivery of sprays by the sprayer.

Table 10: Mean deposits (µg/flower bud, normalised to a 1 kg/ha application of dye) on flower buds in two canopy zones

Tmt	Spray volume (L/ha)	Canopy zone: Leader	Canopy zone: Centre row	**Tmt mean**
AI + DStop	800	23.60 b	23.22 b	**23.41 *B***
AI + DStop	1000	21.78 b	24.52 b	**23.15 *B***
AI + DWett	1000	30.86 a	26.64 ab	**28.75 *A***
ATR + DWett	1000	30.50 a	31.75 a	**31.12 *A***
Mean		**26.69 A**	**26.53 A**	

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

Treatment means for deposits on top and bottom surfaces of single leaves showed equivalent or better deposits for AI nozzles compared to conventional ATR nozzles (Table 11). This confirmed the top and bottom leaf WSPs (Figs 23 & 24). The trend for leaves in lower canopy zones to receive higher deposits confirmed that trend in bulk leaf samples (Table 9). The male (leader) vine foliage in the upper canopy was most poorly contacted by sprays, while, as in the bulk sampling, the leader lower canopy and centre upper canopy zones received similar deposits.

Table 11: Deposits (µg/cm^2, normalised to a 1 kg/ha application of dye) on top and bottom surfaces of individual leaves in four canopy zones.

Tmt	Spray vol. (L/ha)	**Leaf surface**	Leader (male): upper canopy	Leader (male): lower canopy	Centre row: upper canopy	Centre row: lower canopy	**Tmt Mean**
AI + DStop	800	**top**	1.38	0.87	1.94	1.20	**1.35 *CD***
		bottom	0.50	1.20	1.77	3.74	**1.80 *BC***
AI + DStop	1000	**top**	1.33	1.24	1.37	1.06	**1.25 *DE***
		bottom	0.49	2.57	1.99	4.52	**2.44 *A***
AI + DWett	1000	**top**	0.38	0.69	1.38	0.65	**0.77 *E***
		bottom	0.32	1.66	1.66	5.40	**2.26 *AB***
ATR + DWett	1000	**top**	0.69	1.12	1.70	1.21	**1.18 *DE***
		bottom	0.15	2.32	1.61	2.72	**1.70 *CD***
Mean			**0.65 C**	**1.48 B**	**1.68 B**	**2.56 A**	

Means in tables sharing common postscripts are not significantly different (LSD, P=0.05).
LSD (P=0.05) for data in shaded table = 1.1.

Determining deposits on separate leaf surfaces is difficult and time-consuming, but the significance of where sprays are deposited has become very important with the arrival of Psa. As seen in previous studies (Gaskin *et al*. 2011 & 2012), mean deposits on the bottom surfaces of leaves were substantially higher than on top surfaces (P<0.0001; Table 12). These differences were greatest on leaves directly exposed to the sprayer (lower canopy) and were lower in the upper canopy.

The top surface of kiwifruit leaves is very easy-to-wet. Deposits on top surfaces of leaves were reasonably consistent within canopy zones (Fig. 21) and show much less variation across all zones than on the difficult-to-wet bottom surfaces (Fig. 22). Bottom leaf surfaces, with their high hair density, are capable of retaining a far greater volume of spray before runoff than the top surfaces. This is reflected in the disparity between deposits on leaf surfaces in the lower zones, that were well contacted by sprays. In contrast, the top surface of leaves in the upper leader zone always intercepted more spray than the bottom surface, suggesting spray contact was primarily from sprays projected through the canopy settling back down on leaves. In this scenario, AI (plus Driftstop) nozzles did a better job than conventional ATR nozzles, and volume had no effect on deposits.

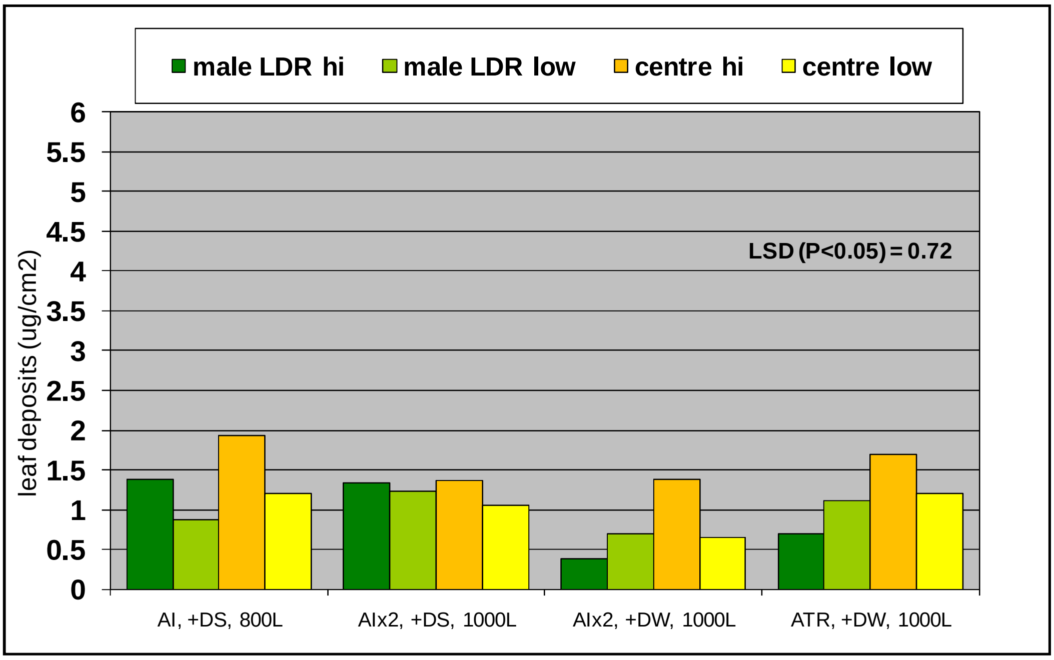


Fig. 21: Mean deposits on adaxial (top) leaf surfaces in four canopy zones

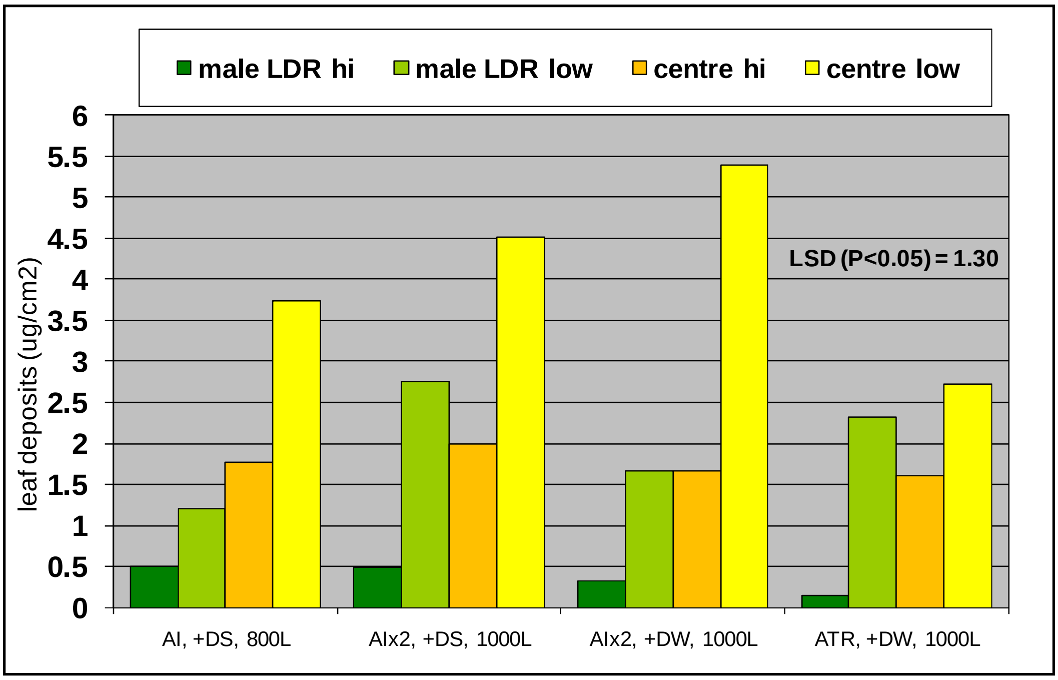
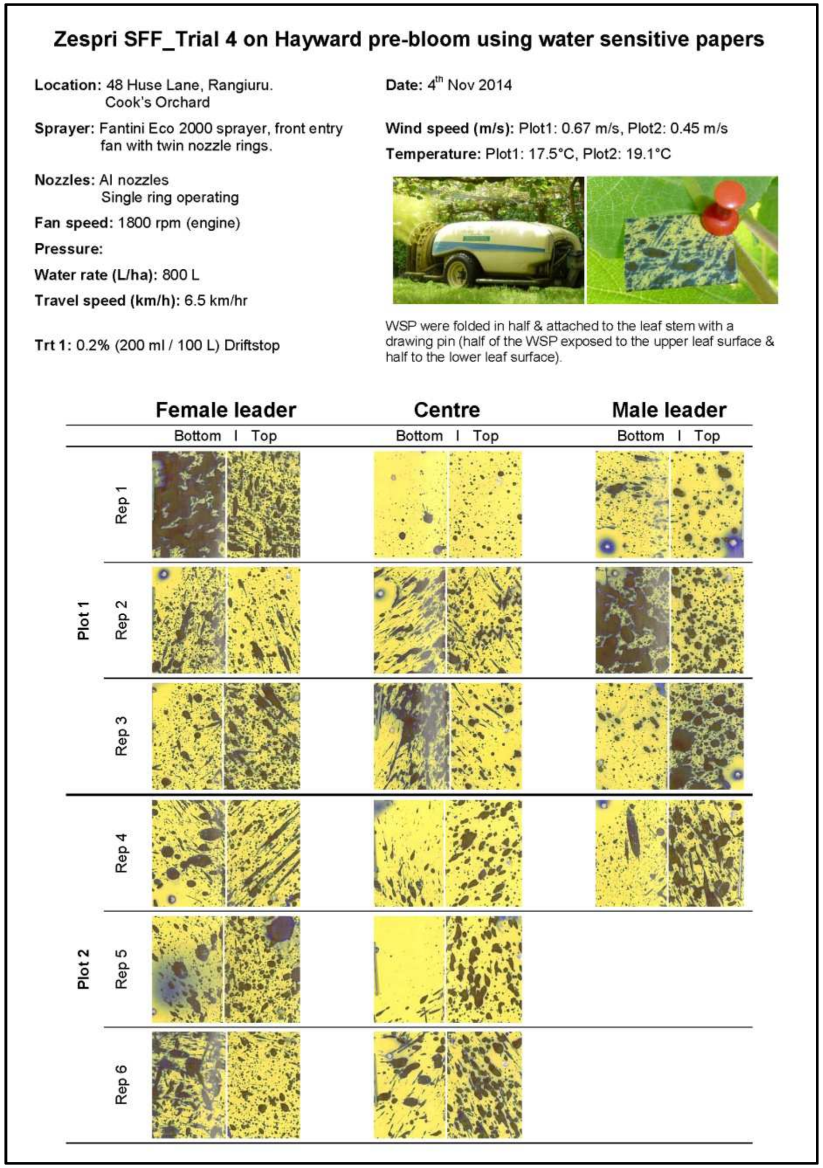


Fig. 22: Mean deposits on abaxial (bottom) leaf surfaces in four canopy zones

The results confirm that sprays applied through AI nozzles with a well setup sprayer can cover a managed pergola, pre-flower canopy equally as well as conventional fine droplet ATR nozzles. The exception is that male vines, with more dense canopies, cannot be adequately covered by typical sprays used at this time, even with a good sprayer setup.

Fig. 23: WSPs for Study 4, Treatments 1 & 2



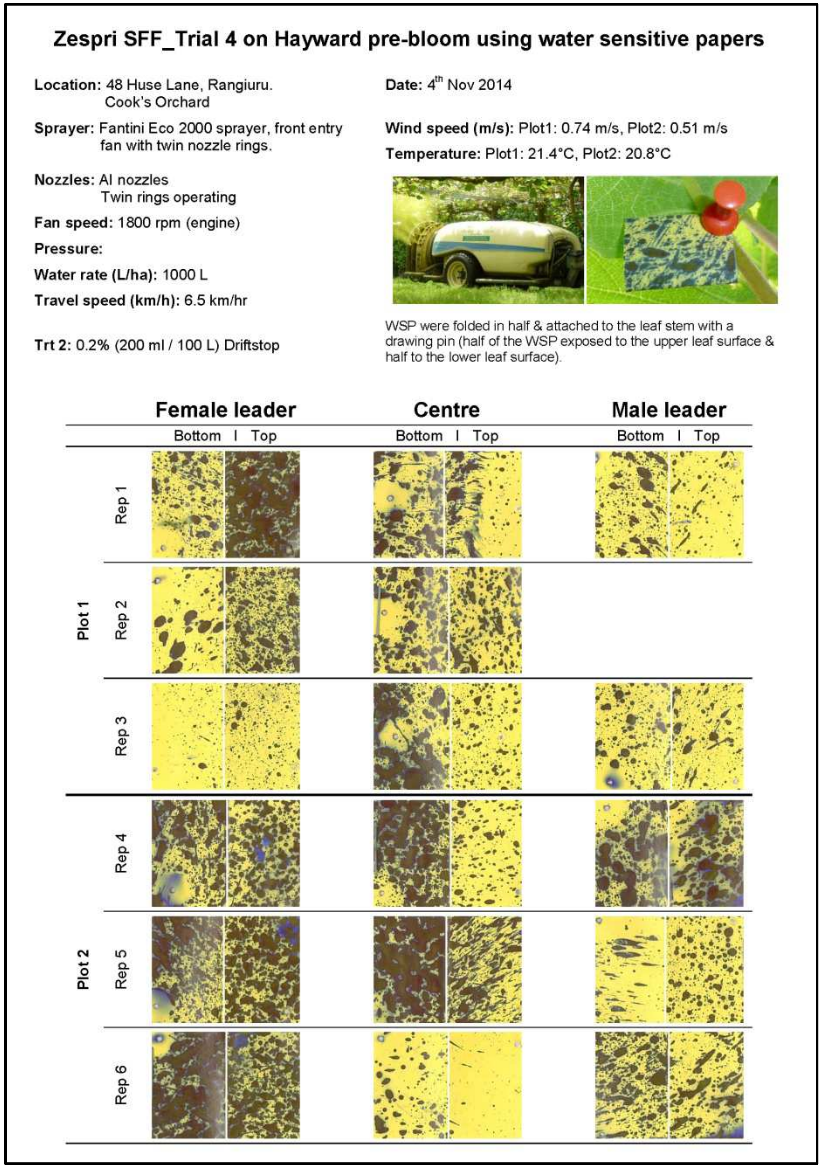
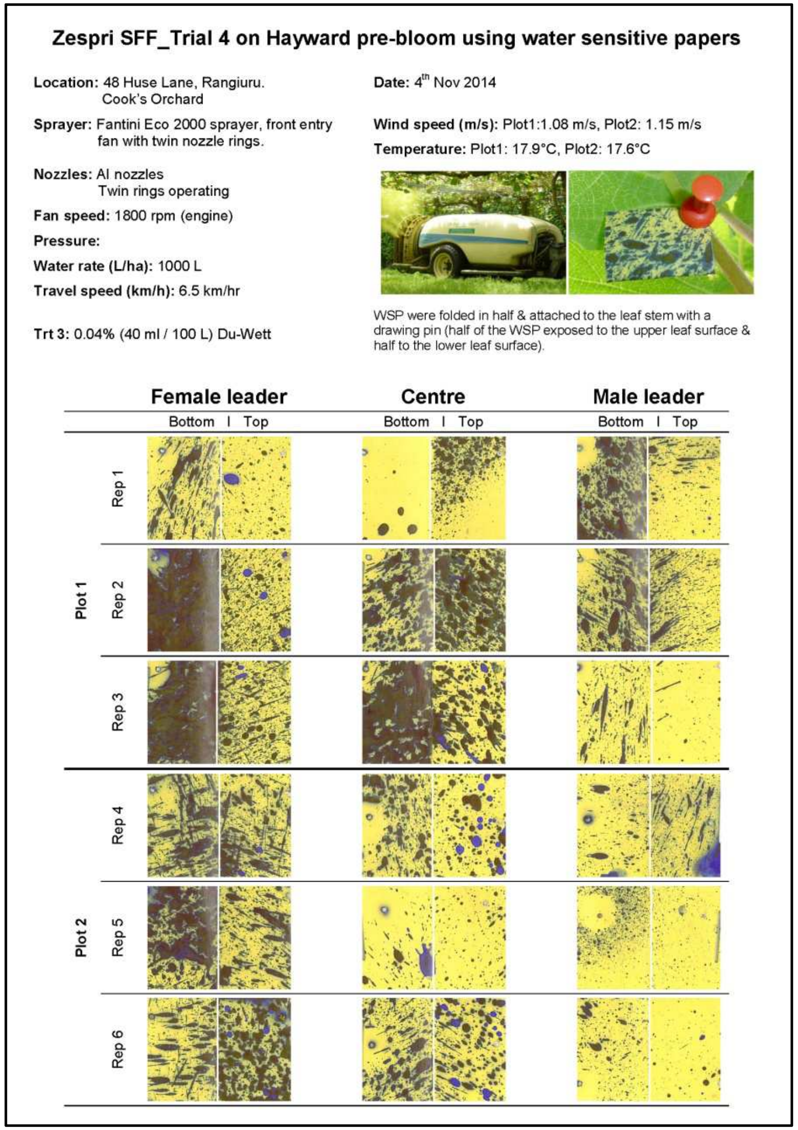
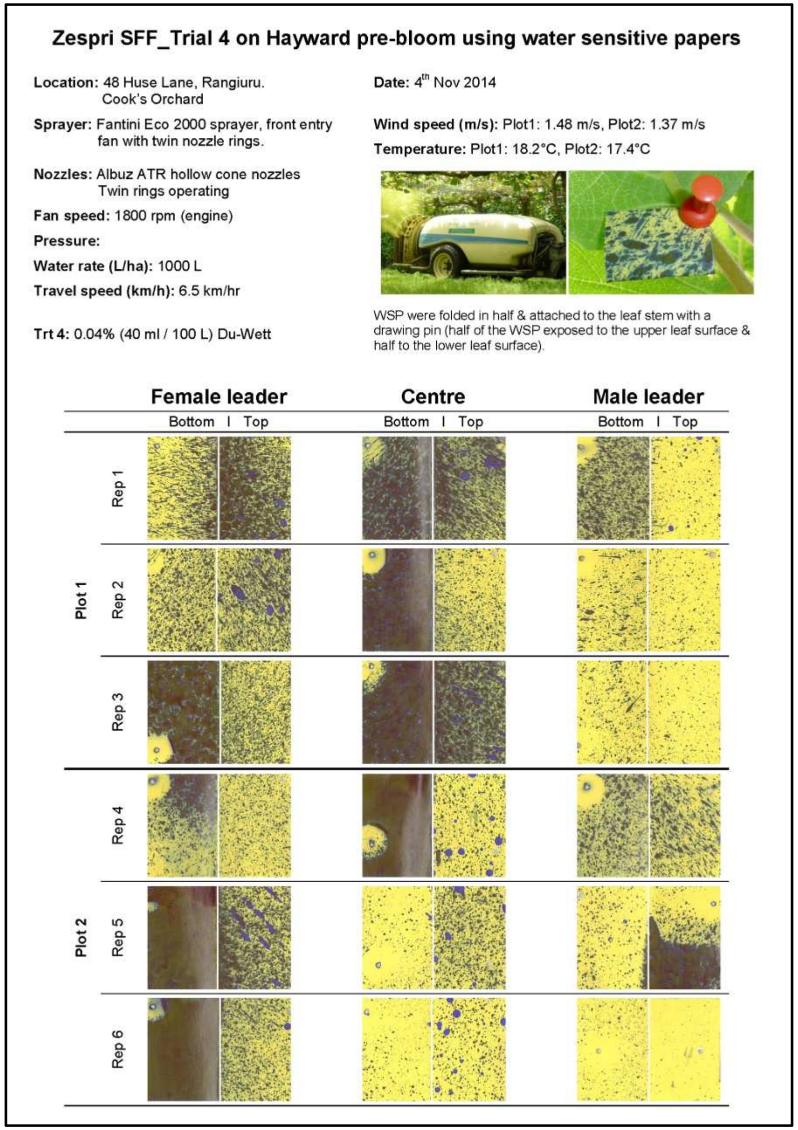


Fig. 24: WSPs for Study 4, Treatments 3 & 4





Study 5

UV visualisation of deposits on flowers and calyxes revealed generally better and more even distribution of sprays with ATR nozzles. Open flowers could be contacted and wet thoroughly by the Du-Wett sprays applied through either ATR or AI nozzles (Fig. 25), but the calyxes were very difficult to target by either spray. These appeared to have difficult-to-wet surfaces and be protected from sprays by their position. When calyx surfaces were contacted by sprays, the fine droplet ATR sprays appeared to do a better job of providing even deposits (Fig. 25).

ATR nozzles **AI nozzles**

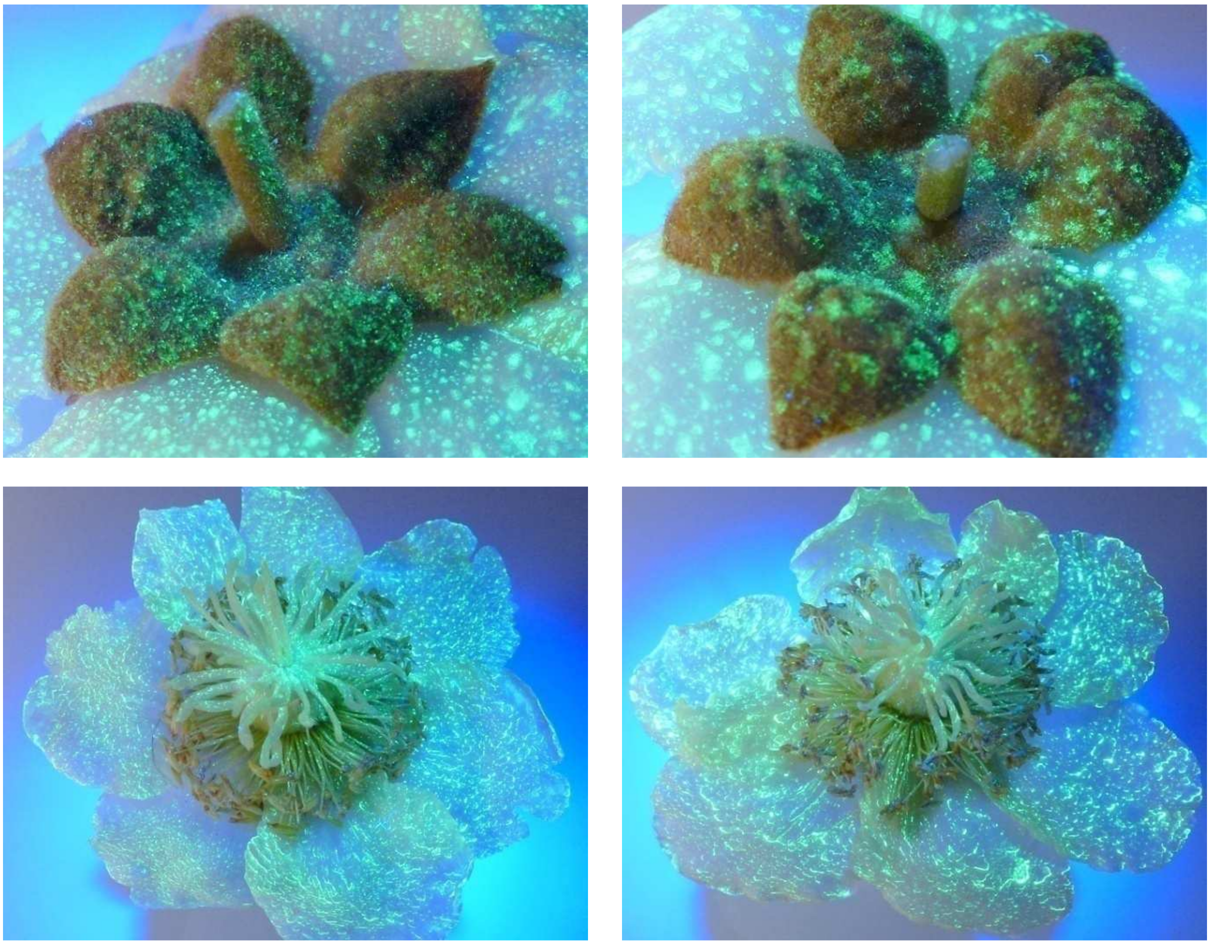


Fig. 25: Typical spray coverage of flower calyxes and open flowers sprayed by ATR and AI nozzles.

The female vines had increased in density (leaf layers; Table 7) since the deposit trial two weeks earlier (cf Table 5). While Du-Wett sprays applied through both the AI and ATR sprays could wet leaf surfaces thoroughly (Fig. 26), the WSPs indicated that the AI sprays were not contacting leaves in most zones as well as ATR sprays (Fig. 27). Female leader zones were well contacted by both sprays, but centre canopy and male leader lower canopy zones were targeted less well by AI sprays. As seen in the previous study, neither nozzle type managed to adequately target foliage in the dense upper canopy of the male leader (Fig. 27). It is probable that AI nozzles will perform less efficiently than ATR nozzles in delivering protectant sprays to flowering canopies.

ATR nozzles **AI nozzles**

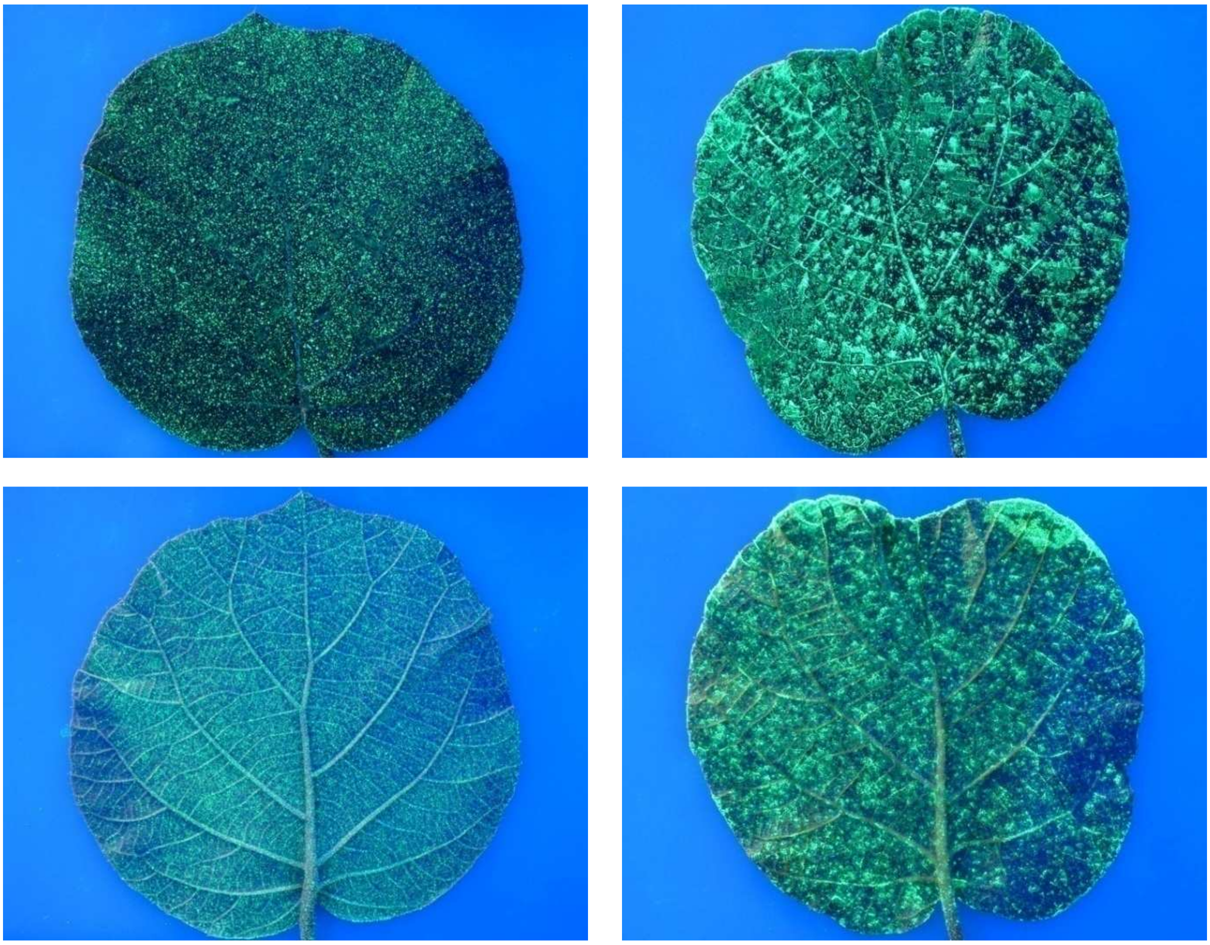
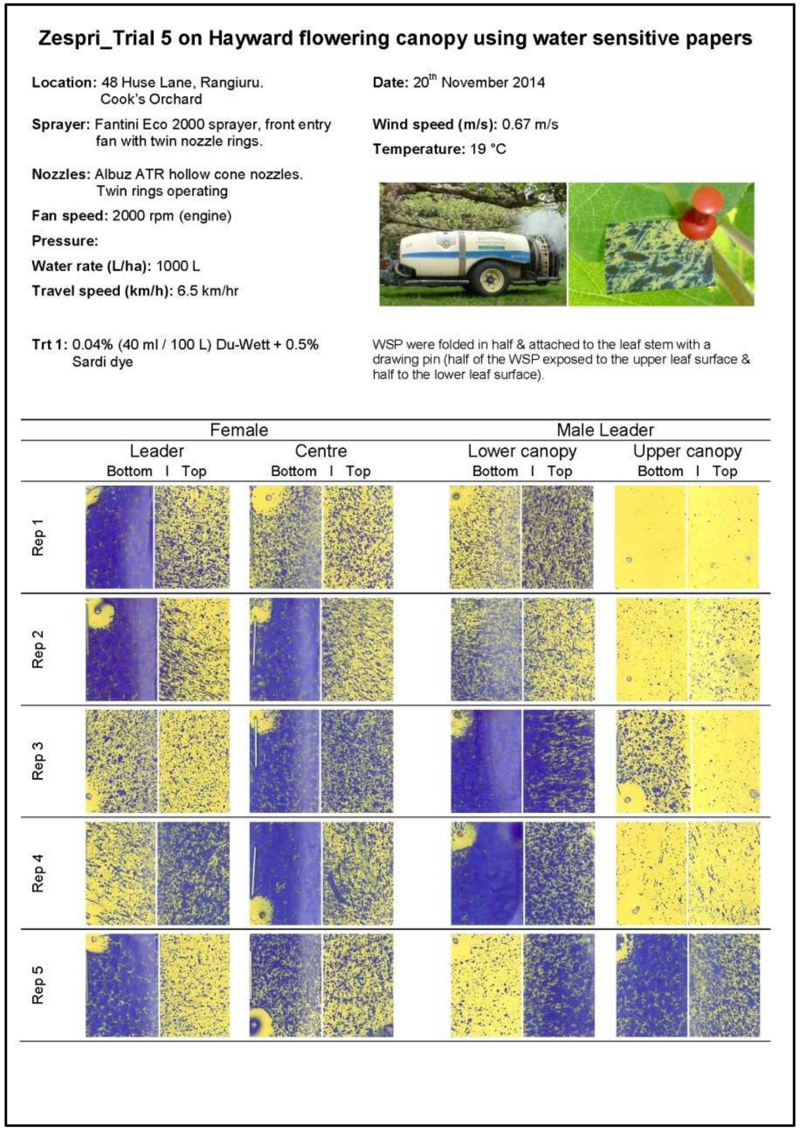
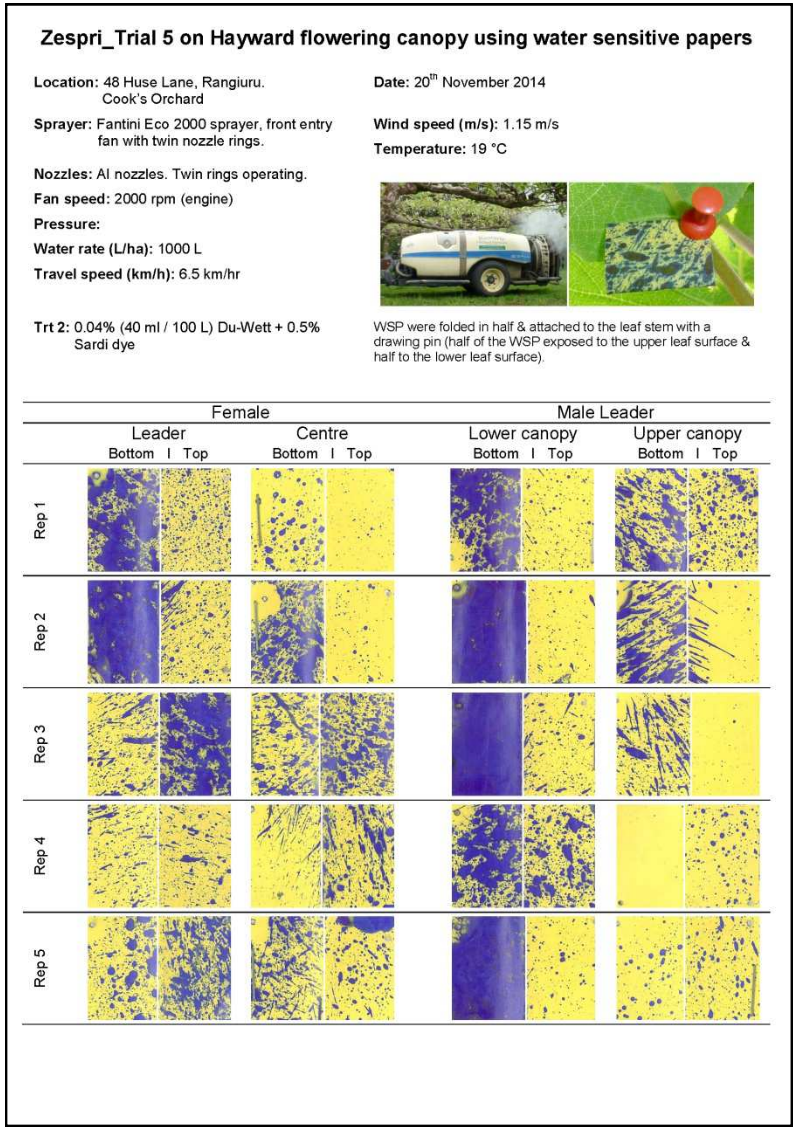


Fig. 26: Typical coverage of adaxial (top) and abaxial (bottom) leaf surfaces sprayed by ATR and AI nozzles.

Fig. 27: WSPs for Study 5, Treatments 1 & 2





Summer deposit study
This pre-harvest study on a G3 canopy confirmed results from previous work on Hayward and Hort 16A varieties; that concentrate and dilute sprays can target summer canopies equally well (Gaskin *et al*. 2010) and that dense pre-harvest canopies may often not be adequately protected in all zones by the airblast sprayer technologies currently used by growers (Gaskin *et al*. 2012).

Mean bulk deposits showed equivalency of concentrate and dilute sprays in all canopy zones (Table 12 & Fig. 28). This was confirmed by WSPs (Fig. 29). As expected, the lower and centre canopy positions were targeted best by sprays, and strung vines received unacceptably low deposits, from both dilute and concentrate applications (Table 12).

Table 12: Mean deposits (μg/cm^2, normalised to a 1 kg/ha application of tracer) on bulk leaves in all zones and canopy positions

Tmt	Spray vol. (L/ha)	Female vines					Tmt mean
		Leader upper	Leader lower	Centre upper	Centre lower	Strings	
Dilute	2000	0.67 c	1.03 b	0.65 c	1.39 a	0.20 d	**0.79 *A***
2x conc+DWett	1000	0.74 c	1.07 b	0.67 c	1.45 a	0.19 d	**0.82 *A***
mean		**0.71 C**	**1.05 B**	**0.66 C**	**1.42 A**	**0.20 D**	

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

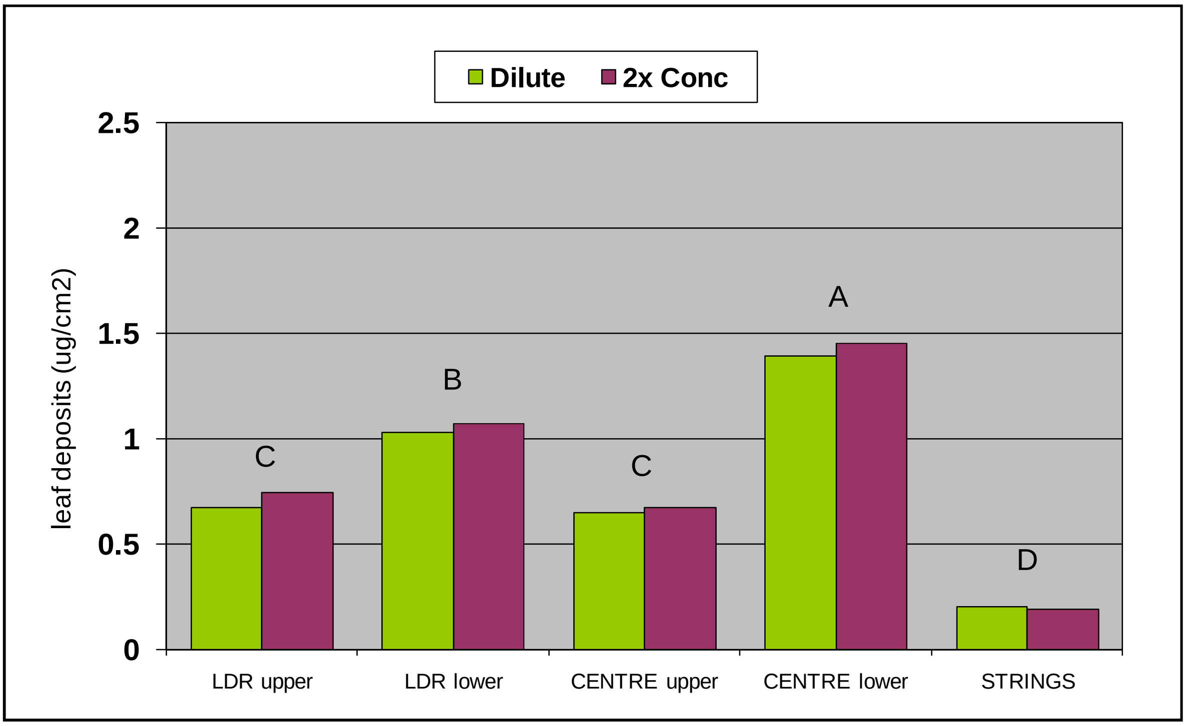


Fig. 28: Mean deposits on bulk G3 leaves, in dilute and 2x concentrate treatments, in all zone and canopy positions (zones sharing common letters are NSD, P<0.05)

Deposits on individual leaves (Table 13) confirmed the bulk deposit data, that there were no differences between dilute and concentrate spray applications. There was a difference between spray retained on top and bottom leaves (P=0.026) but this was entirely due to the high volume of spray retained on the bottom surface of leaves in the lower centre canopy zone, i.e. exposed directly to the sprayer. WSPs confirmed high spray volumes contacted the bottom surface of some of these leaves.

Table 13: Deposits (μg/cm^2, normalised to a 1 kg/ha application of dye) on top and bottom surfaces of individual leaves in four canopy zones.

Tmt	Spray vol. (L/ha)	**Leaf surface**	Leader		Centre row		**Tmt mean**
			upper canopy	lower canopy	upper canopy	lower canopy	
Dilute	2000	**top**	0.89 bc	0.61 c	0.57 c	0.90 bc	**1.00** ***A***
		bottom	0.49 c	1.04 bc	1.07 bc	2.50 a	
2x conc+DWett	1000	**top**	0.57 c	0.86 c	1.17 bc	0.80 c	**0.91** ***A***
		bottom	0.52 c	0.81 c	0.82 c	1.66 ab	
Mean			**0.62 C**	**0.83 B**	**0.91 B**	**1.46 A**	

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

Fig. 29: WSPs for Summer deposit study, Treatments 1 & 2

SFF_Trial 1 on Gold3 fruiting canopy using water sensitive papers

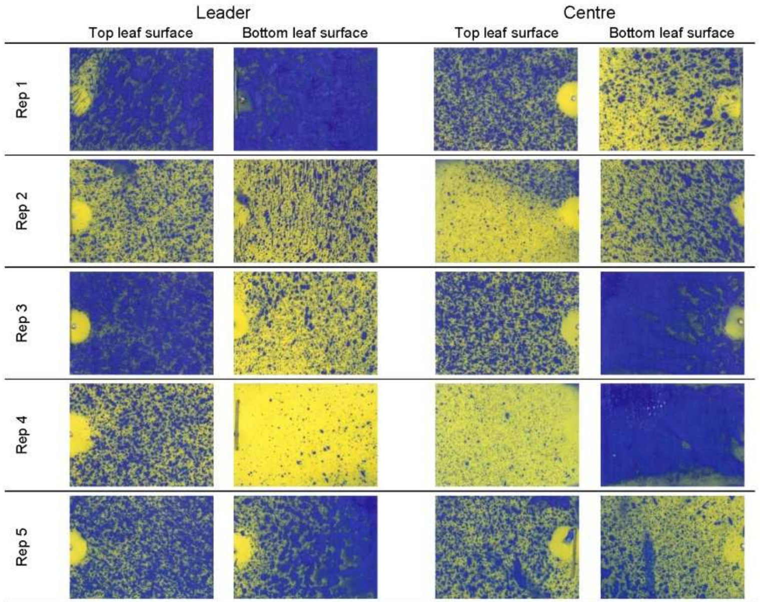
Location: 41 Mark Rd, Te Puke
Sprayer: Atom 2000 Evo.

Nozzles: Art. 58 nozzles.
Twin rings operating
Fan speed:
Pressure: 16 bar
Water rate (L/ha): 2000 L
Travel speed (km/h): 6 km/hr

Date: 25th March 2015
Wind speed (m/s): 0.3 m/s
Temperature: 24 °C

Water sensitive papers were cut in half. Half of the WSP was attached with a drawing pin to the upper surface of the leaf, and the other half to the lower surface of the same leaf.

Trt 1: dilute spray



SFF_Trial 1 on Gold3 fruiting canopy using water sensitive papers

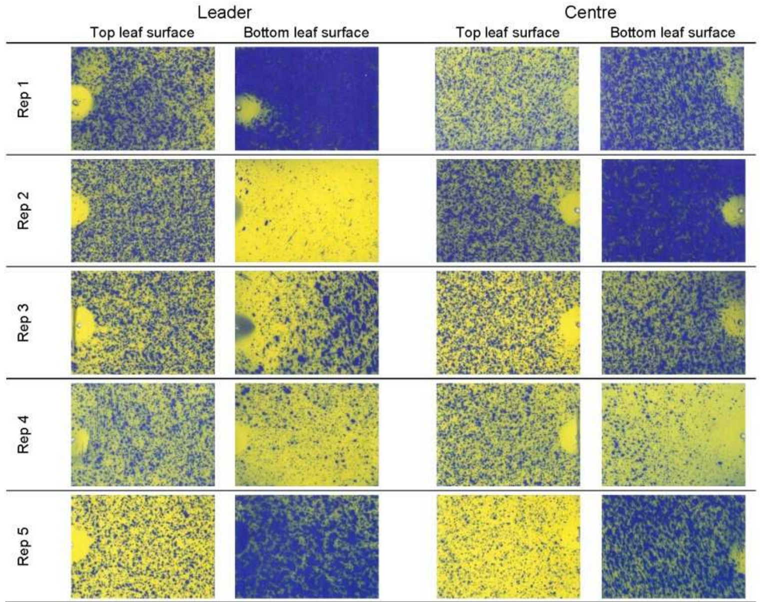
Location: 41 Mark Rd, Te Puke
Sprayer: Atom 2000 Evo.

Nozzles: Albuz ATR hollow cone &
Art. 58 nozzles.
Twin rings operating
Fan speed:
Pressure: 15.5 bar
Water rate (L/ha): 1000 L
Travel speed (km/h): 6 km/hr

Date: 25th March 2015
Wind speed (m/s): 0.3 m/s
Temperature: 28 °C

Water sensitive papers were cut in half. Half of the WSP was attached with a drawing pin to the upper surface of the leaf, and the other half to the lower surface of the same leaf.

Trt 2: conc spray + 0.04% Du-Wett (40 ml / 100 L)



CONCLUSIONS

<u>On spring canopies:</u>

- AI nozzles performed equally as well as conventional fine droplet ATR nozzles in delivering protectant sprays to pergola canopies, from budburst through to pre-flowering.

- AI nozzles visibly reduced off-target drift compared to fine droplet ATR nozzles, in sprays applied to expanding spring canopies.

- Large droplet AI sprays targeting expanding shoots should contain Driftstop adjuvant, at a suggested rate of 200 ml/100 L (0.2%), to maximise spray deposits and ensure surface coverage (spreading) of large droplets.

- AI sprays delivered at 800 L/ha targeted foliage equally as well as, or better than, AI sprays delivered at 1000 L/ha.

- AI sprays targeting flower buds may benefit from the preferential use of a better superspreader adjuvant (e.g. Du-Wett at 40 ml/100 L {0.04%}), rather than Driftstop.

- It is probable that AI nozzles will not deliver adequate deposits to protect open flowers and flowering canopies, due to the increased canopy density. More conventional fine droplet nozzles are recommended at this stage; coverage of target surfaces will benefit from use of a very good superspreading adjuvant (e.g. Du-Wett, 40 ml/100 L).

<u>On Gold3 summer/pre-harvest canopies:</u>

- 2x concentrate volume (1000 L/ha), with the addition of Du-Wett (400 ml/ha), performed equally to dilute volume (2000 L/ha) in delivering protectant sprays to all canopy zones.

- Both dilute and concentrate protectant sprays can provide equivalent good deposits on lower canopy zone foliage.

- Both dilute and concentrate protectant sprays can provide equivalent adequate deposits on foliage in upper canopy zones, dependent on canopy density.

- Both dilute and concentrate protectant sprays failed to provide adequate deposits on foliage of vines strung above the main canopy.

ACKNOWLEDGEMENTS

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APPENDIX 1 –
Sprayer setup and calibration notes for spring deposit studies comparing large droplet AI nozzles with fine droplet nozzles

Most kiwifruit sprayers are now fitted with a set of large droplet AI nozzles that are calibrated for application of hydrogen cyanamide. Hydrogen cyanamide is usually applied using a spray volume of between 600-700 L/ha and examples of recommended nozzle selections for different row spacings and for sprayers with different numbers of available nozzle positions have been published in technical bulletins and other industry publications on low drift spraying. Typical nozzle setups for pergola canopies use between one and three hollow cone (80^o output angle) Albuz TVI nozzles in the top section of the spray ring to target the mid row canopy. Another two or three flat fan (60^o and 40^o output angles) Agrotop TD nozzles are fitted in the lower part of the spray ring to project spray accurately to the vine leader zone and beyond.

The typical travel speeds used for hydrogen cyanamide applications are between 5-6.5 km/hr and typical nozzle operating pressures are in the range of 1000 to 2000 kPa. It is possible to deliver higher spray volumes from a standard hydrogen cyanamide nozzling by; 1) increasing nozzle pressures, 2) slowing down, 3) adding additional nozzles or 4) changing to larger output nozzles. It is possible to achieve a slight reduction in travel speed for any given gear selection by dropping tractor engine speed. Normal sprayer operating PTO speeds are 540 rpm, but it is usually practical to drop PTO speed by up to 20% (down to no less than 440 RPM) without compromising pump performance (most pumps on kiwifruit sprayers have the capacity to deliver spray volumes required for 2000 or more L/ha, so will still have ample capacity to deliver the volumes required for up to 1000 L/ha at reduced pump RPM). Dropping tractor engine and PTO speed will significantly reduce fan air delivery, but in most cases spring canopies require limitations in fan air delivery to avoid shoot damage, and slowing travel speed slightly can compensate for lower air delivery.

For gear driven tractors, the expected reduction in travel speed is directly proportional to any drop in engine RPM. For example if a tractor travels at 6 km/hr in a particular gear at 2000 engine RPM, a 10% drop in engine speed to 1800 RPM should deliver a travel speed of 5.4 km/hr. A 10% drop in travel speed for any given nozzle setup will deliver a 10% increase in spray application volume, so a delivery volume of 600 L/ha at 6 km/hr will be 660 L/ha at 5.4 km/hr.

The ceramic AI nozzles recommended for hydrogen cyanamide applications are capable of being used at nozzle operating pressures up to around 3000 kPa (ideally pressures up to 2500 kPa are better for pump and nozzle life). Increasing nozzle operating pressures will reduce spray droplet sizes from both conventional and AI nozzles. However, AI nozzles will still provide a significant spray drift reduction over conventional nozzles even when operated at higher pressures.

A combination of speed reduction with increased nozzle pressure allows typical AI nozzle setups for hydrogen cyanamide use to deliver up to ca. 850 L/ha. The range of potential spray delivery volumes from the single ring AI nozzle setup used in the spring studies reported here are shown in the table below. This simple option to increasing spray volumes is a cost effective way to potentially extend the use of an existing nozzle investment to help maintain spray coverage on developing spring canopies while achieving some spring spray drift risk reduction. This configuration was tested in the work reported here.

Many kiwifruit sprayers are now fitted with two sets of nozzle rings. An alternative approach to increasing spray application volumes from AI (or other) nozzles is to use two nozzle rings in combination. The addition of a second set of AI nozzles was tested in the spring spraying studies described in this report to achieve the 1000 L/ha treatments.

Table 1: Single nozzle ring low drift AI nozzle setup (as used in the spring deposit tests) and the potential range of spray application volumes that this setup can deliver through a combination of changing nozzle pressure and travel speeds.

TARGET APPLICATION VOLUME & SPEED

Target Volume	**600**	l/ha
	30	l/100m row
Target speed	**6.5**	km/hr
Row spacing	**5**	metres
Output required	**32.5**	**l/min total**
Note output below =	*32.5*	*l/min*

NOTES Single ring AI nozzle setup for kiwifruit low drift applicaton of hydrogen cyanamide

NOZZLING DETAILS

Nozzle pressure	**1450**	**kPa**	**210 PSI**	*1450 kpa required in theory*
Gauge pressure		**kPa**		

Description		Nozzle name	Predicted output	LHS l/min measured	RHS l/min measured	%	Cum%	Nozzle angle
Front ring	1	Off	0.00			0.0%	0%	0
Back ring	1b	TVI Lilac	2.20			13.5%	14%	80
Front ring	2	Off	0.00			0.0%	14%	0
Back ring	2b	TVI Blue	2.64			16.2%	30%	80
Front ring	3	Off	0.00			0.0%	30%	0
Back ring	3b	TD Red 60	3.52			21.6%	51%	60
Front ring	4	Off	0.00			0.0%	51%	0
Back ring	4b	TD Brown 40	4.39			27.0%	78%	40
Front ring	5	Off	0.00			0.0%	78%	0
Back ring	5b	TD Red 40	3.52			21.6%	100%	40
Front ring	6	Off	0.00			0.0%	100%	0
Back ring	6b	Off	0.00			0.0%	100%	0
Front ring	7	Off	0.00			0.0%	100%	0
Back ring	7b	Off	0.00			0.0%	100%	0
Output from one side (l/min)			**16.27**	**0.00**	**0.00**			

OUTPUT MATRIX 1 Speed X Pressure

	Pressure (kPa)				
	870	**1160**	**1450**	**1740**	**2030**
Speed (km/hr)	*Output (l/ha)*				
4.5	520	700	870	1040	1220
5.5	430	570	710	850	990
6.5	360	480	600	720	840
7.5	310	420	520	620	730
8.5	280	370	460	550	640

Table 2: Details of the twin nozzle ring setup with AI nozzles used to deliver 1000 L/ha in the spring deposit studies.

TARGET APPLICATION VOLUME & SPEED

Target Volume	1000	l/ha
	50	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*

NOTES Twin ring AI nozzle setup for kiwifruit low drift applicaton of hydrogen cyanamide

NOZZLING DETAILS

Nozzle pressure	1530	kPa	222 PSI	*1530 kpa required in theory*
Gauge pressure		kPa		

Description		Nozzle name	Predicted output	LHS l/min measured	RHS l/min measured	%	Cum%	Nozzle angle
Front ring	1	TVI Green	1.35			5.0%	5%	80
Back ring	1b	TVI Lilac	2.26			8.3%	13%	80
Front ring	2	TVI Yellow	1.81			6.7%	20%	80
Back ring	2b	TVI Blue	2.71			10.0%	30%	80
Front ring	3	TD Violet 60	2.26			8.3%	38%	60
Back ring	3b	TD Red 60	3.61			13.3%	52%	60
Front ring	4	TD Blue 40	2.71			10.0%	62%	40
Back ring	4b	TD Brown 40	4.51			16.7%	78%	40
Front ring	5	TD Violet 40	2.26			8.3%	87%	40
Back ring	5b	TD Red 40	3.61			13.3%	100%	40
Front ring	6	Off	0.00			0.0%	100%	0
Back ring	6b	Off	0.00			0.0%	100%	0
Front ring	7	Off	0.00			0.0%	100%	0
Back ring	7b	Off	0.00			0.0%	100%	0
Output from one side (l/min)			27.10	0.00	0.00			

OUTPUT MATRIX 1 Speed X Pressure

	Pressure (kPa)				
	918	1224	1530	1836	2142
Speed (km/hr)	*Output (l/ha)*				
4.5	870	1160	1450	1740	2030
5.5	710	940	1180	1420	1650
6.5	600	800	1000	1200	1400
7.5	520	700	870	1040	1220
8.5	460	620	770	920	1080

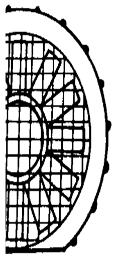
APPENDIX 2 - Sprayer setup for Summer deposit study in Gold3

Orchard	**M Holmes, Te Puke**
Description	**PPCNZ rate comparison**
Sprayer	**Atom 2000 EVO**
Year	**2015**

Calibration Summa

Spray-Tec Consultants Limited

Kiwifruit Pergola, 4.5m row sp
1000 l/ha (2 x concentrate) a
2000 l/ha "dilute" spraying



	1000 l/ha		% per nozzle	2000 l/ha		% per nozzle
	Tip/Core	Tip/Core		Tip/Core	Tip/Core	
1	A-orange	A-yellow	12	1.5/NCH	1.5/NCH	1
2	1.2/NCH	A-yellow	15	1.5/1.0	1.5/1.0	1
3	1.2/NCH	A-orange	16	1.5/1.0	1.5/1.0	19
4	1.5/NCH	A-orange	21	1.5/1.2	1.5/1.2	
5	1.2/1.0	D3/35	26	1.5/1.2	1.5/1.2	
6	----	D2/35	10	----	1.5/1.5	
7	----	----		----	----	
8	----	----		----	----	
	----	----		----	----	
	----	----		----	----	
Gauge Pressure	**15.6**	bar		**15.9**	bar	
Total Discharge	**45.0**	l/min		**90.0**	l/min	
Speed	6.0	km/hr		6.0	km/hr	

900mm 12 blade fan in "medium" pitch, 32.5 degrees. Approximately 30,000 cu. m. per hour output.

Using front and back nozzle galleries combined to utilise more nozzles and finer droplets.

Crop Details					Sprayer			Flow Monitor			Tractor: ATOM 2000			Speed
Spray	App Rate (l/ha)	Setup #	Dilute/ Conc	Switches	Nozzles	Fan	Pressure (bar)	Flow Cal	Circ/ Wheel		Ratio	Revs		km/hr
2000 l/ha **(dilute)**	2000	**11**	Dilute	**1 & 2**	2000 l/ha	In	16.0	680.0	475		**Low**	**1800**		**6.0**
1000 l/ha **(2 x concentrate)**	1000	**8**	Dilute	**1 & 2**	1000 l/ha	In	15.5	680.0	475		**Low**	**1800**		**6.0**

red ties	white ties
green ties	yellow ties
black ties	blue ties
Back ring	Front ring

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

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