FIRST TRIALS AIMED AT ESTABLISHING THE COMMERCIAL POTENTIAL OF A 1-METHYLCYCLOPROPENE TREE SPRAY FORMULATION (HARVISTA; AGROFRESH) ON AVOCADO FRUIT

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ABSTRACT

During the 2020 and 2021 seasons, seven trials were performed with a recently developed 1-methylcyclopropene (1-MCP) tree spray application (Harvista; AgroFresh) that acts as an ethylene inhibitor. Three of these were conventional randomized block designed trials that were done with the Hass cultivar while the remaining four studies were *ad hoc* trials that were performed with the Hass and Maluma Hass cultivars to elucidate specific aspects. The present report concerns two of the conventional registration trials. The results indicated that Harvista has similar ripening inhibition characteristics to the currently used SmartFresh postharvest gas application. An additional control mechanism exists in that the ripening inhibition effect can be adjusted upwards or downwards by shortening or lengthening the period from application to harvest. The range may, however, become wider under dry, late season conditions as the period from application to harvest increases. The biggest challenge regarding the routine usage of Harvista concerns the severe inhibition of ripening in non-export fruit that are locally marketed. At this early stage, the most appropriate application for Harvista would appear to be the inhibition of on-tree ripening in fruit with dead seeds. The *ad hoc* trials indicated that Harvista may be sprayed at lower rates than those currently used by the apple industry. During 2022 we will be performing registration trials at these lower rates.

INTRODUCTION

The ethylene inhibitor 1-methylcyclopropene (1-MCP) is currently used as a postharvest application (SmartFresh; AgroFresh) to slow down the ripening and improve the quality (especially the reduction of grey pulp) of avocado fruit. Similarly to ethylene, 1-MCP is a gas. The commercial preparation is embedded in cyclodextrin that is dissolved in a release solution at the time of application.

In the case of Harvista, different technologies were developed to ensure that the gas does not evaporate during spraying. The most advanced of these were evaluated by the deciduous fruit industry (Crouch & Viljoen, 2016; Crouch *et al.*, 2014a, 2014b, 2015) and Harvista is currently being used to delay on-tree ripening and increase the size of apples.

Seven Harvista trials were performed on avocado during the last two seasons. Three of these were conventional registration type trials while the remaining four were *ad hoc* trials that were designed to elucidate specific aspects. The present report deals with two of the registration type trials that were conducted on 'Hass' avocados during the 2020 and 2021 seasons.

MATERIALS AND METHODS

The spray applications were applied with a custom-built sprayer supplied by the manufacturer and the calibration and spraying instructions were carefully followed.

The first trial was performed in 2020 during the late season (15 September) on 'Hass' in the Soekmekaar area. Three application rates; 0, 200 and 400 grams active ingredient per hectare (g ai/ha), were used. The control consisted of four replicate plots while the 200 and 400 g ai/ha treatments had five replicates. Each replicate contained six trees.

Three samples containing 60 fruit each were sampled after one, two and four weeks from spraying. Half of the fruit were directly ripened while the other half were first stored for four weeks at 5 °C before being ripened at 20 °C.

The second trial was performed in 2021 during the mid-season (19 May) also on 'Hass' in the Soekmekaar area. Four application rates; 0, 100, 150 and 200 g ai/ha, were used. Each treatment had three replicate plots containing 6 trees each.

Three samples containing 20-30 fruit per replicate were sampled one, four and eight weeks after spraying. The fruit were stored for four weeks at 5 °C before being ripened at 20 °C.

The period required to reach the ready-to-eat stage was recorded for each fruit after which a complete set of external and internal quality analyses were performed.

RESULTS AND DISCUSSION

In both trials, the ripening rates are expressed as the percentage of fruit that reached the ready-to-eat stage per day. By doing this, an accurate representation is obtained as to the day number on which the first fruit ripened as well as the ripening range (this needs to be as narrow as possible).

The results of the 'Hass' trial conducted on 15 September 2020 are shown in Tables 1-6.

The fruit that were directly ripened without any storage are shown in Tables 1-3. The on-tree sprays effectively slowed down the ripening, whether harvested one, two or four weeks after spraying. The fruit from the treated trees took twice as long to ripen than the controls. This may be problematic, as non-export fruit that are locally marketed need to ripen within reasonable time periods. However, the spreads were fairly similar between the control and the treatments.

The fruit that were stored for one month before being ripened are shown in Tables 4-6. When harvested one week after spraying, all the control replicates contained fruit that were already at the ready-to-eat stage when removed from storage. In contrast, fruit treated with both Harvista application rates only started to ripen as from day three. The controls' ripening ranges were shorter (5 days) than those of the treatments which were typically between 6 and 8 days. The treatments' ranges further increased as the period from spraying to harvest lengthened.

The ripening profiles of the fruit from the trial that was sprayed on 19 May 2021 are shown in Tables 7-9. When harvested one week after the Harvista application and stored for one month (Table 7), the first control fruit were ready to eat by day seven. In the case of the 100 and 150 g ai/ha treatments, the first ripe fruit were recorded on day eleven, while those from the 200 g ai/ha treatments started to ripen by day thirteen. In terms of the ripening ranges, all treatments were fairly similar at around 5-7 days.

When harvested four weeks after spraying (Table 8), the first ripe control fruit were recorded three days earlier than the control fruit harvested after one week, while the Harvista treated fruit start dates advanced by 5-6 days. Importantly, the ranges of the Harvista treated fruit remained comparable with those of the control.

When sampled eight weeks after the spray treatment (Table 9), all the control replicates contained fruit that were ready to eat at the time of removal from cool storage. In contrast, only one replicate each of the 100 and 150 g ai/ha treatments contained ripe fruit on day one, while the first fruit in the 200 g ai/ha treatment were ripe on day two. The ripening span of the Harvista treatments increased to 7-8 days while that of the control was around 5 days.

The Harvista treatments had no effect on fruit size and the incidences of physiological and pathological disorders were low (data not shown).

The observation that the ripening ranges of fruit from longer hanging/late season trees increase as the period from spraying to harvest increases, concurs with observations made with SmartFresh treated fruit. We have previously found that drying-out of orchards delays the ripening of avocado fruit in general and 1-MCP treated fruit in particular (Kruger & Magwaza, 2012; Kruger & Lemmer, 2014; Kruger *et al*., 2013; Kruger *et al*., 2017). In many cases, this happens in poorly irrigated orchards, especially when producers wait too long before starting to irrigate after the end of a rainy season

At this early stage, the most appropriate application for Harvista concerns the inhibition of on-tree ripening in fruit with dead seeds. In most avocado cultivars, a percentage of the fruits' seedcoats die off during early summer. A proportion of these drop from the tree, but some remain hanging and do not increase further in size and are mostly to be found in the 'Small' category. These fruit slowly ripen on the tree and may cause soft landings and exhibit grey pulp during export, especially during the late season. However, with a cultivar such as Maluma Hass, the seedcoats may continue dying during the mid-season and are prevalent from Count 20 and smaller. We provisionally propose that trees be sprayed at such a stage that Harvista's effect is "worked out" by the time of harvest. Less on-tree ripening will have taken place in dead seed fruit, while healthy avocados will ripen normally.

The *ad hoc* trials performed during the 2020 and 2021 seasons aimed primarily at establishing whether lower rates than the current apple rate (150 g ai/ha) will be effective on avocados. The results were positive and we will be performing registration trials at lower rates during the 2022 season.

Acknowledgements

The authors would like to thank AgroFresh and SAAGA for financial and technical assistance, Agrivet for the fruit and Mark Penter for editing the manuscript.

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Table 1: Ripening profiles of 'Hass' avocado fruit that were sprayed on 15 September 2020 and sampled one week after spraying, followed by immediate ripening without prior storage

Application rate (g ai/ha)	Rep. no	Ripe fruit per day (%)																				
		D6	D7	D8	D9	D10	D11	D12	D13	D14	D15	D16	D17	D18	D19	D20	D21	D22	D23	D24	D25	D26
0	1			3		3	3	10	7	13	20	27	13									
	2		3	10	7	20	10	17	10	13	7	3										
	3			7	7	10	3	7	13	13	17	7	10	7								
	4		3	3	10	7	13	13	17	10	13	10										
	Mean		**1,7**	**5,8**	**5,8**	**10,0**	**7,5**	**11,7**	**11,7**	**12,5**	**14,2**	**11,7**	**5,8**	**1,7**								
200	1									3	3	7	7	13	17	20	13	13		3		
	2										7	3	17	27	17	13	7	3	7			
	3											3	10	20	20	20	13	7	7			
	4												7	10	17	17	10		10	13	13	3
	5										7	7	20	23	23	10	7		3			
	Mean									**0,7**	**3,3**	**4,0**	**12,0**	**18,7**	**18,7**	**16,0**	**10,0**	**4,7**	**5,3**	**3,3**	**2,7**	**0,7**
400	1										3	7	10	13	20	20	13	10	3			
	2										7	17	20	17	17	10	7	7				
	3										7	7	17	20	17	17	13		3			
	4											3	10	23	27	30		3		3		
	5										3	10	20	20	13	13	17	3				
	Mean										**4,0**	**8,7**	**15,3**	**18,7**	**18,7**	**18,0**	**10,0**	**4,7**	**1,3**	**0,7**		

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Table 2: Ripening profiles of 'Hass' avocado fruit that were sprayed on 15 September 2020 and sampled two weeks after spraying, followed by immediate ripening without prior storage

Application rate (g ai/ha)	Rep. no	Ripe fruit per day (%)																				
		D6	D7	D8	D9	D10	D11	D12	D13	D14	D15	D16	D17	D18	D19	D20	D21	D22	D23	D24	D25	D26
0	1		7	3	3	13	10	20	20	17	7											
	2	3		10	7	13	7	10	17	17	10	7										
	3		3	10	13	7	10	13	17	17	10											
	4		3	7	7	10	17	20	17	10	7		3									
	Mean	**0,8**	**3,3**	**7,5**	**7,5**	**10,8**	**10,8**	**15,8**	**17,5**	**15,0**	**8,3**	**1,7**	**0,8**									
200	1										10	3	10	13	20	20	13	10				
	2										7	7	10	17	20	17	10	13				
	3										3	10	13	20	20	10	13	10				
	4										3	7	3	10	10	10	17	13	13	10	3	
	5										7	10	7	3	10	10	17	13	17	7		
	Mean										**6,0**	**7,3**	**8,7**	**12,7**	**16,0**	**13,3**	**14,0**	**12,0**	**6,0**	**3,3**	**0,7**	
400	1									3	10	7	13	10	10	17	20	7	3			
	2										3	10	13	10	17	10	13	17	7			
	3									3	13	13	10	17	10	20	13					
	4												7	10	17	17	10	13	10	10	7	
	5									7	3	10	7	7	13	10	7	17	20			
	Mean									**2,7**	**6,0**	**8,0**	**10,0**	**10,7**	**13,3**	**14,7**	**12,7**	**10,7**	**8,0**	**2,0**	**1,3**	

Table 3: Ripening profiles of 'Hass' avocado fruit that were sprayed on 15 September 2020 and sampled four weeks after spraying, followed by immediate ripening without prior storage

Application rate (g ai/ha)	Rep. no	Ripe fruit per day (%)																				
		D6	D7	D8	D9	D10	D11	D12	D13	D14	D15	D16	D17	D18	D19	D20	D21	D22	D23	D24	D25	D26
0	1	3	10	3	7	10	10	13	17	13	10	3										
	2	3	3	7	13	10	13	10	7	13	13	7										
	3	3	3	10	7	3	13	10	13	13	17	3		3								
	4	3	10	7	13	10	10	13	13	10	7	3										
	Mean	**3,3**	**6,7**	**6,7**	**10,0**	**8,3**	**11,7**	**11,7**	**12,5**	**12,5**	**11,7**	**4,2**		**0,8**								
200	1										10	7	10	17	20	20	17					
	2									7	3	7	13	10	17	10	10	7	10	3		3
	3										10	13	13	20	20	13	7	3				
	4										7	10	7	13	20	20	13		7	3		
	5										10	10	13	17	20	23	7					
	Mean									**1,3**	**8,0**	**9,3**	**11,3**	**15,3**	**19,3**	**17,3**	**10,7**	**2,0**	**3,3**	**1,3**		**0,7**
400	1									7	13	10	17	17	20	10	7					
	2									3		7	10	10	17	13	13		10	7	3	7
	3										13	7	10	10	20	13	20	3		3		
	4										7	7	17	17	7	10	13	7	10	3	3	
	5									3	10	20	20	20	13	7	3		3			
	Mean									**2,7**	**8,7**	**10,0**	**14,7**	**14,7**	**15,3**	**10,7**	**11,3**	**2,0**	**4,7**	**2,7**	**1,3**	**1,3**

Table 4: Ripening profiles of 'Hass' avocado fruit from trees that were sprayed on 15 September 2020 and sampled one week later. The fruit were stored for 4 weeks at 5 °C before being ripened at 20 °C

Application rate (g ai/ha)	Rep. no	Ripe fruit per day (%)									
		D1	D2	D3	D4	D5	D6	D7	D8	D9	D10
0	1	20	27	30	20	3					
	2	13	20	27	27	13					
	3	27	30	23	20						
	4	13	23	27	23	13					
	Mean	**18,3**	**25,0**	**26,7**	**22,5**	**7,5**					
200	1			13	17	30	23	17			
	2			13	17	27	23	7	10		3
	3					10	13	23	27	20	7
	4			10	17	23	23	17	3	7	
	5			10	13	20	27	27		3	
	Mean			**9,3**	**12,7**	**22,0**	**22,0**	**18,0**	**8,0**	**6,0**	**2,0**
400	1			3	10	13	27	33	13		
	2		3	10	20	27	23	10	3	3	
	3				7	20	27	13	13	20	
	4			7	17	20	23	20	13		
	5			10	17	23	20	17	3	7	3
	Mean		**0,7**	**6,0**	**14,0**	**20,7**	**24,0**	**18,7**	**9,3**	**6,0**	**0,7**

Table 5: Ripening profiles of 'Hass' avocado fruit from trees that were sprayed on 15 September 2020 and sampled two weeks later. The fruit were stored for 4 weeks at 5 °C before being ripened at 20 °C

Application rate (g ai/ha)	Rep. no	Ripe fruit per day (%)											
		D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12
0	1	23	17	27	17	13			3				
	2	17	23	17	27	10	7						
	3	17	20	13	23	13	13						
	4	23	17	23	23	13							
	Mean	**20,0**	**19,2**	**20,0**	**22,5**	**12,5**	**5,0**	**0,0**	**0,8**				
200	1	3		10	17	13	10	20	17		7	3	
	2		7	17	17	20	10	7	13	3		7	
	3					3	10	17	20	20	27		3
	4			13	10	17	17	10	20	10	3		
	5			13	17	13	17	20	17	3			
	Mean	**0,7**	**1,3**	**10,7**	**12,0**	**13,3**	**12,7**	**14,7**	**17,3**	**7,3**	**7,3**	**2,0**	**0,7**
400	1			7	20	23	23	10	17				
	2		10	7	10	20	20	10	10	3	10		
	3					10	7	17	23	10	10	17	7
	4		3	7	7	17	13	10	13	13	13	3	
	5				10	17	23	27	17	7			
	Mean		**2,7**	**4,0**	**9,3**	**17,3**	**17,3**	**14,7**	**16,0**	**6,7**	**6,7**	**4,0**	**1,3**

Table 6: Ripening profiles of 'Hass' avocado fruit from trees that were sprayed on 15 September 2020 and sampled four weeks later. The fruit were stored for 4 weeks at 5 °C before being ripened at 20 °C

Application rate (g ai/ha)	Rep. no	Ripe fruit per day (%)											
		D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12
0	1	20	23	20	20	13			3				
	2	17	23	23	27	10							
	3	20	27	17	20	17							
	4	20	17	27	17	20							
	Mean	**19,2**	**22,5**	**21,7**	**20,8**	**15,0**			**0,8**				
200	1	7	7	13	10	17	17	7	17		3	3	
	2		7	13	20	10	17	13	3	7	3	7	
	3			3	7	7	10	17	10	20	13	7	7
	4		3	7	13	17	13	13	17	7	10		
	5		10	13	17	13	17	17	13				
	Mean	**1,3**	**5,3**	**10,0**	**13,3**	**12,7**	**14,7**	**13,3**	**12,0**	**6,7**	**6,0**	**3,3**	**1,3**
400	1		7	7	17	17	23	10	10	10			
	2	3	7	10	17	20	20	17	7				
	3				7	10	10	13	23	10	13	13	
	4			10	7	17	13	20	10	13	10		
	5		7	17	10	17	23	17	10				
	Mean	**0,7**	**4,0**	**8,7**	**11,3**	**16,0**	**18,0**	**15,3**	**12,0**	**6,7**	**4,7**	**2,7**	

Table 7: Ripening profiles of 'Hass' avocado fruit from trees that were sprayed on 19 May 2021 and sampled one week later. The fruit were stored for 4 weeks at 5 °C before being ripened at 20 °C

Application rate (g ai/ha)	Rep. no	Ripe fruit per day (%)											
		D7	D8	D9	D10	D11	D12	D13	D14	D15	D16	D17	D18
0	1					30	20	20	20	10			
	2	10	10	20		20	20	20					
	3				20	20	30	20	10				
	Mean	**3.3**	**3.3**	**6.7**	**6.7**	**23.3**	**23.3**	**20.0**	**10.0**	**3.3**			
100	1					10	20	30	10	20	10		
	2							20	20	30	20	10	
	3								10	20	20	20	30
	Mean					**3.3**	**6.7**	**16.7**	**13.3**	**23.3**	**16.7**	**10.0**	**10.0**
150	1							10	20	30	20	20	
	2					10	20	30	20	20			
	3					10	20	30	20	10	10		
	Mean					**6.7**	**13.3**	**23.3**	**20.0**	**20.0**	**10.0**	**6.7**	
200	1								10	20	30	20	20
	2							20	20	30	20	10	
	3							10	30	30	10	20	
	Mean							**10.0**	**20.0**	**26.7**	**20.0**	**16.7**	**6.7**

Table 8: Ripening profiles of 'Hass' avocado fruit from trees that were sprayed on 19 May 2021 and sampled four weeks later. The fruit were stored for 4 weeks at 5 °C before being ripened at 20 °C

Application rate (g ai/ha)	Rep. no	Ripe fruit per day (%)								
		D4	D5	D6	D7	D8	D9	D10	D11	D12
0	1		20	30	30		10	10		
	2	10	20	20	20	20	10			
	3		20	20	30	10	20			
	Mean	**3.3**	**20.0**	**23.3**	**26.7**	**10.0**	**13.3**	**3.3**		
100	1		20	30	30	20				
	2		10	20	30	20	10		10	
	3			20	40	20	10	10		
	Mean		**10.0**	**23.3**	**33.3**	**20.0**	**6.7**	**3.3**	**3.3**	
150	1				30	40	20	10		
	2			10	30	30	20	10		
	3				20	40	20	20		
	Mean			**3.3**	**26.7**	**36.7**	**20.0**	**13.3**		
200	1				30	20	30		10	10
	2				20	30	20	20	10	
	3					20	30	20	20	10
	Mean				**16.7**	**23.3**	**26.7**	**13.3**	**13.3**	**6.7**

Table 9: Ripening profiles of 'Hass' avocado fruit from trees that were sprayed on 19 May 2021 and sampled eight weeks later. The fruit were stored for 4 weeks at 5 °C before being ripened at 20 °C

Application rate (g ai/ha)	Rep. no	Ripe fruit per day (%)							
		D1	D2	D3	D4	D5	D6	D7	D8
0	1	10	15	25	25	25			
	2	10	20	35	25	10			
	3	15	15	30	20	20			
	Mean	**11.7**	**16.7**	**30.0**	**23.3**	**18.3**			
100	1		20	25	20	20	15		
	2		10	20	30	30	10		
	3	5	5	20	30	20	10	5	5
	Mean	**1.7**	**11.7**	**21.7**	**26.7**	**23.3**	**11.7**	**1.7**	**1.7**
150	1		10	15	15	20	30	10	
	2		15	25	20	30	10		
	3	20	5	20	30	20		5	
	Mean	**6.7**	**10.0**	**20.0**	**21.7**	**23.3**	**13.3**	**5**	
200	1		20	15	20	20	5	10	10
	2		5	25	25	20	10	10	5
	3			15	25	20	15	10	15
	Mean		**8.3**	**18.3**	**23.3**	**20.0**	**10.0**	**10.0**	**10.0**