Digital Viticulture Project: LiDAR and PACE For Vineyards

Andrew Hewitt, Chris O'Donnell, Bruce Llewellyn, Liao Juan

Heping Zhu. Many thanks to hosts (Sergi, TWE, Vineland Estates, Ballandean Estates, Savina Lane Wines) and equipment suppliers (Silvan, FMR)

Goals

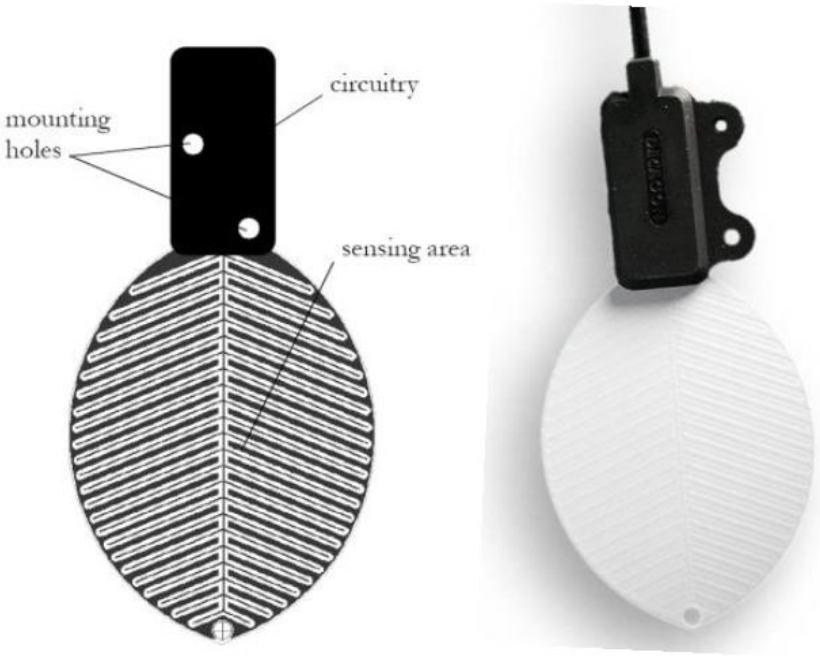
- Use Digital Systems (compared to current physical approaches) to optimise spraying for correct targeting and dosing in vineyards in different canopy conditions
- LiDAR and imaging sensors for canopy (instead of the human eye) – vertical and horizontal range spatially
- Electronic leaves for coverage assessments and auditing in real-time (instead of foliage and paper collectors which require post-analysis)

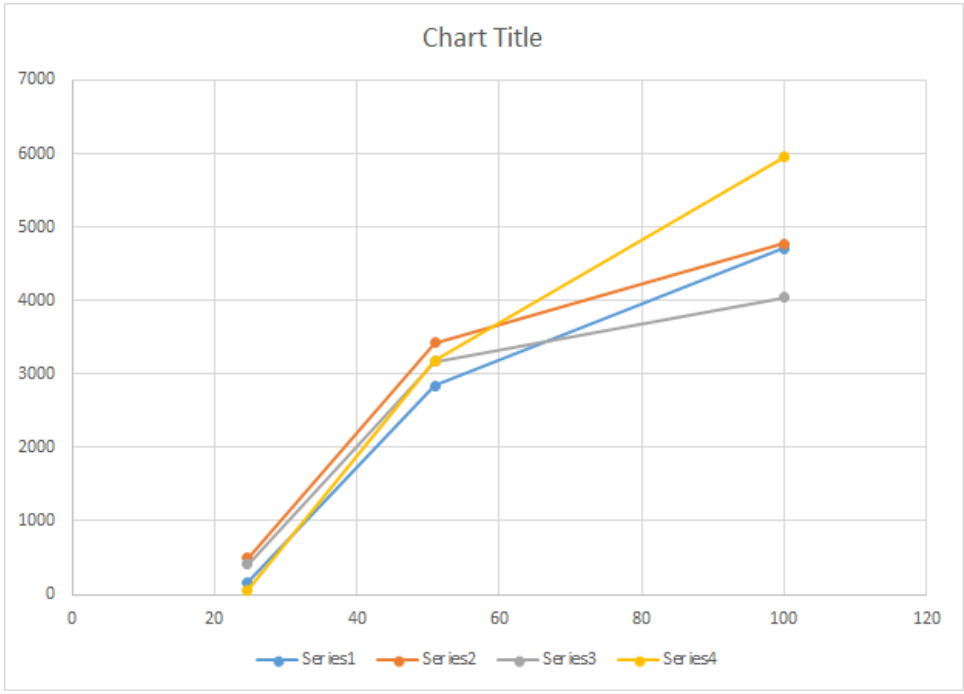
- Electrohydrodynamics for droplet attraction to leaves
- Different application platforms

Wind Tunnel Studies

- Testing sensors, sprayers, electronic leaves, electrostatics, and spray dynamics

Sensors for Spray Deposition on Leaves





Sensors for Spray Movement in and Beyond Vines

Field Studies

- Different growth stages from dormant to full canopy with fruit
- Table and wine grapes
- Two different approaches to optimised dosing:
  - Capturing/ recycling spray
  - Sensing target in 4D and adjusting spray direction/ location and rate in real-time

Recapture/ Recycle

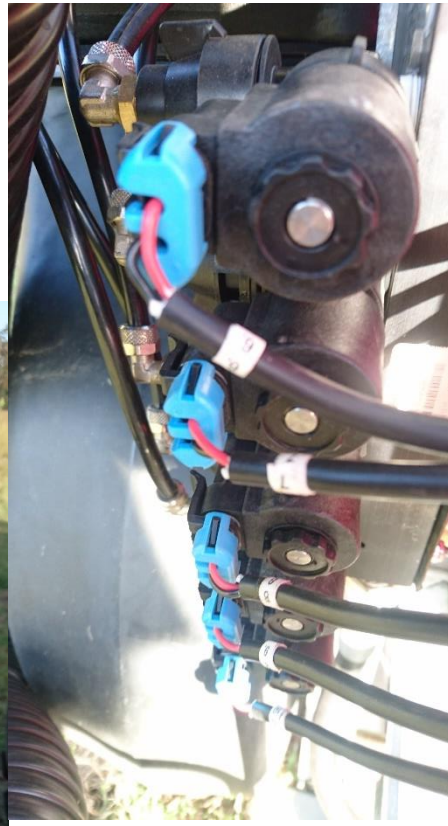
- Spray at normal volume rate for the canopy stage to achieve coverage to runoff, and reuse any spray that misses the target
- Benefit in terms of chemical reduction will tend to be inversely proportional to canopy density (and will increase with higher vine spacing/ gap frequency), though drift reduction is a large benefit at all times
- Requires specific equipment

Sensor Spraying

- Spray at normal volume rate for the canopy stage to achieve coverage to runoff, and turn spray on only when there is a target (foliage)
- Benefit in terms of chemical reduction will tend to be inversely proportional to canopy density (and will increase with higher vine spacing/ gap frequency), though drift reduction is always important
- Most sprayers can be modified by adding LiDAR

Silvan Oktopus Modified with LiDAR, Doppler RADAR and Pulsed Width Modulation

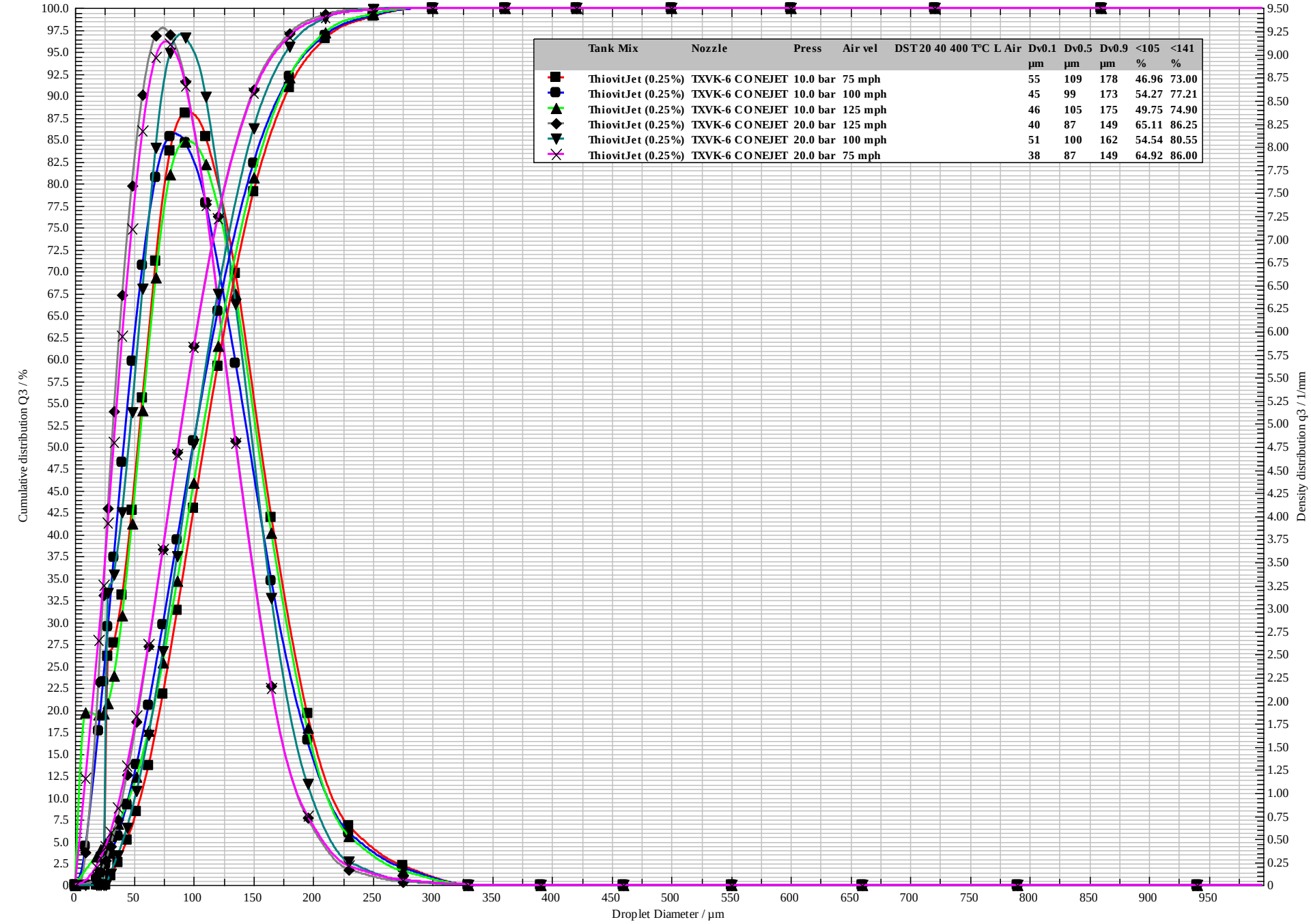
Nozzle angle
appropriate
for spray width
at target distance
e.g. 40 degree



Model No.	UTM-30LX
Power source	12VDC±10%(Current consumption:Max:1A,Normal:0.7A)
Light source	Semiconductor laser diode(λ=905nm) Laser safety Class 1(FDA)
Detection Range	0.1 to 30m(White Square Kent Sheet 500mm or more),Max.60m 270°
Accuracy	0.1 to 10m:±30mm, 10 to 30m:±50mm*1
Angular Resolution	0.25°(360°/1,440 steps)
Scan Time	25msec/scan
Sound level	Less than 25dB
Interface	USB2.0(Full Speed)
Synchronous output	NPN open collector
Command system	Exclusively designed command SCIP Ver.2.0
Connection	Power and Synchronous output:2m flying lead wire
	USB:2m cable with type-A connector
Amblent(Temperature /Humidity)	-10 to +50 degrees C, less than 85%RH(without dew and frost)
Vibration Resistance	Double amplitude 1.5mm 10 to 55Hz, 2 hours each in X, Y and Z direction
Impact Resistance	196m/s^2, 10 times in X, Y and Z direction
Weight	Approx. 370g(with cable attachment)

Sensing Top and Bottom of Canopy; Density

- LiDAR senses top and bottom of canopy without requiring human judgement
- Where some foliage sticks up intermittently, the sprayer turns on only at those times
- As most spray drift occurs from incorrect sprayer setup for targeting the top of the canopy, this helps avoid drift
- The row spacing is linked with the LiDAR data to estimate canopy width for dose rate adjustment and pulsed width modulation delivers the correct dose without changing spray pressure (and therefore droplet size). Each nozzle is controlled separately for on/off (target present/ absent) and variable rate (canopy width/ density)
- This is a true targeted and variable rate system (we are also adding dose/ coverage auditing via electronic leaves and warp-around coverage via electrostatics)

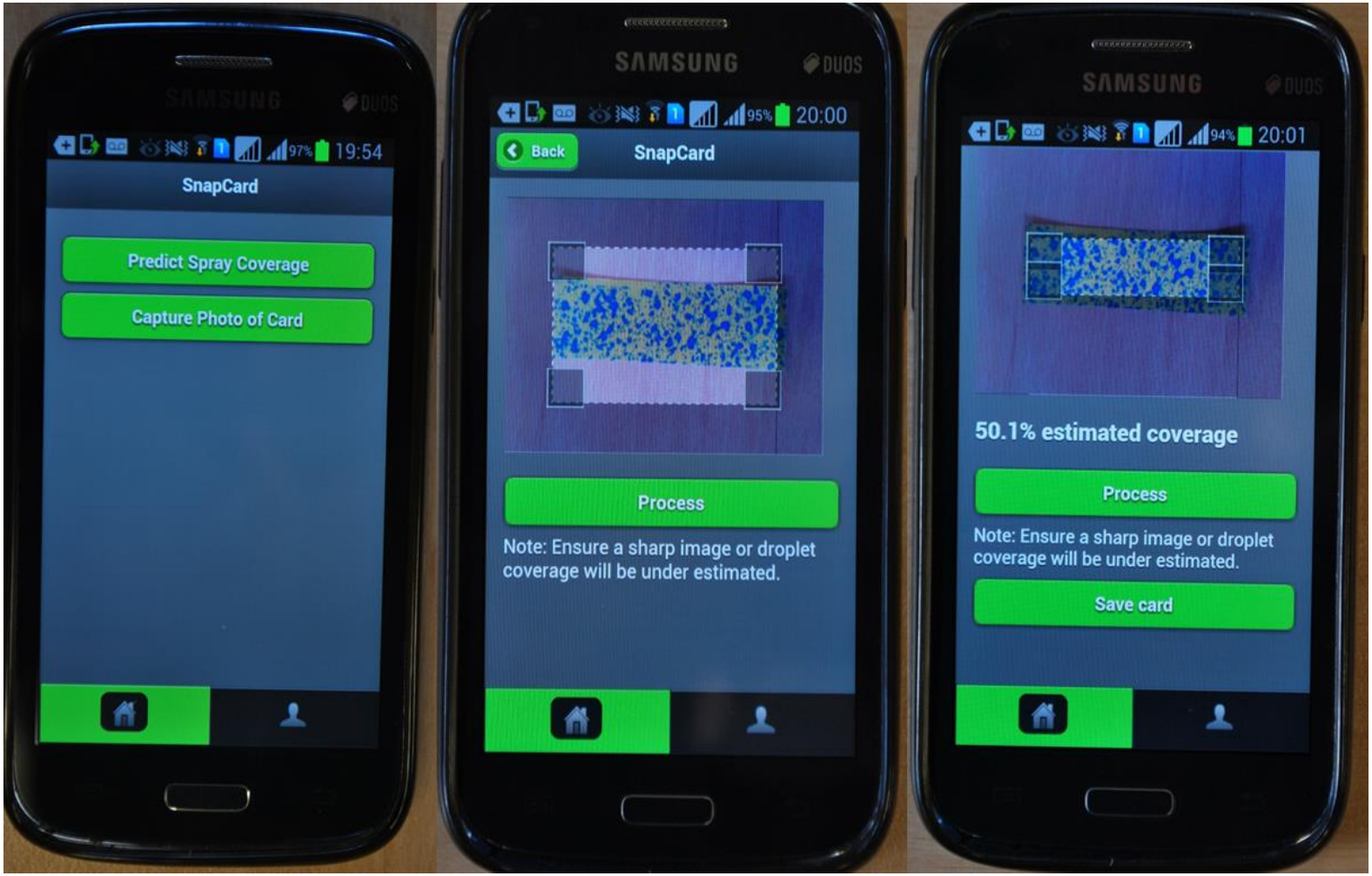

Tank Mix Nozzle Press Air vel DST 20 40 400 T°C L Air Dv0.1 µm Dv0.5 µm Dv0.9 µm <105 % <141 %
ThiovitJet (0.25%) TXVK-6 CONEJET 10.0 bar 75 mph 55 109 178 46.96 73.00
ThiovitJet (0.25%) TXVK-6 CONEJET 10.0 bar 100 mph 45 99 173 54.27 77.21
ThiovitJet (0.25%) TXVK-6 CONEJET 10.0 bar 125 mph 46 105 175 49.75 74.90
ThiovitJet (0.25%) TXVK-6 CONEJET 20.0 bar 125 mph 40 87 149 65.11 86.25
ThiovitJet (0.25%) TXVK-6 CONEJET 20.0 bar 100 mph 51 100 162 54.54 80.55
ThiovitJet (0.25%) TXVK-6 CONEJET 20.0 bar 75 mph 38 87 149 64.92 86.00
Cumulative distribution Q3 / %
Density distribution q3 / 1/mm
Droplet Diameter / µm

Field Studies

- Water sensitive cards for visual assessment of coverage on top and bottom of leaves (and dyes in some studies, e.g. for assessing losses through runoff and drift – but not usually with fruit on crops)
- Electronic leaves and PDI field lasers in some studies
- Flow meters to record total applied spray volume per treated area (usually 4 rows, per international standards and regulatory data needs)

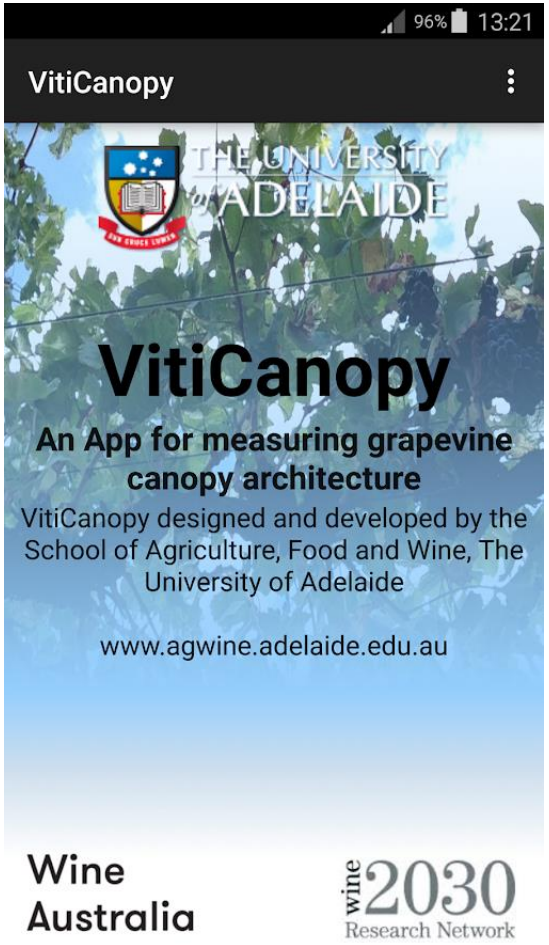
Water Sensitive Papers processed with Image Analysis System – cover, drop size

SnapCard also available for free for deposition assessments



Assessed Coverage at Top, Middle, Bottom of Canopy in Inner and Outer Areas. Also on vine trunks where 100% coverage is required for >60% control of Eutypa and Botryosphaeria dieback (SARDI)

Characterised Canopy with Measurements, Viticanopy, Imagery



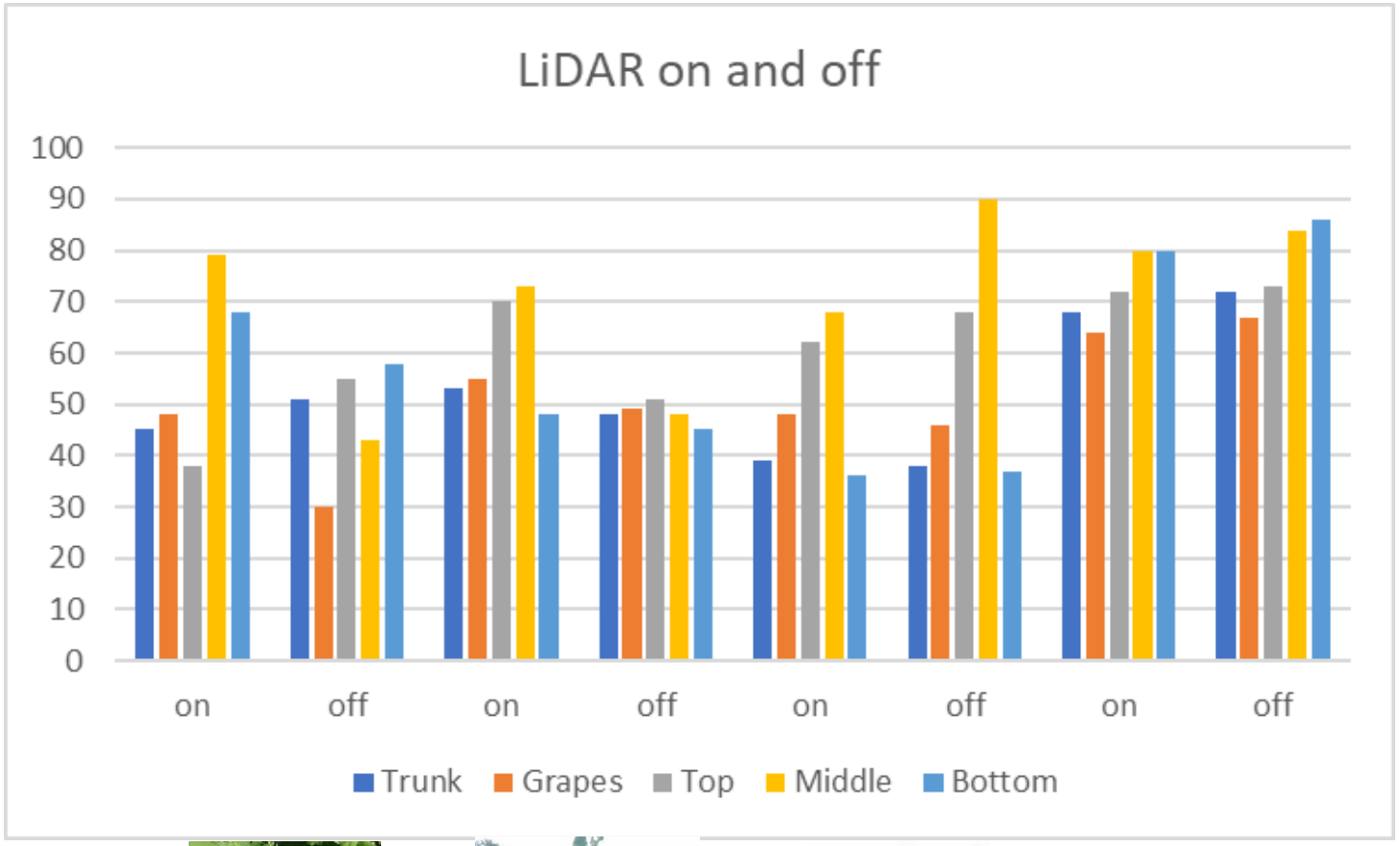
FILE	LAIE	LAI	CANOPY COVER	CROWN POROSITY	CLUMPING INDEX	GAP THRES	EXTINCTION	NUM DIV	TOTAL PIXEL	BIG GAPS	TOTAL GAPS
Triang	0.000439	0.002314	0.000309	0.00527	0.189657	0.75	0.7	25	307200	307105.13	307105.625
T8	1.622505	1.93756	0.8525	0.20373	0.837396	0.75	0.7	25	307200	45312	98666.5
T9	3.090516	3.422519	0.965931	0.083721	0.902994	0.75	0.7	25	307200	10466.125	35309
T10	0.00162	0.009506	0.001136	0.002864	0.170389	0.75	0.7	25	307200	306850.88	306851.875
T11	0	0.000233	0.99978	0.999919	0	0.75	0.7	25	307200	307175	307175
T11	0.000177	0.000898	0.000125	0.006515	0.197379	0.75	0.7	25	307200	307161.63	307161.875
T12	0	0.000641	0.999388	0.999776	0	0.75	0.7	25	307200	307131.13	307131.125
T13	0.000142	0.000636	0.000101	0.012097	0.223781	0.75	0.7	25	307200	307169	307169.375
T14	4.198383	4.198383	1	0.052926	1	0.75	0.7	25	307200	0	16258.75
T15	2.572789	2.572789	1	0.165142	1	0.75	0.7	25	307200	0	50731.5
T16	0	0.000205	0.999754	0.999928	0	0.75	0.7	25	307200	307178	307178
T2	3.259069	3.259069	1	0.102146	1	0.75	0.7	25	307200	0	31379.375
T17	3.097075	3.097075	1	0.114412	1	0.75	0.7	25	307200	0	35147.25
T18	2.810212	2.810212	1	0.139855	1	0.75	0.7	25	307200	0	42963.5
T19	0	0.000209	0.999791	0.999927	0	0.75	0.7	25	307200	307177.5	307177.5
T20	2.212363	2.3481	0.961418	0.180933	0.942193	0.75	0.7	25	307200	11852.375	65290.375
T21	2.534396	2.742518	0.960529	0.135518	0.924113	0.75	0.7	25	307200	12125.5	52113.375
vin1	1.505173	2.092557	0.763373	0.146777	0.719299	0.75	0.7	25	1228800	290767.38	428449.25
vin2	1.27551	1.824004	0.706424	0.164077	0.699291	0.75	0.7	25	1228800	360746.25	503174.25
vin3	2.25909	2.378223	0.967372	0.178904	0.949906	0.75	0.7	25	1228800	40093	252757.5
vin4	1.014512	1.307734	0.69401	0.267397	0.775779	0.75	0.7	25	1228800	376000.63	604036.625
vin6	1.549845	1.639335	0.938149	0.29429	0.94541	0.75	0.7	25	1228800	76002	415258.875
T3	3.730482	3.730482	1	0.073436	1	0.75	0.7	25	307200	0	22559.625
vin7	1.863988	1.942774	0.963888	0.243925	0.959447	0.75	0.7	25	1228800	44374.75	333286.25
vin8	1.712474	1.781432	0.960876	0.273138	0.961291	0.75	0.7	25	1228800	48076.125	370577
vin9	1.891711	2.189806	0.895828	0.180664	0.863871	0.75	0.7	25	1228800	128007	326880.875
vin10	1.552546	1.727927	0.893426	0.258249	0.898503	0.75	0.7	25	1228800	130957.63	414474.25
vin5	1.89093	2.17762	0.898598	0.183352	0.868347	0.75	0.7	25	1228800	124602.88	327059.625
vin11	1.615848	1.740804	0.925189	0.267912	0.928219	0.75	0.7	25	1228800	91927.25	396509.375
vin12	1.240849	1.447577	0.816492	0.289082	0.85719	0.75	0.7	25	1228800	225494.75	515532
BE1	1.919467	2.105474	0.929465	0.204809	0.911656	0.75	0.7	25	1228800	86673	320591
BE2	1.667437	1.732673	0.960406	0.28284	0.96235	0.75	0.7	25	1228800	48652.875	382446
BE3	1.183927	1.513885	0.740311	0.238962	0.782046	0.75	0.7	25	1228800	319106.13	536488
T4	2.939404	2.939404	1	0.127762	1	0.75	0.7	25	307200	0	39248.625
BE4	1.390697	1.664484	0.820636	0.241762	0.835513	0.75	0.7	25	1228800	220402.88	464195.375
BE5	1.397365	1.622692	0.84325	0.260011	0.86114	0.75	0.7	25	1228800	192614.25	462033.875
BE5	1.120772	1.679675	0.650305	0.163977	0.667255	0.75	0.7	25	1228800	429704.63	560737.625
BE6	0.986111	1.318554	0.663857	0.24899	0.747873	0.75	0.7	25	1228800	413052.38	616165.75
BE7	0.850459	1.080864	0.654851	0.314937	0.786833	0.75	0.7	25	1228800	424118.5	677542.125
BE8	0.855069	1.159106	0.614455	0.267008	0.737697	0.75	0.7	25	1228800	473757.13	675359.625
BE9	0.67627	0.867409	0.582536	0.352637	0.779644	0.75	0.7	25	1228800	512979.25	765404.375
BE10	1.059651	1.370218	0.703932	0.256004	0.773345	0.75	0.7	25	1228800	363808.25	585249.25
BD11	0.811004	1.135304	0.581327	0.254854	0.71435	0.75	0.7	25	1228800	514464.88	696515.75
BD12	0.667568	0.926617	0.527635	0.292492	0.720435	0.75	0.7	25	1228800	580441.88	770081.25
T4	0	0.000426	0.999572	0.999851	0	0.75	0.7	25	307200	307154.25	307154.25
BD13	0.951126	1.263828	0.657108	0.260195	0.752576	0.75	0.7	25	1228800	421345.25	631441.25
BD14	0.631347	0.833446	0.541785	0.340673	0.757514	0.75	0.7	25	1228800	563054.88	789856
BD15	0.818131	1.018669	0.660125	0.339527	0.803137	0.75	0.7	25	1228800	417638.88	693049.875
BD16	1.353905	1.653349	0.801562	0.236015	0.818887	0.75	0.7	25	1228800	243840.75	476305.625
D17	1.310865	1.571149	0.807165	0.256007	0.834335	0.75	0.7	25	1228800	236955.25	490874.25

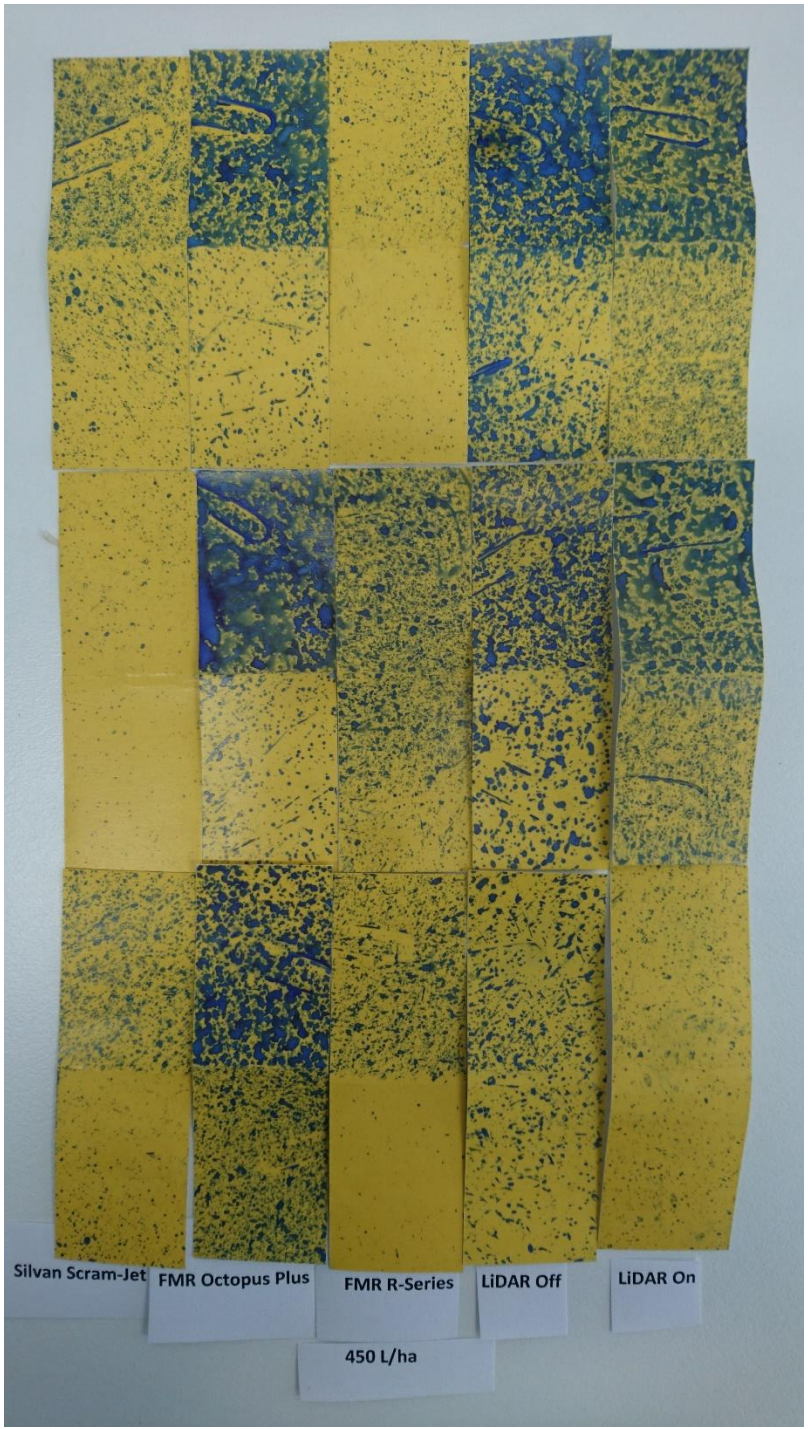
Silvan

Results

- Basically the “performance” of the LiDAR system will vary with sprayer type and setup because it offers the same coverage with LiDAR on versus LiDAR off, but with a lower chemical use rate when on. Future tests will fit the system to other sprayers than the Oktopus

Initial Tests LiDAR on v off. Savings in chemical 47-64%

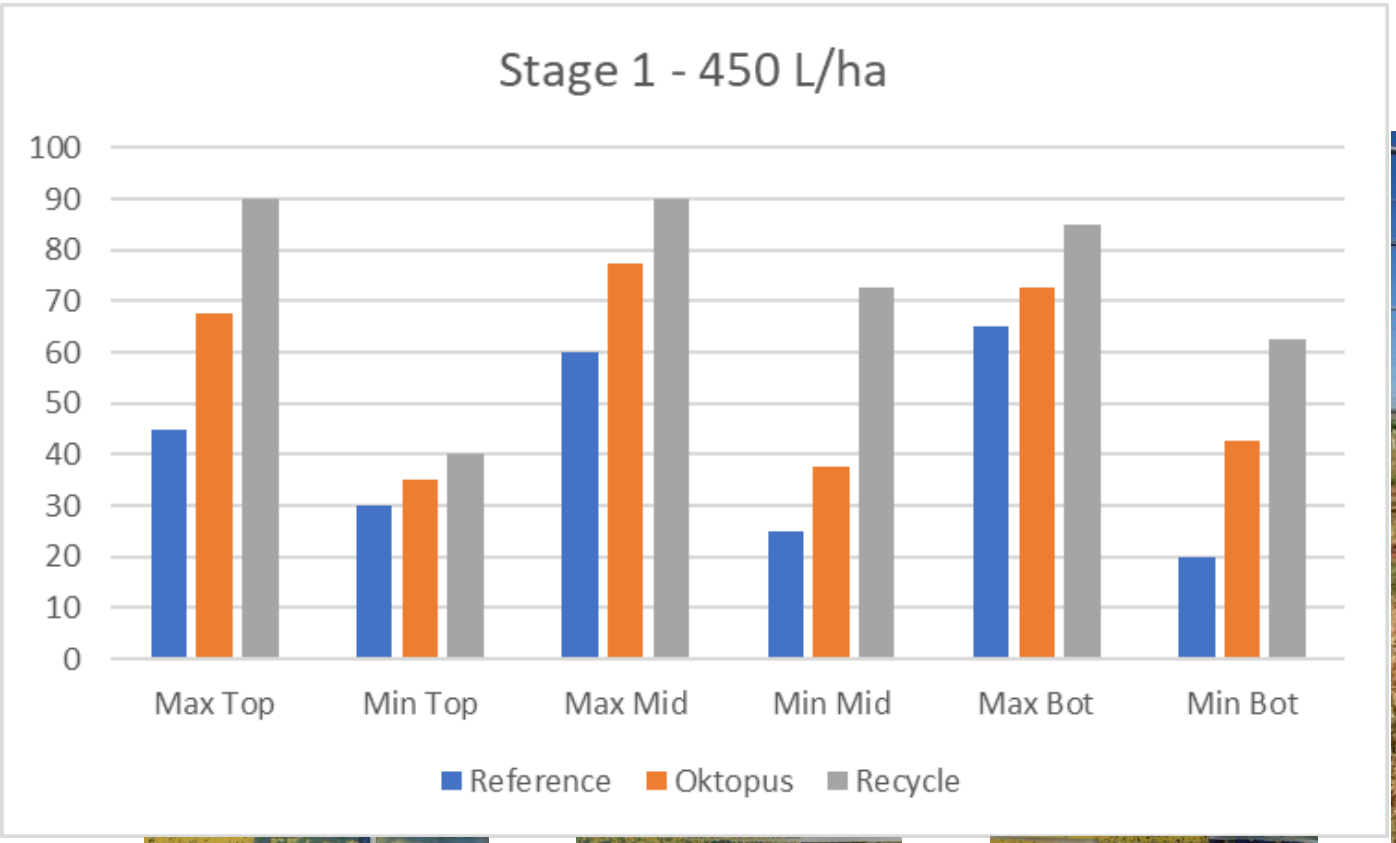



Silvan Scram-Jet
FMR Octopus Plus
FMR R-Series
LiDAR Off
LiDAR On
450 L/ha

Inner Canopy Coverage

- Stage 1 vines very small so can only present data for one canopy area – not inner v outer
- Minimum and maximum coverage allow assessment of lowest coverage relative to highest – i.e. we can look at areas where spray may not be sufficiently dense for intended disease/ pest control

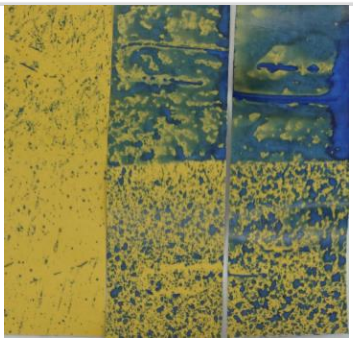
LiDAR Sprayer 70-90% less chemical
Recapture/ Recycle Sprayer 50-80% less chemical

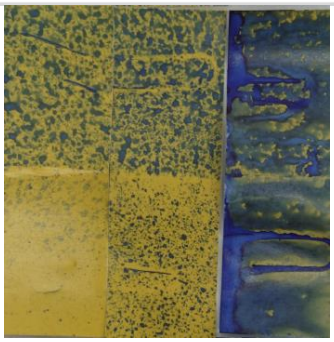


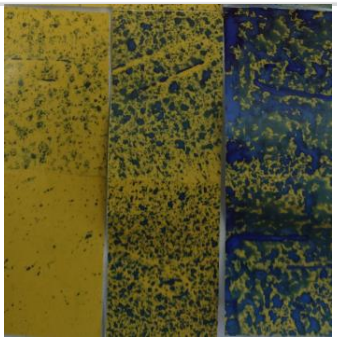
LAI 0.3-1.1

Max

Min

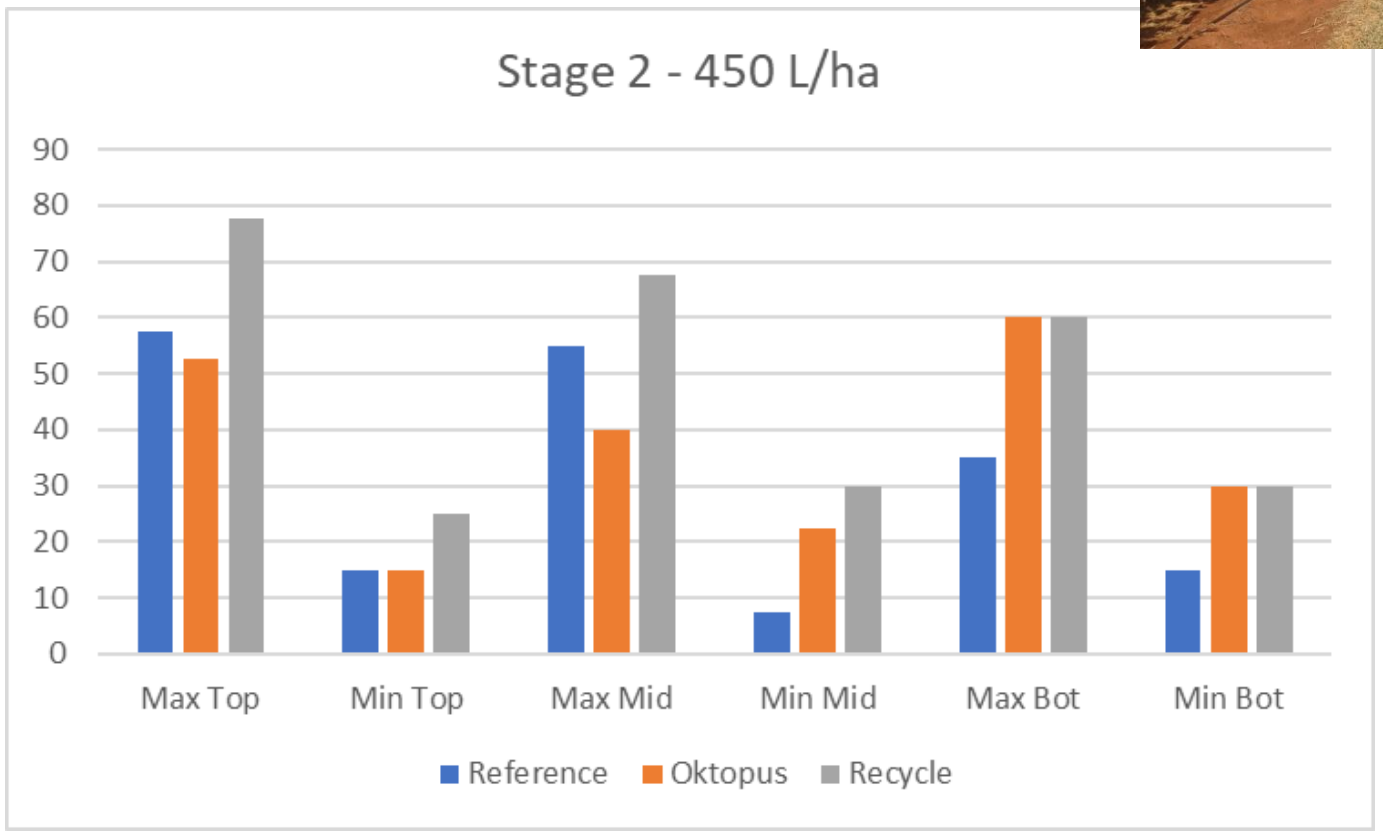






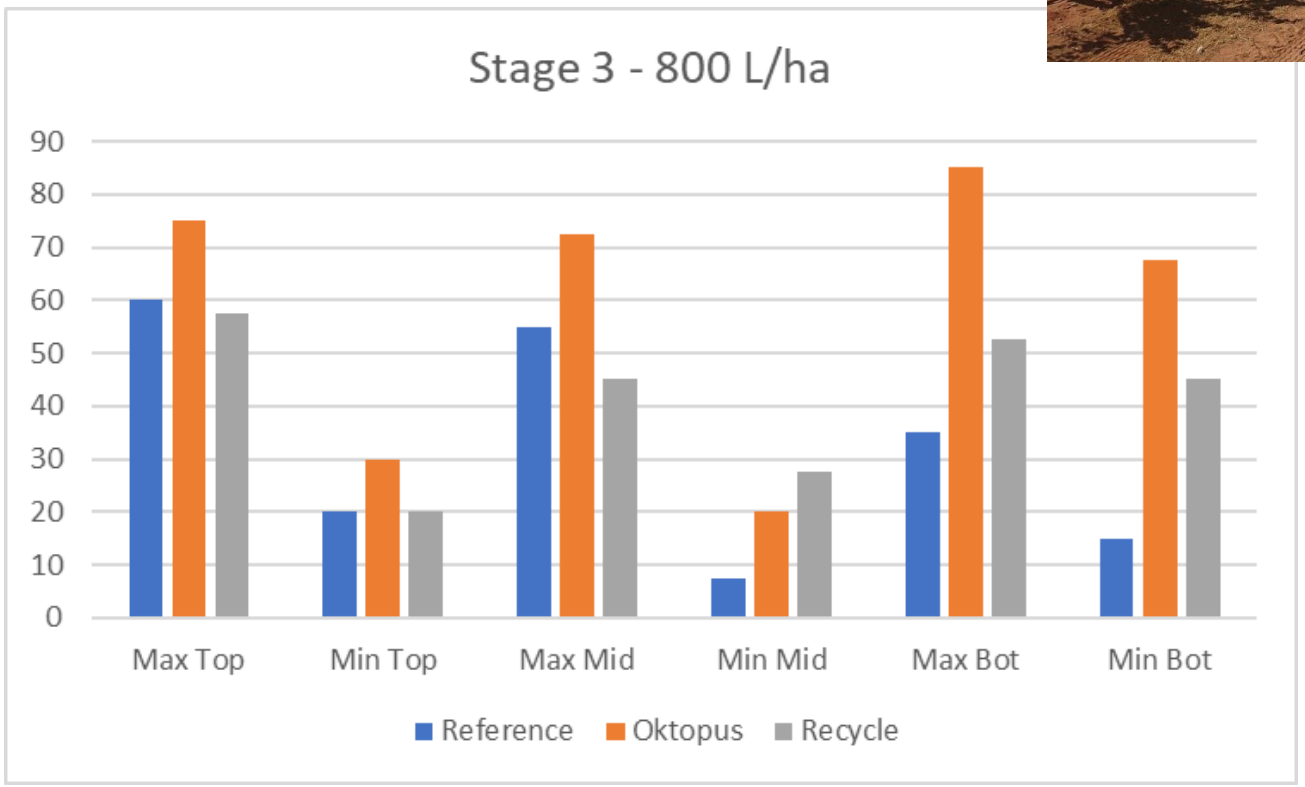
LiDAR Sprayer 60-80% less chemical
Recapture/ Recycle Sprayer 50-70% less chemical

LAI 1.3-2.3



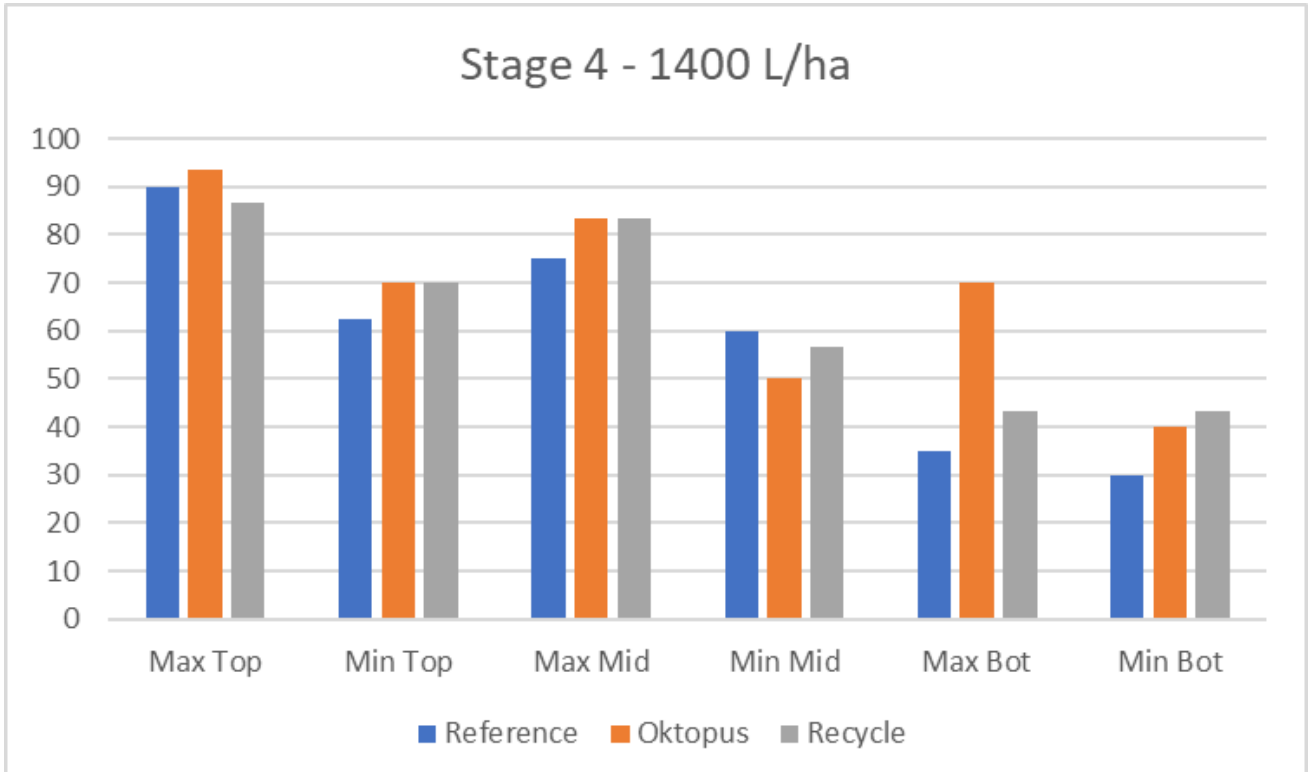
LiDAR Sprayer 40-60% less chemical
Recapture/ Recycle Sprayer 40-60% less chemical

LAI 1.4-2.6

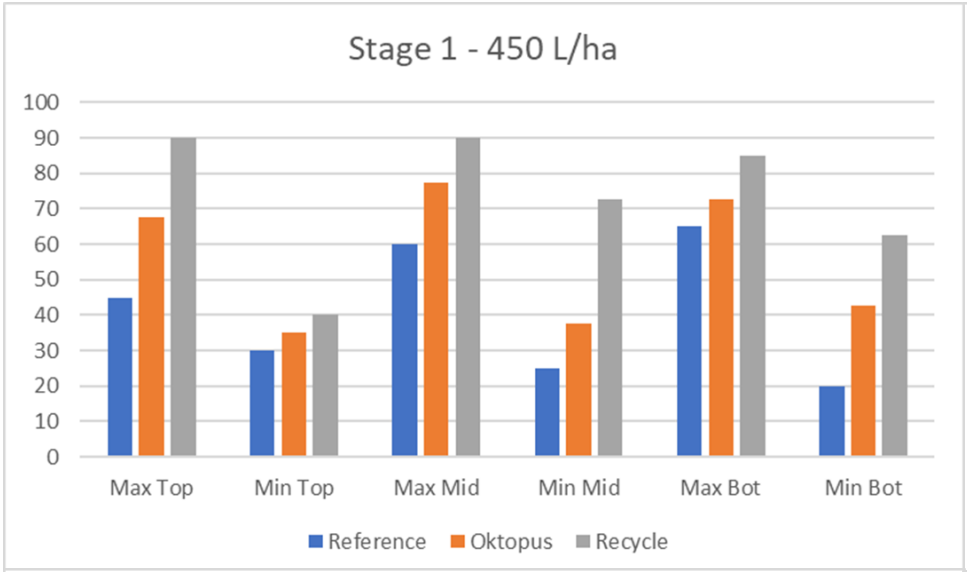


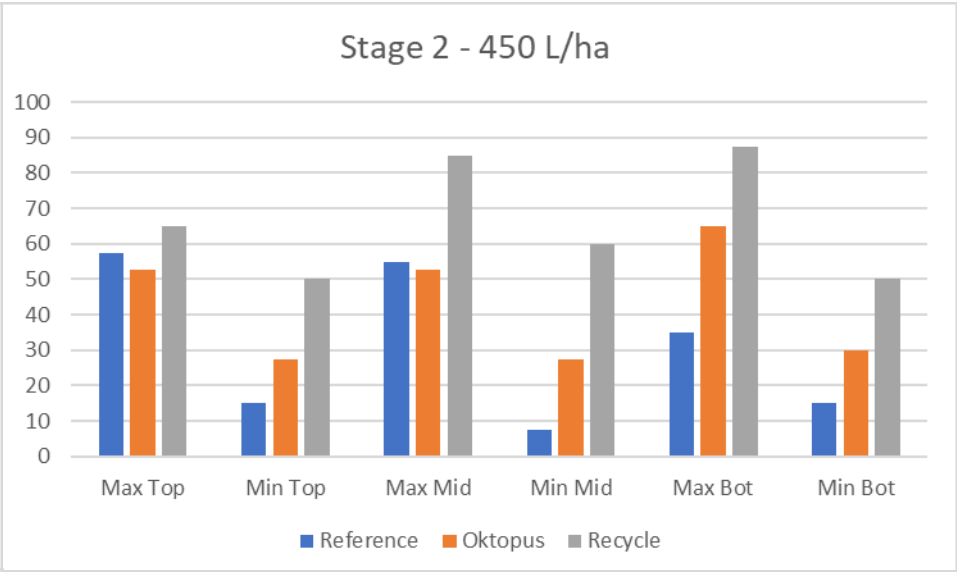
LiDAR Sprayer 10-50% less chemical
Recapture/ Recycle Sprayer 10-20% less chemical

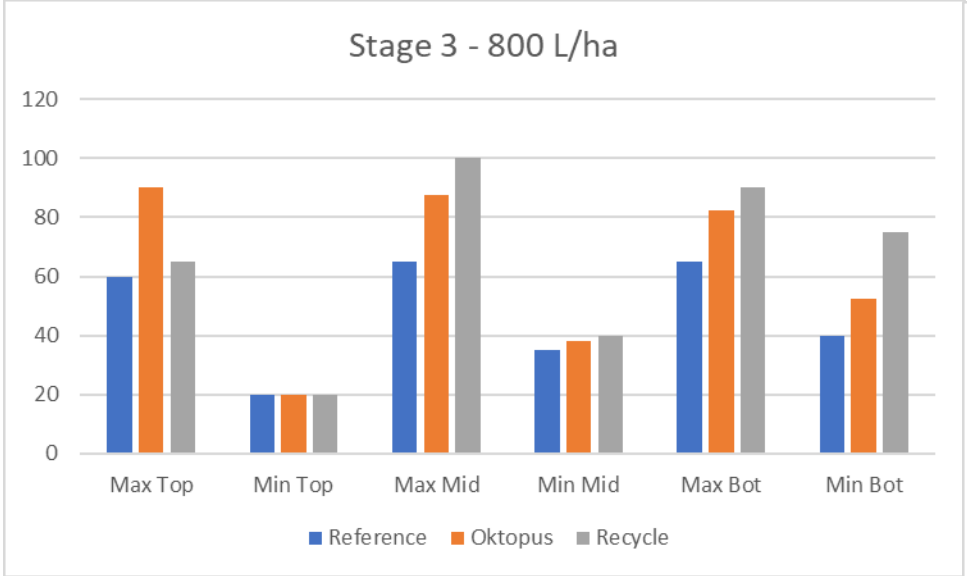
LAI 2.0-4.2

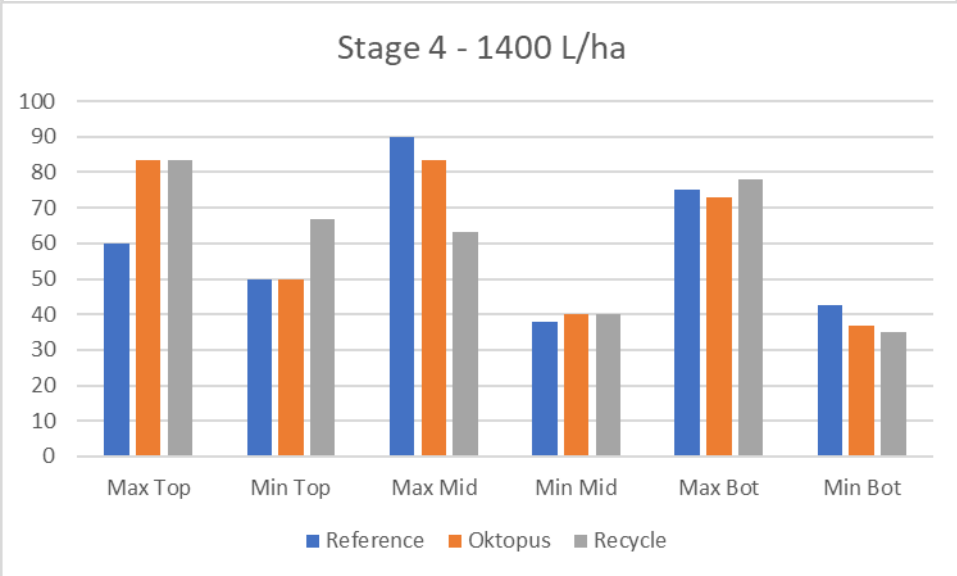


Outer Canopy Coverage









Conclusions

- Dose optimisation with high coverage can be achieved with recapture/ recycle spraying or LiDAR sensor systems but the spray rate must still be set close to that for the canopy (e.g. correct nozzle choice, driving speed etc are still important)
- Targeting can be optimised with sensors – especially to avoid drift by spraying above the top of the canopy which may vary spatially and temporally
- The benefit of dose optimisation and targeting is higher when the canopy is less dense and/ or has gaps and non-uniformity (e.g. early season)

Future Studies

- More field studies throughout season in wine and table grapes including:

  Robotic platforms (self driving sprayers/ UAVs)
  Electrostatics + LiDAR for coverage without drift
  Explore sensing fruit only for abscisic acid applications
  Fitting LiDAR system to other sprayers
  Progressing electronic leaf concept for spray auditing

- Bridging the LiDAR sprayer work to simpler dosing models using PACE (Pesticide Adjusted to the Crop Environment)

- Regulatory link with new APVMA drift policy and other pesticide exposure assessments. One main benefit of targeted, optimised dose systems is reduced exposure of humans, the environment and non-target areas to pesticides through lower chemical use rates and improved targeting (especially digital assessment of top of canopy which may vary both spatially and temporally and gaps and ends of rows)

Thank you

Wine Australia

Australian Government
Department of Agriculture and Water Resources

Hort Innovation

Sergi Vineyards
Treasury Wine Estates
Vineland Estates
Savina Lane Wines
Ballandean Estates

Silvan
FMR
Spectrum

USDA
NERCITA

CRDC

TWG/ NWPPA

Acknowledgement

This project is supported by Wine Australia, through funding from the Australian Government Department of Agriculture and Water Resources as part of its Rural R&D for Profit program and The University of Queensland