CFPA	SAAPPA / SASPA / SAT	DFTS	Winetech
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	X		

Indicate (X) client(s) to whom this final report is submitted.
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FINAL REPORT
FOR 2012

PROGRAMME & PROJECT LEADER INFORMATION

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PROJECT INFORMATION

Project number	A 01-10
Project title	Optimisation of chemical application to improve pome fruit disease and pest management
Project Keywords	

Industry programme	**CFPA**	
	Deciduous	X
	DFTS	
	Winetech	
	Other	

Fruit kind(s)	Apple
Start date (dd/mm/yyyy)	November 2009
End date (dd/mm/yyyy)	October 2012

(Note: adjust footer – insert the project number no, researcher and research institution)

FINAL REPORT

1. EXECUTIVE SUMMARY

Summary for 2012

- Deposition quantity was affected significantly by the applicator type and delivery energy.
- Deposition quantity varied according to the location of the fruit, as well as the leaves, within the tree canopy.
- Deposition quantity was not affected significantly by the ground speed.
- Standard energy delivery at 26,600 m^3/h generally resulted in higher spray deposition using the Atasa (+) Turret applicator system, compared to delivery at 45,600 m^3/h (high energy).
- Spray deposition was higher on fruit and leaves where a turret was added to the Atasa applicator.
- Deposition quantity levels were generally higher on fruit and leaves using the Atasa applicator, compared to the Cima, both with a turret added to the system. It though needs to be noted that adaptations have been made for the 2012 trials, to improve deposition with the Atasa system.
- Deposition quantity was higher for most applicator types, especially the Atasa (+)Turret, on top fruit and leaves, as well as outer fruit and leaves, compared to the same two target sites at the bottom and inner position of the tree canopy.
- Differences between top and bottom and between inner and outer target surfaces were higher for standard energy delivery compared to high energy, as well as the Atasa (+)Turret compared to the Cima (+)Turret. This finding corresponds to the quantity delivered to the different target surfaces.

Summary for 2011

- Deposition quantity, efficiency and uniformity of spray applications of leaves and fruit of Pink Lady apples were affected by applicator type, use of a turret, energy delivery level and droplet size, all relative to each other, with specific advantageous attributes on leaves and fruit.
- Deposition quantity and efficiency was higher on outer leaves, at the bottom of the tree.
- Deposition quantity and efficiency improved with a Turret affixed to the Atasa sprayer.
- Quantity and efficiency generally better with use of the Cima applicator (+)Turret, than the Atasa with or without Turret.
- Quantity and efficiency not affected by droplet size.
- Deposition quantity and efficiency only affected by energy delivery level with use of the Atasa (+)Turret spray system, with higher deposition quantity achieved with the Std. energy application than Reduced energy.

Summary for 2010

- Deposition quantity and quality, as well as spray uniformity and efficiency on leaves and fruit of Pink Lady apples sprayed in the orchard, were significantly affected by applicator type, spray volume, tree height and canopy depth.

- Deposition quantity was higher at the top or centre of the tree, across applicators.
- The Atasa (+) turret generally deposited more product on outer fruit and leaves than the Cima (+) turret.
- The Atasa (-) turret showed a tendency to deposit more product on the outer leaves and fruit in the centre of the tree, compared to the Atasa (+) turret.
- Generally, results for deposition quality were the inverse of deposition quantity.
- Deposition quality was better with the Cima (+) turret at the top and centre on outer leaves and fruit than both the Atasa applicators, most likely since the latter applicators deposited more product at these zones.
- High volume spraying deposited more product onto fruit and leaves, especially in the outer position on the tree.
- The quantity of deposition on inner leaves was not affected by the applicator type.
- The use of a turret along with the applicator could generally ensure deposition of more product on inner leaves and fruit.
- Low volume spraying generally resulted in better deposition quality than high volume at the top and centre of the tree.
- Spray efficiency was better for the Cima (+) turret at low volume application, while better for the Atasa (+) turret at high volume.
- Spray efficiency was higher at the top and centre of the tree than at the bottom for high volume application.
- Spray uniformity, a function of deposition quantity and the coefficient of variation, was generally better for high than low volume application.
- Spray uniformity was least affected by volume variation with use of the Cima applicator.

Summary across seasons (2010, 2011 & 2012)

- The study across the years showed that spray deposition of a chemical is dependent on various parameters, such as applicator type, spray volume, energy delivery and droplet size, with further differences likely to occur depending on the location of the target surface, not to mention the effect of timing, whether conditions, fruit kind, trellis systems and horticulture practices, etc.
- The findings imply that efficacy of sprays could vary depending on the various spray factors outlined above.
- The importance of spray management and understanding the effect of certain parameters may have on spray deposition and hence, are clearly shown across seasons in different trials.

2. Problem identification and objectives

Adequate spray deposition on susceptible tissue is an essential requirement for effective chemical control of economically important pre- and post-harvest pome fruit pests and diseases. Practical management by chemical application relies almost exclusively on well-timed and/or routine fungicide/insecticide applications. However, given favourable environmental conditions and

insufficient chemical deposition, severe crop losses are experienced. Research regarding spray application to ensure efficient spray deposition recovery is needed to ensure more effective disease management on pome fruit.

The objectives of this study were to use protocols recently developed by University of Stellenbosch Plant Pathology (USPP) to assess deposition quantity and quality, and spray efficiency and spray uniformity, to evaluate methods for improved spray application in pome fruit orchards by determining the **effect of spray volume and applicator types in effective disease and pest management on apple trees.** The study was conducted in collaboration with the USPP, who supplied microscopic analysis of the samples, Thanks is expressed to Mr Gideon van Zyl and Dr Paul Fourie for their inputs in the study.

Milestones and date expected that these milestones be reached

1. Evaluate spray volume and applicator technology in a commercial apple orchard for improved deposition on leaves and fruit (2009-2010). Qualitative deposition, quantitative deposition, spray efficiency and spray uniformity were evaluated for spray applications.
2. Evaluate applicator type and droplet size at reduced energy and low volume application, to improve spray applications on leaves and fruit (2010-2011). Quantitative deposition, spray efficiency and spray uniformity were evaluated for spray applications.
3. Evaluate applicator technology, air volume / energy delivery and ground speed for best practice and the effect on quantitative deposition on leaves and fruit (2011-2012).

3. Workplan (materials & methods)

Cultivar

Pink Lady apple trees

Trial site

A commercial Pink Lady apple orchard at Oakvalley Farm (G 83) in the Western Cape, Elgin area, was used to conduct the spray trial.

Treatments

Table 1 : Treatment combinations for: applicator technology x air volume / energy delivery x ground speed, used for the evaluation of spray deposition on leaf and fruit surfaces (all applications were done at low volume spraying of 586 L/ha)

Applicator type	Applicator technology	Blade pitch / energy delivery	Ground Speed (km/h)	Droplet size	Nozzles			Bars	Kw
					Top	Middle	Bottom		
1. Atasa	Axial fan sprayer (air blast)/ (+)Turret	28° / 26 600 m³/h (Low fan)	3.9	(68-95 µm)	8 x Green	8 x Yellow	6 x Brown	± 12	6.6
2. Atasa	Axial fan sprayer (air blast)/ (+)Turret	28° / 26 600 m³/h (Low fan)	6.2	(80-105 µm)	8 x Red	8 x Brown	6 x Yellow	± 8.0	6.6
3. Atasa	Axial fan sprayer (air blast)/ (+)Turret	35° / 45 600 m³/h (Low fan)	6.2	(80-105 µm)	8 x Red	8 x Brown	6 x Yellow	± 8.0	25.3
4. Atasa	Axial fan sprayer (air blast)/ (-)Turret	35° / 45 600 m³/h (Low fan)	6.2	(84-112 µm)	8 x Red	10 x Yellow		± 6.5	25.3
5. Cima	Centrifugal pump sprayer (air shear)/ (+)Turret		6.2	-	Nr 11	Nr 9	Nr 6	1.0 +	

Experimental detail

- All applications were conducted using the Atasa and Cima spray applicators, commonly used commercial. Spray applicators were calibrated to respective specifications (Table 1) by Mike Heath and Marius Ras of Rovic & Leers, Kuilsrivier (thanks expressed for their inputs in the trial). Spray treatments were executed in a commercial apple orchard to determine deposition quantity on the spray targets (leaves and fruit).
- The spray consisted of a yellow fluorescent pigment (400 g L^{-1}, EC; South Australian Research and Development Institute, Loxton SA 5333 Australia) at 2 ml/L (Furness, 2000). The applied spray dilution or concentration of pigment were done on recommendation by USPP.
- Sprays were conducted at one phenological stage (full leaf canopy, after thinning).
- Sprayed plots consisted of 15 trees, which were sprayed from both sides of the canopy, with 5 buffer trees left unsprayed between the plots, as well as two unsprayed orchard rows adjacent to each plot.
- The sprayed leaves and fruit were left to dry-off, where after 12 samples of each were randomly collected at 2 canopy heights (top [4.0 m] and bottom [1.0m]) x 2 canopy depths (outer [closest to spray applicator and nozzle] and inner [± 80 cm in the canopy close to the tree centre / trunk]). Leaves and fruit were transported in isolated cooled containers, to decrease respiration and retain turgidity.
- Pigmented leaves and fruit were illuminated using a Labino Mid-light (UV-A; ≈365 nm) and digital photos taken of the upper and lower leaf surfaces and front and back fruit surfaces of 12 samples per position, using a Canon EOS 40D camera equipped with a 50 mm macro lens. Spray deposition assessment involved digital image analyses with Image-Pro Plus version 6.2 software (Media Cybernetics, www.mediacy.com)

Examination parameters

Deposition quantity per leaf analysis involved the measurement of the area covered by pigment particles, but as a percentage of total leaf area (presented as percentage fluorescent coverage {% FPC}). The skewing effect of outliers was negated by using median values for deposition quantity in the analysis. Data from upper and lower leaf surfaces and front and back fruit surfaces were analysed separately, but were combined when describing the results for either the leaf or fruit.

Statistical layout and analyses

The experimental layout was a block design, where each treatment was repeated three times in separate orchard sections. A tree was considered a replicate. Fruit and leaf samples were randomly selected at the specific target positions. Data were subjected to analysis of variance and Student's T-test for least significant difference (P = 0.05).

Table 2: Treatment combinations specifically compared to ascertain specific information of treatment effects, where applicator type was indicated to influence the examination parameter

Treatments compared	Treatment description	Comment
T1 vs. T2	Atasa (+)Turret (standard energy delivery of 26600 m^3/h) **3.5km/h vs. 6.2 km/h**	Effect of ground speed/ tractor on deposition with Atasa (+)Turret at standard energy delivery, at 3.9 km/h vs. 6.2 km/h
T2 vs. T3	Atasa (+)Turret (6 km/h) **standard vs. higher energy** (26600 vs 45600 m^3/h)	Effect of lower compared to higher energy delivery on deposition quantity for Atasa with turret at 6.2 km/h
T3 vs. T4	Atasa (6 km/h, high energy delivery) **(+)Turret vs. (-)Turret**	Effect of a turret on deposition for Atasa applicator, at high energy delivery
T1 vs. T2& T3	Atasa (+)Turret **3.9 km/h vs. 6.2 km/h** and **standard vs. high energy**	Best practice Atasa (+)Turret combination on deposition, evaluating ground speed and energy delivery
T5 vs. T2 & T3	**Cima (+)Turret at 6.2 km/h vs. Atasa (+)Turret at 6.2 km/h** and **standard vs. high energy**	Effect of Cima (+)Turret vs. Atasa (+)Turret at lower and higher energy delivery, at similar ground speeds for applicator types

4. Results and discussion

.

Milestone	Achievement
1. **Evaluate applicator technology, air volume / energy delivery and ground speed for best practice quantitative deposition on leaves and fruit**	**Effect of Spray applicator x Canopy height** ▪ Generally, standard energy delivery of Atasa (+)Turret at 3.9 and 6.2 km/h, exhibited significantly better quantitative deposition on leaves and fruit in the top of the tree, compared to high energy application of Atasa (+) & (-)Turret, or Cima (+)Turret, at 6.2 km/h. ▪ Deposition quantity was higher using the high energy delivery, with Atasa (+)Turret, compared to the Atasa (-)Turret or the Cima (+)Turret. ▪ Generally, deposition quantity was significantly higher on the top, compared to bottom leaves and fruit, except for Atasa (-)Turret and Cima (+)Turret, exhibiting similar but lower levels across the tree canopy. ▪ Standard energy delivery of Atasa (+)Turret at 3.9 km/h exhibited the highest quantitative deposition on bottom fruit, significantly higher than application at high energy delivery of the Atasa (+) and (-)Turret or the Cima (+)Turret.
	Spray applicator x Canopy depth ▪ Standard energy delivery of Atasa (+)Turret, irrespective of the ground speed, deposited significantly more fluorescent pigment on outer than inner leaves. ▪ Deposition quantity was generally higher using the high energy delivery of Atasa (+)Turret, compared to the Atasa (-)Turret or the Cima (+)Turret on outer leaves. ▪ Deposition rating was generally higher on outer, compared to inner leaves, except for the Atasa (-)Turret and Cima (+)Turret which exhibited similar but lower levels across the canopy. ▪ Standard energy delivery of Atasa (+)Turret, irrespective to ground speed, generally exhibited best quantitative deposition on inner leaves and fruit, compared to high energy delivery, for application at 6.2km/h.

RESULTS :

Table 3 : Analyses of variance for different spray treatments, following spray application with a fluorescent pigment, on the **leaf surface and fruit surface**, respectively, of Pink Lady apple trees, as affected by **Applicator type, Canopy height and Canopy depth** on median values for deposition quantity

		Deposition quantity (%)			
Source	**DF[1]**	**Leaf surface**		**Fruit surface**	
		MS[2]	**P[3]**	**MS**	**P**
Applicator	4	38.1525	**< 0.0001**	4.5724	**< 0.0001**
Canopy height	1	95.5733	**< 0.0001**	12.6140	**< 0.0001**
Canopy depth	1	103.6321	**< 0.0001**	5.3024	**< 0.0001**
Canopy height*Canopy depth	1	3.3740	0.2235	0.0002	0.9773
Applicator*Canopy height	4	26.2951	**< 0.0001**	3.0794	**< 0.0001**
Applicator*Canopy depth	4	10.5671	**0.0039**	0.7071	**0.0325**
Applicator*Canopy height*Canopy depth	4	3.1553	0.2437	0.1179	0.7297

1. DF = Degrees of freedom
2. MS = Mean sum of squares
3. P = Probability
4. P values in bold indicate significant differences. Tables were drafted for the applicable treatment factor combinations

Table 4 : **Deposition quantity** of a fluorescent pigment on the **leaf surface** of Pink Lady apple trees as significantly affected by **Spray applicator x Canopy height**

Interaction[2]					Prob > F[1]
Spray applicator (Factor A)			Canopy height[3] (Factor B)		
Applicator technology	Energy delivery[4] (m^3 / h)	Ground Speed (km/h)	Top leaves	Bottom leaves	AB
1. Atasa (+)Turret	Standard	3.9	9.2a	3.8bc	***
2. Atasa (+)Turret	Standard	6.2	8.2a	2.6cd	
3. Atasa (+)Turret	High	6.2	5.1b	2.6cd	
4. Atasa (-)Turret	High	6.2	2.0d	2.2cd	
5. Cima (+)Turret		6.2	2.6cd	3.3cd	

1. Two-way ANOVA table with Spray applicator (Factor A) and Canopy height (Factor B) as the main factors, with *, **, and *** representing significance at the 5%, 1% or 0.1% levels, respectively. Values followed by different letters in a row, or column and row, indicate significant differences according to the LSD test (P ≤ 0.05)
2. An interaction occurred between Factor A and B
3. Canopy height: Top leaves (± 4.0 m); Bottom leaves (± 1.0 m)
4. Energy delivery level by fan; standard = 28° / 26,600 m^3/h, High = 35° / 45,600 m^3/h

Table 5 : **Deposition quantity** of a fluorescent pigment on the **leaf surface** of Pink Lady apple trees as significantly affected by **Spray applicator x Canopy depth**

Interaction[2]					Prob > F[1]
Spray applicator (Factor A)			Canopy depth[3] (Factor B)		
Applicator technology	Energy delivery[4] (m³ / h)	Ground Speed (km/h)	Outer leaves	Inner leaves	AB
1. Atasa (+)Turret	Standard	3.9	8.7a	4.3bc	***
2. Atasa (+)Turret	Standard	6.2	7.5a	3.3cd	
3. Atasa (+)Turret	High	6.2	5.3b	2.4de	
4. Atasa (-)Turret	High	6.2	3.0cde	1.3e	
5. Cima (+)Turret		6.2	2.9cde	3.0cde	

1. Two-way ANOVA table with Spray applicator (Factor A) and Canopy height (Factor B) as the main factors, with *, **, and *** representing significance at the 5%, 1% or 0.1% levels, respectively. Values followed by different letters in a row, or column and row, indicate significant differences according to the LSD test (P ≤ 0.05)
2. An interaction occurred between Factor A and B
3. Canopy depth: Outer fruit, closest to spray applicator and nozzle; Inner fruit, ± 80 cm within the canopy, closest to the tree center / trunk
4. Energy delivery level by fan; standard = 28° / 26,600 m^3/h, High = 35° / 45,600 m^3/h

Table 6 : **Deposition quantity** of a fluorescent pigment on the **fruit surface** of Pink Lady apple trees as significantly affected by **Spray applicator x Canopy height**

Interaction[2]					Prob > F[1]
Spray applicator (Factor A)			Canopy height[3] (Factor B)		
	Applicator technology	Energy delivery[4] (m³ / h)	Ground Speed (km/h)	Top fruit	Bottom fruit	AB
1.	Atasa (+)Turret	Standard	3.9	2.3ab	1.0c	***
2.	Atasa (+)Turret	Standard	6.2	2.8a	0.9cd	
3.	Atasa (+)Turret	High	6.2	2.0b	0.4d	
4.	Atasa (-)Turret	High	6.2	0.4d	0.4d	
5.	Cima (+)Turret		6.2	0.5cd	0.8cd	

1. Two-way ANOVA table with Spray applicator (Factor A) and Canopy height (Factor B) as the main factors, with *, **, and *** representing significance at the 5%, 1% or 0.1% levels, respectively. Values followed by different letters in a row, or column and row, indicate significant differences according to the LSD test (P ≤ 0.05)
2. An interaction occurred between Factor A and B
3. Canopy height: Top fruit (± 4.0 m); Bottom fruit (± 1.0 m)
4. Energy delivery level by fan; standard = 28° / 26,600 m^3/h, High = 35° / 45,600 m^3/h

Table 7 : **Deposition quantity** of a fluorescent pigment on the **fruit surface** of Pink Lady apple trees as significantly affected by **Spray applicator x Canopy depth**

Interaction[2]					Prob > F[1]
Spray applicator (Factor A)			Canopy depth[3] (Factor B)		
Applicator technology	Energy delivery[4] (m³ / h)	Ground Speed (km/h)	Outer fruit	Inner fruit	AB
1. Atasa (+)Turret	Standard	3.9	2.2a	1.2b	***
2. Atasa (+)Turret	Standard	6.2	2.5a	1.2b	
3. Atasa (+)Turret	High	6.2	1.3b	1.1bc	
4. Atasa (-)Turret	High	6.2	0.5cd	0.3d	
5. Cima (+)Turret		6.2	0.8bcd	0.5cd	

1. Two-way ANOVA table with Spray applicator (Factor A) and Canopy height (Factor B) as the main factors, with *, **, and *** representing significance at the 5%, 1% or 0.1% levels, respectively. Values followed by different letters in a row, or column and row, indicate significant differences according to the LSD test (P ≤ 0.05)
2. An interaction occurred between Factor A and B
3. Canopy depth: Outer fruit, closest to spray applicator and nozzle; Inner fruit, ± 80 cm within the canopy, closest to the tree center / trunk
4. Energy delivery level by fan; standard = 28° / 26,600 m^3/h, High = 35° / 45,600 m^3/h

FINDINGS:

Leaves :

Deposition quantity (Tables 3, 4 & 5)

Deposition quantity on leaves showed no significant interaction between applicator type, canopy height and canopy depth. A significant interaction was though indicated between applicator type x canopy height and applicator type x canopy depth (Tables 3, 4 & 5) for spray quantity recorded on leaves.

i. Spray applicator x Canopy height (summation of Table 4)

Treatments compared	Treatment description	Comment
T1 vs. T2	Atasa (+)Turret (standard delivery) **3.5km/h vs. 6.2 km/h**	▪ No significant difference in deposition quantity occurred on top or bottom leaves, between ground speeds of 3.9 vs 6.2 km/h, at standard energy delivery (26600 m^3/h). ▪ Deposition was significantly higher on top than bottom leaves, at both ground speeds.
T2 vs. T3	Atasa (+)Turret (6.2 km/h) **standard vs. higher energy delivery**	▪ Deposition quantity was significantly higher on top leaves for standard, compared to higher energy spraying, at 6.2 km/h. ▪ No difference in deposition occurred on bottom leaves between the standard vs. higher energy delivery. ▪ Deposition was significantly higher on top, compared to bottom leaves, at both energy delivery rates.
T3 vs. T4	Atasa (6.2 km/h, high delivery) **(+)Turret vs. (-)Turret**	▪ Deposition quantity was significantly higher on top leaves for Atasa (+)Turret, compared to the Atasa (-)Turret, at 6.2 km/h and high energy delivery. ▪ No difference in deposition occurred on bottom leaves between the Atasa (+)Turret and (-)Turret applicator types. ▪ Deposition was significantly higher on top, compared to bottom leaves, however, for the Atasa (+)Turret applicator only.
T1 vs. T2 & T3	Atasa (+)Turret **3.9 km/h vs. 6.2 km/h** at **standard and high energy**	▪ Deposition quantity was significantly higher for Atasa (+)Turret applicators on top leaves if sprayed at standard, compared to high energy delivery at 6.2 km/h, with ground speed having no effect at similar, standard energy delivery. ▪ No difference in deposition rating occurred on bottom leaves between treatment variation of energy delivery or ground speed, using the Atasa (+)Turret applicator. ▪ Deposition was significantly higher on top, compared to bottom leaves, for all treatment variations of the Atasa (+)Turret.
T5 vs. T2 & T3	Cima (+)Turret vs. Atasa (+)Turret (at 6.2 km/h) for **standard and high energy**	▪ Deposition quantity was significantly lower on top leaves, for the Cima (+)Turret applicator, compared to the Atasa (+)Turret applicator at standard as well as high energy delivery, at a common ground speed of 6.2 km/h. ▪ No difference in deposition occurred on bottom leaves between energy variations for the Atasa (+) turret and the Cima (+)Turret. ▪ Deposition rating was significantly higher on top, compared to bottom leaves, for both the Atasa (+)Turret applicators, but not for the Cima (+)Turret.

Leaves **Spray applicator x Canopy height** **(Across applicator types)**	▪ Fluorescent pigment / product deposition was not affected on top or bottom leaves by ground speed, for the Atasa (+)Turret applicator, at standard energy delivery of 26600 m^3/h. ▪ Deposition quantity was higher on top than bottom leaves for the Atasa (+)Turret applicator, across all ground speed and energy delivery combinations. Differences between deposition on top and bottom leaves were less for the combination of high energy, at high ground speed, compared to standard energy, at low or high ground speed, using the Atasa (+)Turret applicator. ▪ Deposition quantity was higher for the Atasa (+)Turret, compared to the Atasa (-)Turret, at high energy delivery, as well as for the Cima (+)Turret, however, on top leaves only. ▪ Deposition quantity was significantly higher on top, compared to bottom leaves, for the Atasa (+)Turret treatment combinations, but not the Atasa (-)Turret, or the Cima (+)Turret.

ii Spray applicator x Canopy depth (summation of Table 5)

Treatments compared	Treatment description	Comment
T1 vs. T2	Atasa (+)Turret (standard delivery) **3.5km/h vs. 6.2 km/h**	▪ No significant difference in deposition quantity occurred on outer or bottom leaves, between ground speeds of 3.9 vs 6.2 km/h, at standard energy delivery (26600 m^3/h). Albeit not significant, deposition quantity was slightly higher for the application at 3.5 km/h ground speed. ▪ Deposition was significantly higher on outer than inner leaves, at both ground speeds at standard energy delivery.
T2 vs. T3	Atasa (+)Turret (6.2 km/h) **standard vs. higher energy delivery**	▪ Deposition quantity was significantly higher on outer leaves for standard energy, compared to higher energy spraying, at 6.2 km/h. ▪ No significant difference in deposition occurred for inner leaves between standard vs. higher energy delivery. ▪ Deposition was significantly higher on outer, compared to inner leaves, for both energy delivery rates.
T3 vs. T4	Atasa (6.2 km/h, high delivery) **(+)Turret vs. (-)Turret**	▪ Deposition quantity was significantly higher on outer leaves for the Atasa (+)Turret, compared to the Atasa (-)Turret, at 6.2 km/h and high energy delivery. ▪ No difference in deposition occurred on bottom leaves between the Atasa (+)Turret and (-)Turret applicator types. ▪ Deposition was significantly higher on outer, compared to inner leaves, however, for the Atasa (+)Turret applicator only. ▪ Deposition rating significantly higher for outer compared to inner leaves for Atasa (+) turret. Albeit not significant, a similar trend was exhibited for the Atasa applicator (-)Turret.
T1 vs. T2 & T3	Atasa (+)Turret **3.9 km/h vs. 6.2 km/h** at **standard and high energy**	▪ Deposition quantity was significantly higher for Atasa (+)Turret applicators on outer leaves if sprayed at standard energy, compared to high energy delivery at 6.2 km/h. Ground speed did not have an effect at a similar, standard energy delivery. ▪ Deposition on inner leaves was higher for the Atasa (+)Turret at standard energy delivery and 3.9 km/h ground speed, compared to high energy delivery at 6.2 km/h. Deposition did not differ between energy delivery rates at a similar ground speed of 6.2 km/h. ▪ Deposition was significantly higher on outer, compared to inner leaves, for all treatment variations using the Atasa (+)Turret.
T5 vs. T2 & T3	Cima (+)Turret vs. Atasa (+)Turret (at 6.2 km/h) for **standard and high energy**	▪ Deposition rating for the Cima applicator was significantly lower on outer leaves, compared to Atasa (+)Turret applicator at standard, as well as high energy delivery, at 6.2 km/h. Significantly more pigment were deposited on outer leaves using the Atasa (+)Turret and standard energy delivery at 6.2 km/h. ▪ No difference in deposition occurred on inner leaves between of energy variations for the Atasa (+) turret and the Cima (+)Turret. ▪ Deposition was significantly higher on outer compared to inner leaves for Atasa applicators at standard and high energy delivery, but not for the Cima (+)Turret.

Leaves Spray applicator x Canopy depth (Across applicator types)	▪ Fluorescent pigment / product deposition was not affected on outer or inner leaves by ground speed, for the Atasa (+)Turret applicator at standard energy delivery of 26600 m^3/h. ▪ Deposition quantity was higher on outer than inner leaves for the Atasa (+)Turret applicator, across all ground speed and energy delivery combinations. Differences between deposition on outer and inner leaves were less for the combination of high energy, at high ground speed, compared to standard energy, at low or high ground speed, using the Atasa (+)Turret applicator. ▪ Deposition quantity was higher for the Atasa (+)Turret, compared to the Atasa (-)Turret, at high energy delivery, as well as for the Cima (+)Turret, however, on outer leaves only. ▪ Deposition quantity was significantly higher on outer, compared to inner leaves, using the Atasa (+)Turret, but not the Atasa (-)Turret, or the Cima (+)Turret.

Fruit :

Deposition quantity (Tables 3, 6 & 7)

Deposition quantity on fruit showed no significant interaction between applicator type, canopy height and canopy depth. A significant interaction was though indicated between applicator type x canopy height and applicator type x canopy depth (Tables 3, 6 & 7) for spray quantity recorded on fruit.

i Spray applicator x Canopy height (summation for Table 6)

Treatments compared	Treatment description	Comment
T1 vs. T2	Atasa (+)Turret (standard delivery) **3.5km/h vs. 6.2 km/h**	▪ Similar to deposition on fruit, no significant difference in deposition quantity occurred on top or bottom fruit, between ground speeds of 3.9 vs 6.2 km/h, at standard energy delivery (26600 m^3/h). ▪ Like leaves, deposition was significantly higher on top than bottom fruit, at both ground speeds.
T2 vs. T3	Atasa (+)Turret (6.2 km/h) **standard vs. higher energy delivery**	▪ Deposition was significantly higher on top fruit for standard energy, compared to higher energy spraying, at 6.2 km/h. ▪ No significant difference in deposition occurred for bottom fruit between standard vs. higher energy delivery. Albeit not significant, deposition quantity was lower on fruit for application at a higher energy delivery. ▪ Deposition was significantly higher on top, compared to bottom fruit, at both energy delivery rates.
T3 vs. T4	Atasa (6.2 km/h, high delivery) **(+)Turret vs. (-)Turret**	▪ Similar to leaves, deposition was significantly higher on top fruit for the Atasa (+)Turret, compared to Atasa (-)Turret, at 6.2 km/h and high energy delivery. ▪ No significant difference in deposition occurred for bottom fruit between Atasa (+)Turret and the (-)Turret applicators. ▪ Deposition was significantly higher on top, compared to bottom fruit, for all treatment variations of the Atasa (+)Turret.
T1 vs. T2 & T3	Atasa (+)Turret **3.9 km/h vs. 6.2 km/h** at **standard and high energy**	▪ Deposition quantity was significantly higher for the Atasa (+)Turret on top fruit, if sprayed at standard, compared to high energy delivery at 6.2 km/h, with ground speed having no effect at a similar, standard energy delivery. ▪ Deposition was significantly higher on top, compared to bottom fruit, for all treatment variations of the Atasa (+)Turret.
T5 vs. T2 & T3	Cima (+)Turret vs. Atasa (+)Turret (at 6.2 km/h) for **standard and high energy**	▪ Similar to the finding on leaves, deposition was significantly lower on top fruit for the Cima (+)Turret applicator, compared the Atasa (+)Turret applicator at standard, as well as high energy delivery, at a common ground speed of 6.2 km/h. ▪ No significant difference in deposition occurred on bottom fruit between energy variations for the Atasa (+) turret and the Cima (+)Turret applicators. ▪ Deposition quantity was significantly higher on top, compared to bottom fruit, for the Atasa (+)Turret applicators at standard and high energy delivery, but not for the Cima (+)Turret applicator.

Fruit **Spray applicator x Canopy height** **(Across applicator types)**	▪ Similar to spray deposition on fruit, fluorescent pigment / product deposition was not affected on top or bottom fruit by ground speed, for the Atasa (+)Turret applicator, at standard energy delivery. ▪ Deposition quantity was higher on top than bottom fruit for the Atasa (+)Turret applicator, across all ground speed and energy delivery combinations. Differences between deposition on top and bottom fruit was less for the combination of high energy, at high ground speed, compared to standard energy, at low or high ground speed, using the Atasa (+)Turret applicator. However, the deposition levels may be too low for high energy and high ground speed spraying to support effective control of pathogens or insects. ▪ Deposition quantity was higher for the high energy Atasa (+)Turret, compared to the Atasa (-)Turret, however, on top fruit only. Deposition quantity was significantly higher on top, compared to bottom fruit, for the Atasa (+)Turret treatment combinations, but not for spraying with the Atasa (-)Turret, or the Cima (+)Turret.

ii Spray applicator x Canopy depth (Table 7)

Treatments compared	Treatment description	Comment
T1 vs. T2	Atasa (+)Turret (standard delivery) **3.5km/h vs. 6.2 km/h**	▪ No significant difference in quantity deposited on outer & inner fruit occurred for ground speed of 3.9 km/h vs 6.2 km/h, at standard energy delivery. ▪ Deposition was significantly higher on outer than inner fruit, at both ground speeds at standard energy delivery.
T2 vs. T3	Atasa (+)Turret (6.2 km/h) **standard vs. higher energy delivery**	▪ Deposition quantity was significantly higher on outer fruit for standard energy, compared to higher energy spraying, at 6.2 km/h. ▪ No significant difference in deposition occurred on inner fruit between standard vs. higher energy delivery. ▪ Deposition rating was significantly higher on outer, compared to inner fruit, for Atasa (+)Turret at 6.2 km/h, however, only for standard energy delivery.
T3 vs. T4	Atasa (6.2 km/h, high delivery) **(+)Turret vs. (-)Turret**	▪ Deposition was significantly higher on outer and inner fruit, for Atasa (+)Turret, compared to Atasa (-)Turret at 6.2 km/h and high energy delivery. ▪ Deposition did not differ between outer and inner fruit, for Atasa (+)turret and Atasa (-)Turret for application 6.2 km/h and high energy delivery.
T1 vs. T2 & T3	Atasa (+)Turret **3.9 km/h vs. 6.2 km/h** at **standard and high energy**	▪ Deposition quantity was significantly higher for Atasa (+)Turret applicators on outer fruit if sprayed at standard energy, compared to high energy delivery at 6.2 km/h. Ground speed did not have an effect at a similar, standard energy delivery. ▪ No difference in deposition occurred on inner fruit for the Atasa (+)Turret between any of the treatment combinations. ▪ Deposition was significantly higher on outer compared to inner fruit for Atasa(+)Turret sprayed at standard delivery, irrespective of ground speed, while non-significant when sprayed at high energy delivery.
T5 vs. T2 & T3	Cima (+)Turret vs. Atasa (+)Turret (at 6.2 km/h) for **standard and high energy**	▪ Deposition for the Cima applicator was lower on top and inner fruit, compared to the Atasa (+)Turret at standard energy delivery, but not at high energy, for application at a ground speed of 6.2 km/h. ▪ Deposition was significantly higher on outer compared to inner fruit, for the Atasa (+)Turret at standard energy delivery, but not for the Cima (+)Turret.

Fruit **Spray applicator x Canopy depth** **(Across applicator types)**	▪ Standard energy delivery of Atasa (+)Turret, irrespective to ground speed, deposited significantly more fluorescent pigment on outer fruit than most other treatments. ▪ Fluorescent pigment / product deposition was not affected on outer or inner fruit by ground speed, for the Atasa (+)Turret applicator at standard energy delivery of 26600 m^3/h. ▪ Differences between deposition on outer and inner fruit were less for the combination of high energy, at high ground speed, compared to standard energy, at low or high ground speed, using the Atasa (+)Turret applicator. ▪ Deposition quantity was higher for the Atasa (+)Turret, compared to the Atasa (-)Turret, on outer and inner fruit.

RECOMMENDATIONS :

It is recommended to continue research on spray deposition and factors affecting it. A new project application is submitted which will focus on factors affecting chemical application for improved pome and stone fruit disease and pest management.

BENEFIT TO CLIENT :

Spray deposition quantity was affected by parameters such as, applicator type, delivery energy, location of the target surface in relation to the tree canopy (height and depth) and to a lesser extent, ground speed. Research indicated that standard energy delivery was generally better, to ensure higher quantitative deposition. The negative result with high delivery is most likely due to the deposit blown away from the target surface, or the target surface reacting to the higher energy delivery. The producer/ farm manager and other involved with spray applications need to be aware of factors affecting spray deposition and the possible outcome with regard to pest and disease control, which necessitate the continuation of research regarding spray application.

APPENDIX A

Table 11 : **Deposition quantity of non-pooled data** for effect of spray treatments on the **leaf surface** of Pink Lady apple trees as affected by **Spray applicator, Canopy height and Canopy depth**

Assessment parameter	Interaction[2]						Prob > F[1]
	Spray applicator (Factor A)			Canopy depth[3] (Factor B)	Canopy height[4] (Factor C)		
	Applicator	Energy delivery[6] (m³ / h)	Ground speed (Km/h)		Top leaves	Bottom leaves	ABC
Deposition quantity (%)[5]	1. Atasa (+)Turret	Standard	3.9	Outer	11.9	5.6	NS
				Inner	6.5	2.1	
	2. Atasa (+)Turret	Standard	6.2	Outer	11.3	3.7	
				Inner	5.0	1.5	
	3. Atasa (+)Turret	High	6.2	Outer	6.5	4.1	
				Inner	3.7	1.0	
	4. Atasa (-)Turret	High	6.2	Outer	2.6	3.3	
				Inner	1.5	1.2	
	5. Cima (+)Turret		6.2	Outer	2.6	3.3	
				Inner	2.7	3.3	

1. Three-way ANOVA table with Spray applicator (Factor A), Canopy depth (Factor B) and Canopy height (Factor C) as the main factors, with *, **, and *** representing significance at the 5%, 1% or 0.1% levels, respectively. Values followed by different letters in a row, or column and row, indicate significant differences according to the LSD test (P ≤ 0.05)
2. No interaction occurred between Factor A, B and C
3. Canopy depth: Outer leaves, closest to spray applicator and nozzle; Inner leaves, ± 80 cm within the canopy, closest to the tree center / trunk.
4. Canopy height: Top leaves (± 4.0 m); Bottom leaves (± 1.0 m)
5. Deposition quantity = area covered by fluorescent pigment particles, expressed as a percentage of the total leaf area

Table 12 : **Deposition quantity of non-pooled data** for effect of spray treatments on the **fruit surface** of Pink Lady apple trees as affected by **Spray applicator, Canopy height and Canopy depth**

Assessment parameter	Interaction[2]						Prob > F[1]
	Spray applicator (Factor A)			Canopy depth[3] (Factor B)	Canopy height[4] (Factor C)		
	Applicator	Energy delivery[6] (m³ / h)	Ground speed (Km/h)		Top leaves	Bottom leaves	ABC
Deposition quantity (%)[5]	1. **Atasa (+)Turret**	**Standard**	**3.9**	**Outer**	2.8	1.5	**NS**
				Inner	1.8	0.6	
	2. **Atasa (+)Turret**	**Standard**	**6.2**	**Outer**	3.5	1.4	
				Inner	2.1	0.3	
	3. **Atasa (+)Turret**	**High**	**6.2**	**Outer**	2.2	0.4	
				Inner	1.8	0.3	
	4. **Atasa (-)Turret**	**High**	**6.2**	**Outer**	0.5	0.5	
				Inner	0.3	0.6	
	5. **Cima (+)Turret**		**6.2**	**Outer**	0.5	1.1	
				Inner	0.5	0.5	

1. Three-way ANOVA table with Spray applicator (Factor A), Canopy depth (Factor B) and Canopy height (Factor C) as the main factors, with *, **, and *** representing significance at the 5%, 1% or 0.1% levels, respectively. Values followed by different letters in a row, or column and row, indicate significant differences according to the LSD test (P ≤ 0.05)
2. No interaction occurred between Factor A, B and C
3. Canopy depth: Outer fruit, closest to spray applicator and nozzle; Inner fruit, ± 80 cm within the canopy, closest to the tree center / trunk.
4. Canopy height: Top fruit (± 4.0 m); Bottom fruit (± 1.0 m)
5. Deposition quantity = area covered by fluorescent pigment particles, expressed as a percentage of the total fruit area

5. Accumulated outputs

Technology development, products and patents

Human resources development/training

	Student level (BSc, MSc, PhD, Post doc)	Cost to project (R)
1.		
2.		
3.		
4.		
5.		

Publications (popular, press releases, semi-scientific, scientific)

Presentations/papers delivered

4. Total cost summary of project

	Year	CFPA	Deciduous	DFTS	Winetech	THRIP	Other	TOTAL
Total cost in real terms for year 1	2010		182,034					**182,034**
Total cost in real terms for year 2	2011		194,776					**194,776**
Total cost in real terms for year 3	2012		216,148					**216,148**
Total cost in real terms for year 4								
Total cost in real terms for year 5								
TOTAL			**592,958**					**592,958**