Interim Report 2018-19

Integrating alternative sprout suppressants for the fresh market

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Contents

1. Summary

The main aim of the trial in this first year of the trials was to carry out an assessment on the comparative efficacy (+/- maleic hydrazide, MH) of a range of approved and near market sprout suppressant treatments: maleic hydrazide, orange oil, 1,4 dimethylnaphthalene (DMN), ethylene and spearmint oil (BIOX-M), on a range of important pre-pack varieties.

Four mainstream pre-packing varieties from the top 20 GB planted area were used in the trial. Maris Piper (1st), King Edward (18th), Melody (5th) and Nectar (4th) were subject to the various treatments and treatment combinations and assessed for sprout control over a 9 month storage period.

In this first year of the trial MH provided significant sprout control activity for all varieties compared to MH-free treatment over the 9 months of storage and also during a succeeding period of shelf life.

DMN and Biox M provided significant sprout control activity for all varieties over the 9 months of storage. Ethylene and orange oil treatments provided control on longer dormant varieties and, in combination with MH, could provide acceptable results for pre-pack storage. DMN was the most effective volatile treatment to control sprouting during shelf life. Nevertheless, it was less effective than MH for this purpose.

There were no observable effects of any treatment on visual appearance or weight loss although there appeared to be an adverse interaction of DMN with the variety Melody which requires further investigation.

2. Introduction

There has been significant reliance on the use of CIPC as sprout suppressant over many years for the fresh market. It has acted for many as a 'crutch' to support refrigerated storage of crops especially in overhead throw stores where temperature alone has struggled to maintain quality due to the inherent variability of the design and a need to manage costs.

The expected withdrawal of approval requires independent information on the relative efficacy of a range of alternatives for use either alone or in combination for sprout suppression in the storage of potatoes destined for the fresh market.

The objectives of this trial were:

1. To carry out an assessment on the comparative efficacy (+/- maleic hydrazide) of a range of sprout suppression treatments: orange oil; 1,4 dimethylnaphthalene; ethylene and spearmint oil (BIOX-M), on a range of important pre-pack varieties.
2. Obtain information on effective treatments and any limitations they display in efficacy, to maximise information availability, and address any identified gaps.

This study is aimed at the assessment of potatoes stored for fresh market, a similar study is being carried out for potatoes stored for the processing market (AHDB Project Ref: 11140043).

3. Materials and methods

Four mainstream pre-packing varieties were assessed for sprout control over a 9 month storage period, using a variety of approved and near market sprout suppressant chemicals.

Fields containing varieties Maris Piper, King Edward, Melody and Nectar were identified during the 2018 growing season. Early crop identification was necessary in order to treat crops with maleic hydrazide (MH), which is typically applied 6 weeks prior to harvest. In cases where the grower was intending to treat the whole field, plots were covered using polythene sheet, just prior to spraying. In crops where MH was not going to be applied, plots were sprayed by hand lance at the appropriate time.

Post-treatment, the covered crops were uncovered and all were treated as per commercial practice for the remainder of the season.

At harvest plots were dug by hand alongside replicate plots of treated / untreated crop taken from the same field. Care was taken to avoid selecting plots adjacent to tramlines. Tubers were harvested directly into storage nets prior to transport.

On arrival at the stores, sample nets from each plot were divided into lots for loading for storage and post-harvest treatments. Plot replication was maintained throughout.

All stores used were identical "new 6 tonne" units that were built at Sutton Bridge Crop Storage Research in 2016. All units have full, computerised control of temperature, humidity & CO_2. They have been built to controlled atmosphere standards, thus potential for cross contamination between treatments is negated.

Table 1. List of varieties and treatments

Variety	Field Treatment	Storage Treatment	Storage durations	Replicate
King Edward	MH-free	Untreated	3 months (SO1)	Rep 1
Maris Piper	MH treated	CIPC	6 months (SO2)	Rep 2
Melody		Ethylene (Restrain)	9 months (SO3)	Rep 3
Nectar		Spearmint Oil (BIOX-M)		Rep 4
		DMN (1-4 Sight)		
		Orange Oil (Argos)		
		Ethylene / Mint Oil		

Each store was loaded with 6 x one tonne boxes of MH treated Maris Piper. Sample nets were randomly located, sub surface, across the 6 boxes.

The harvesting of crops was completed as follows:

17th September 2018 – Maris Piper

21st September 2018 – King Edward

27th September 2018 – Nectar

28th September 2018 – Melody

Store loading was completed on 4th October 2018. Store temperatures, initially at c. 13°C were pulled down at a rate of 1°C per day, until set point was reached at 4.5°C. This temperature was attained by around 16th October.

Table 2. Treatment dates

	Week	Store 1	Store 2	Store 3	Store 4	Store 10	Store 47	Store 23
Treatment		Untreated	Ethylene	BIOX-M	DMN	CIPC	Orange Oil	Ethylene / Mint Oil
	40							
	41				12-Oct	12-Oct		
	42							
	43							
	44							
	45		Start	06-Nov			06-Nov	
	46							
	47				21-Nov			
	48						28-Nov	
	49							
	50			12-Dec				
	51						19-Dec	19-Dec
	52							
SO 1	1							
	2						09-Jan	
	3							
	4			23-Jan				
	5						30-Jan	
	6							
	7				13-Feb			
	8						20-Feb	
	9							
	10			06-Mar				
	11						13-Mar	
	12							20-Mar
	13							
SO 2	14						03-Apr	
	15				10-Apr			
	16			16-Apr				
	17							
	18				05-May			
	19							
	20							
	21							
	22			29-May				
	23							
	24						12-Jun	
	25							19-Jun
	26							
SO 3	27							

Treatment equipment

CIPC was applied using the formulation Aceto CIPC 50M using a Swingfog SN50 hot-fog applicator [Allpest Equipment Services, Flore, Northants, NN7 4LJ]. The applicator (see Figure 2) was fitted with a 1.0mm nozzle giving a chemical flow rate of 20.5 L/h. Once treated with CIPC the store was flushed and returned to normal store control 24 hours after application, as is best practice for crops destined for the fresh market.

Figure 2. Swingfog SN-50 for application of CIPC as a hot fog.

All other treatments treatments (Figure 3) were carried out using a Cedax Electrofog EWH-3000 machine [Cedax S.r.l., Via F. Guarini 15, 47100 Forli, Italy] and applied at a target fog temperature according to label recommendations (Table 3). Temperature and humidity control were re-instated 24 hours after applications.

Treatments were applied at the rates shown in Table 3 and dates of applications in table 2. In each store, post-harvest applications (except Ethylene) were made with fans operating at low speed pushing applied chemical through the crop via the ventilation plenum.

Ethylene was a continuous treatment aiming to maintain an atmosphere concentration of 10ppm ethylene within the store at all times after a pre-programmed, low dose start-up ramp.

Figure 3. CEDAX Electrofog EWH-3000 for application of Mint Oil, DMN and Orange Oil.

Table 3. Rates of application

Treatment		Total
CIPC	Single application at 12g/t	12g
Ethylene	Continuous treatment at 10ppm after start ramping	n/a
Spearmint oil	60ml/t BIOX-M all applications	360ml
DMN	Applications at: 20,15, 15, 10,10 ml/t progressively	70ml
Orange Oil	100ml/t all applications	900ml
Ethylene/Mint	Continuous ethylene at 10ppm after start ramp then 60ml/t BIOX-M mint oil 2 weeks before unloading	60ml

At each sampling occasion, nets were removed from store and assessed for weight loss and sprouting. After initial assessments, samples were returned to a store at 12°C for a further 12 days before being assessed again in a test designed to simulate the shelf life of the product in a retail store. Samples of each variety and field treatment were also assessed for MH residues at each sampling occasion.

Store temperature and ethylene (Restrain) data is available but not shown.

4. Results

Maleic hydrazide (MH) residues

MH residues were analysed from samples at intake and each subsequent sampling occasion. There were differences in residue levels between varieties (Table 4). Notably MH was found in MH-free Melody samples and was therefore excluded from subsequent analysis of overall treatment effects.

Table 4: Average MH residues found in tubers of trial varieties

Variety	Treatment	mg/kg MH
King Edward	+ MH	12.3
Maris Piper	+ MH	11.7
Melody	+ MH	8.9
Melody	MH -	2.7
Nectar	+ MH	16.8

Sprouting after storage

Generally, there was limited sprouting other than in the untreated MH-free samples (Figures 4-7). Sprouting was more evident in shorter dormant than longer dormant varieties. The y axis sprouting scale differs for the different varieties to highlight the effect of treatments. MH treatment statistically significantly ($p<0.05$) reduced sprouting for all varieties compared to MH-free treatment. This was also the case for Melody in which the nominally untreated was known to contain MH. MH treatment alone was, for both Nectar and Melody, sufficient to restrict sprouting to ~1 mm after 9 months storage.

Biox M and DMN both controlled sprouting extremely well in King Edward, Maris Piper and Melody to 9 months storage (SO3) in the absence of MH. There were no statistically significant differences for sprouting between the Biox M and DMN treatments for these varieties. DMN was also able to control sprouting in Nectar with or without MH treatment.

Orange oil, ethylene and ethylene/BioxM treatments were able to control sprouting in Melody and Nectar to 1 mm or less even in the absence of MH. Sprouting in King Edward and Maris Piper were controlled to less than 2.5 mm in the presence of MH. Further data for earlier storage durations is shown in Appendix B.

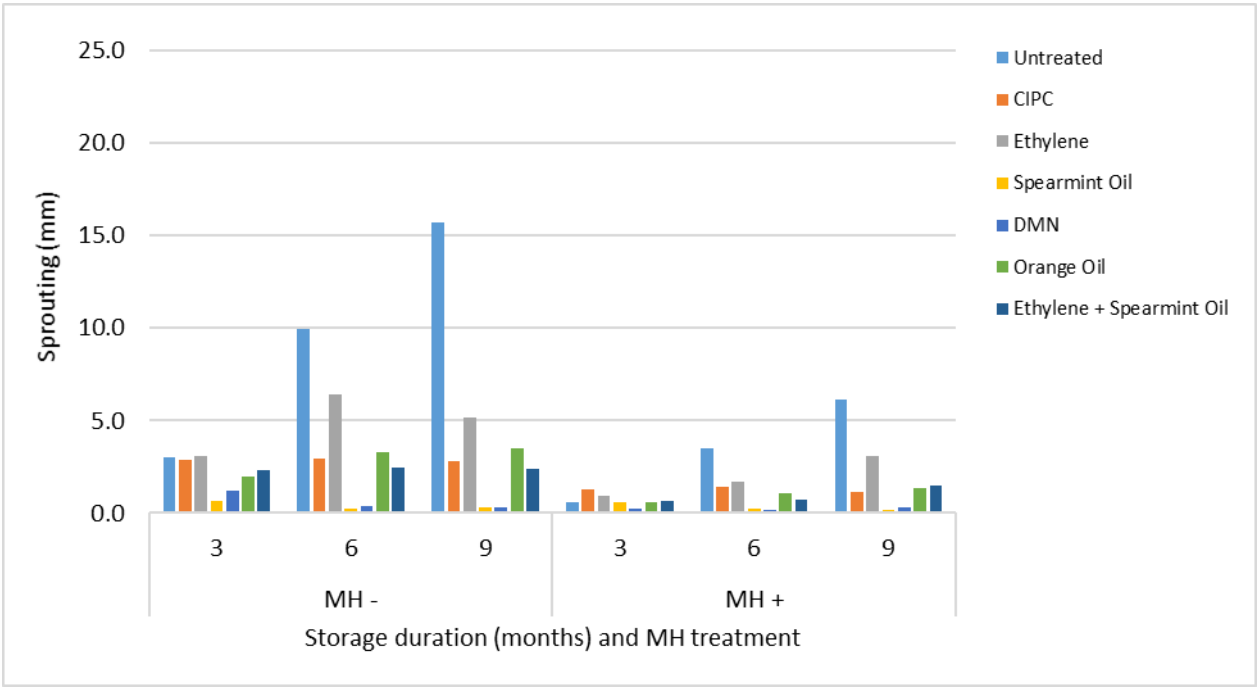

Figure 4. Sprouting of King Edward for each treatment and sampling occasion

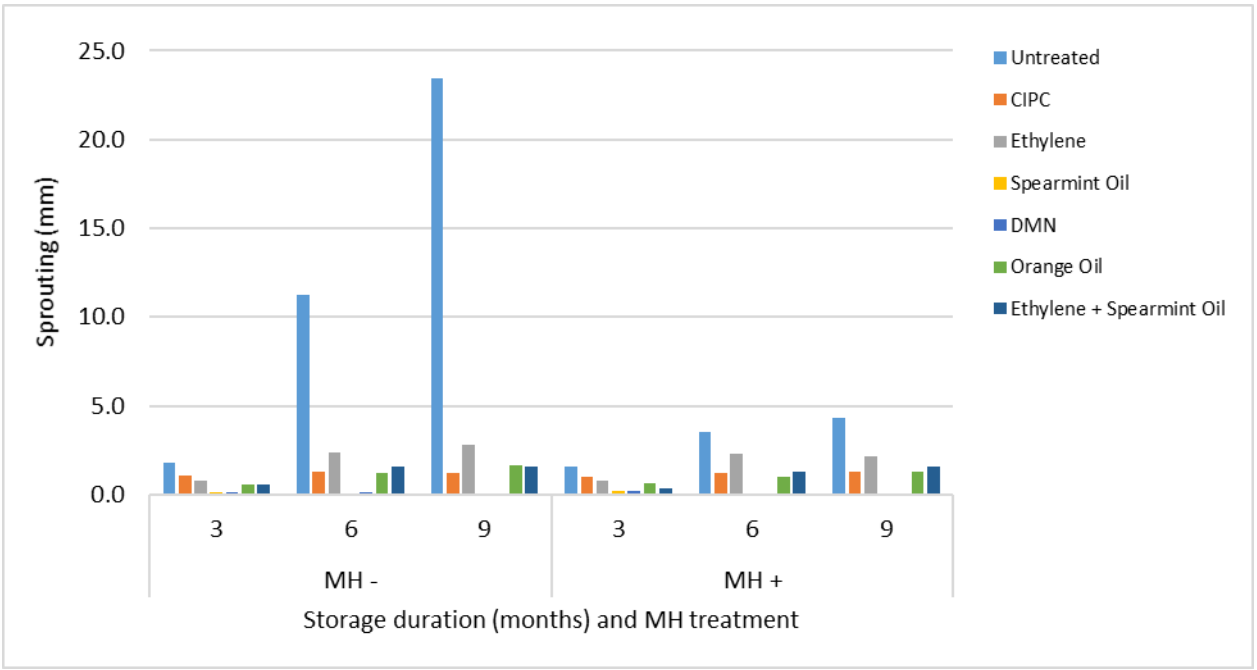

Figure 5. Sprouting of Maris Piper for each treatment and sampling occasion

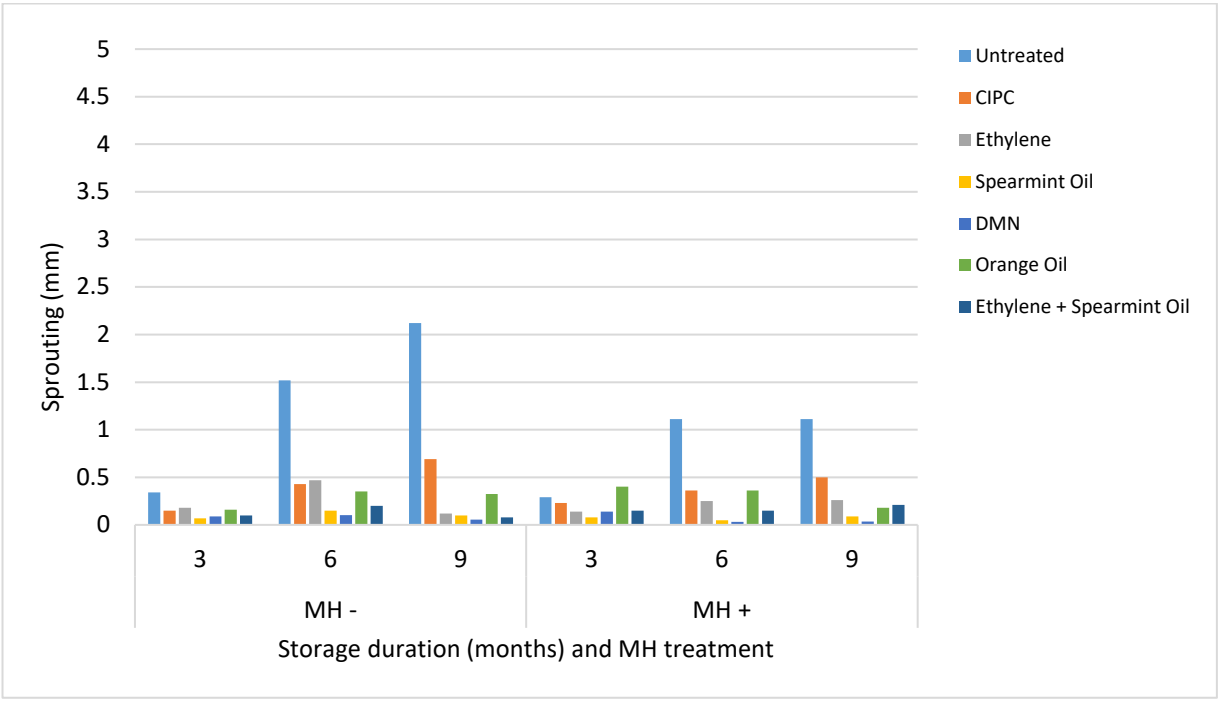

Figure 6. Sprouting of Melody for each treatment and sampling occasion

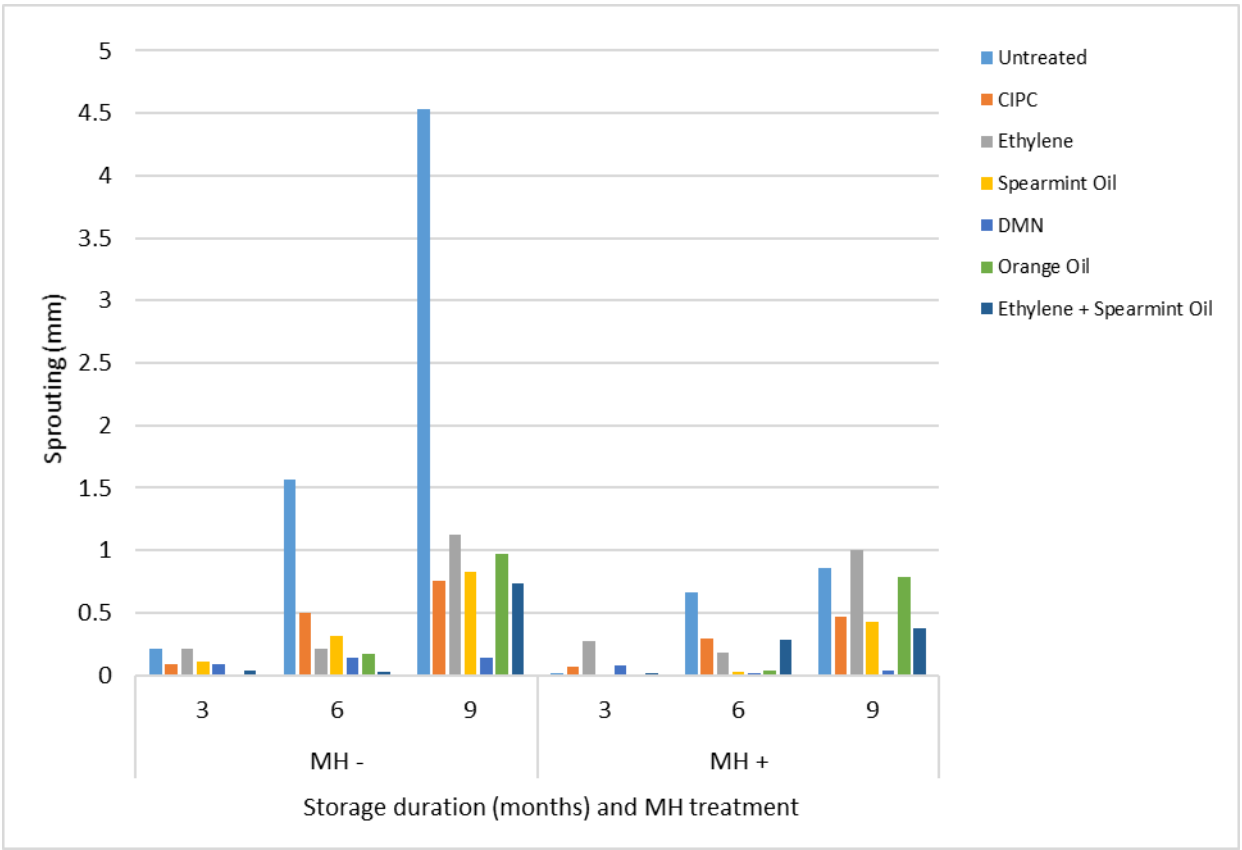

Figure 7. Sprouting of Nectar for each treatment and sampling occasion

Sprouting after shelf life

Sprouting during shelf life minus sprouting at nine months storage is shown in Figure 8. Sprouting was more vigorous following shelf life testing at 3 months storage than at longer storage durations (not shown).

MH showed a statistically significant residual suppressant activity during shelf life even at nine months of testing for all varieties and other treatments. All treatments were more effective in combination with MH. Further data for the individual varieties is shown in the Appendix.

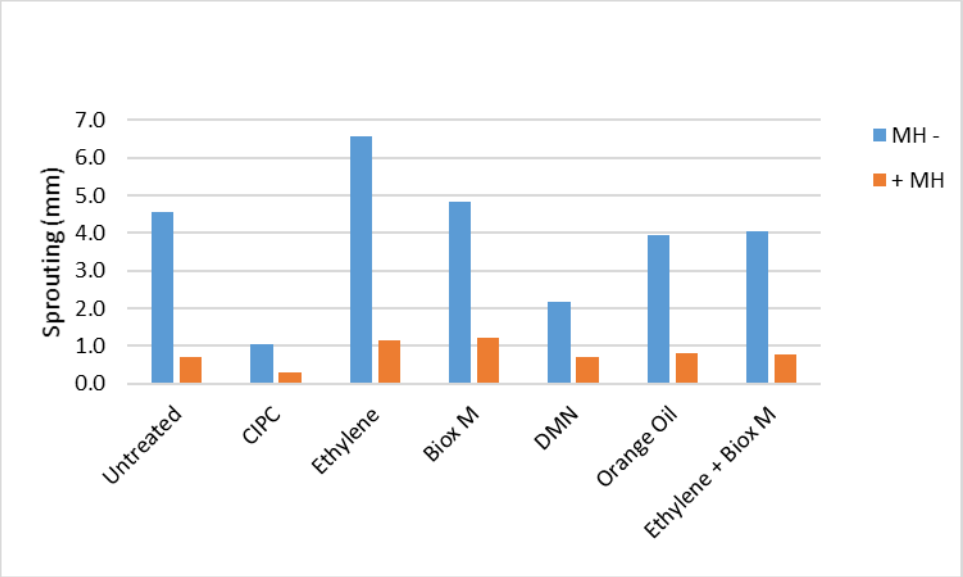

Figure 8. Sprouting after shelf life storage following 9 months storage, average of all varieties Actual sprout length values shelf life minus sprout length at end of storage).

Weight loss

The different varieties had slightly different weight losses over the nine months of storage (Table 5). There were no significant differences between with and without MH treatments on weight loss (not shown). There were no significant differences in weight loss between treatments except with DMN treatment (Table 6) with the results for this treatment on Melody

being affected by bacterial rots. Rotting was found in all replicates of this variety/treatment combination and was particularly evident after 6 and 9 months storage.

Table 5. Percentage weight loss for each variety (all treatments) for each storage occasion.

	Storage term (months)			
Variety	3	6	9	Overall
King Edward	4.3	5.0	6.2	5.2
Maris Piper	2.2	2.8	3.9	3.0
Melody	3.0	4.0	5.4	4.1
Nectar	2.8	3.3	4.1	3.4

Table 6. Percentage weight loss for each treatment (all varieties, sampling occasions and with and without MH)

	Storage term (months)			
Treatments	3	6	9	overall
Untreated	2.8	3.6	4.6	3.6
CIPC	3.2	3.8	4.9	4.0
Ethylene	3.0	3.4	4.3	3.6
Biox M	2.9	3.8	4.9	3.9
DMN	3.2	4.2	6.3	4.5
Orange Oil	3.1	3.8	4.5	3.8
Ethylene + Biox M	3.3	3.9	4.6	4.0

Pre-pack outturn

There were no significant differences between treatments on suitability for packing but there were differences between varieties, with Nectar having a more attractive appearance than King Edward after 6 months storage (Table 7). There were no observable effects of any treatment on visual appearance.

Table 7. Overall pre-pack outturn scores by variety for all treatments and sampling occasions

Variety	Pre-pack outturn score
King Edward	4.1
Maris Piper	3.7
Melody	3.5
Nectar	3.2

5. Discussion

An assessment on the comparative efficacy of a range of sprout suppression treatments including orange oil, 1,4 dimethylnaphthalene, ethylene and BIOX-M, both with and without maleic hydrazide, was carried out. The comparison between with and without MH treatments was direct as the treatments were carried out in the same crop. Maleic hydrazide treatment was very effective as a sprout suppressant either alone for longer dormant varieties or in combination with another suppressant for shorter dormant varieties.

There were differences in the MH residue levels found in samples of the varieties (Table 4), probably a result of differences in the application methods or/and uptake of the chemical following application. MH was found in the control MH-free Melody samples, probably from drift during the MH treatment. It is not known what effect this lower concentration of MH had on sprout control as there was no true MH-free control. However, there was a statistically significant difference in sprout control between the MH+ and MH "free" Melody stocks. The relationship between MH residue concentrations and sprout control is being examined in another current AHDB trial and will be reported in 2020.

DMN and BIOX-M, which is available to the UK market, were the most effective treatments applied in store and were suitable for both short and long dormant varieties, with or without MH. Orange oil, ethylene and ethylene with BIOX-M provided sprout control for longer dormant varieties when in combination with MH.

MH provided effective residual sprout control during shelf life during which the effects of the volatile treatments dissipated. There was little difference between MH treatment alone or in combination with any other treatment. DMN was the most effective store applied suppressant during shelf life.

Vigorous sprouting post-shelf life at 3 months storage was probably due to the extended duration (nine days) over which sprout length measurements were taken after this particular sampling occasion. These measurements were completed within 4 days for the six and nine month sampling occasions.

There were no direct effects of any treatment on weight loss. However, there was an indirect effect from bacterial rotting in DMN treated Melody which was not found with other treatments or varieties. Investigations are being pursued to understand this finding.

The application schedule of treatments for the trial was established from label recommendation and advice from the rights holders. Improved results could be obtained if dose rates and scheduling were made for each individual variety, unfortunately not possible in the current trial.

6. Conclusions

Four mainstream pre-packing varieties from the top 20 GB planted area were assessed for sprout control over a 9 month storage period, using a variety of approved and near market sprout suppressant chemicals.

In this first year of the trial MH provided significant sprout control activity for all varieties compared to MH-free treatment over the 9 months of storage and also during the succeeding period of shelf life. MH will help reduce the costs of storage being an effective sprout suppressant when residue levels are sufficient, providing synergy with other post-harvest treatments and, being non-volatile, is active under conditions where other suppressant atmospheres cannot be provided or maintained. It will provide valuable control during store loading, unloading and shelf life.

DMN and BIOX-M were effective in controlling sprouting s for all varieties and in the absence of other treatments over the 9 months of storage. Ethylene and orange oil treatments provided some control on longer dormant varieties and, in combination with MH, could provide acceptable results for pre-pack storage. DMN was the most effective volatile treatment to control sprouting during shelf life. Nevertheless, it was less effective than MH for this purpose.

An interaction of DMN with Melody requires further investigation.

7. Acknowledgements

We wish to thank William Dickson (QV Foods) and Simon Day (Worth Farms) for their great assistance in acquiring the stocks used in the trial.

Appendix

A. Length of longest sprout by variety, treatment and occasion

Sprouting (longest sprout): 3 months storage

King Edward	MH +	SD	MH -	SD
Untreated	**0.58**	1.67	**3.04**	4.37
CIPC	**1.31**	1.88	**2.91**	3.22
Ethylene	**0.91**	2.38	**3.10**	4.89
Mint Oil	**0.56**	2.21	**0.69**	1.93
DMN	**0.21**	0.81	**1.24**	1.75
Orange Oil	**0.62**	1.43	**1.95**	3.58
Ethylene + Mint Oil	**0.63**	1.59	**2.35**	4.46

Maris Piper	MH +	SD	MH -	SD
Untreated	**1.60**	1.39	**1.80**	1.32
CIPC	**1.00**	0.85	**1.11**	1.63
Ethylene	**0.77**	0.66	**0.82**	0.85
Mint Oil	**0.20**	0.65	**0.12**	0.33
DMN	**0.19**	0.44	**0.12**	0.41
Orange Oil	**0.66**	0.77	**0.56**	0.66
Ethylene + Mint Oil	**0.38**	0.62	**0.54**	1.01

Melody	MH +	SD	MH -	SD
Untreated	**0.29**	1.08	**0.34**	0.92
CIPC	**0.23**	0.65	**0.15**	0.56
Ethylene	**0.14**	0.45	**0.18**	0.61
Mint Oil	**0.08**	0.39	**0.07**	0.36
DMN	**0.14**	0.62	**0.09**	0.51
Orange Oil	**0.40**	1.51	**0.16**	0.47
Ethylene + Mint Oil	**0.15**	0.67	**0.10**	0.56

Nectar	MH +	SD	MH -	SD
Untreated	**0.02**	0.14	**0.21**	1.16
CIPC	**0.07**	0.26	**0.09**	0.51
Ethylene	**0.27**	1.19	**0.21**	0.56
Mint Oil	**0.00**	0.00	**0.11**	0.37
DMN	**0.08**	0.31	**0.09**	0.29
Orange Oil	**0.01**	0.10	**0.00**	0.00
Ethylene + Mint Oil	**0.02**	0.14	**0.04**	0.20

Sprouting (longest sprout): – 6 months storage

King Edward	MH+	SD	MH -	SD
Untreated	**3.50**	7.43	**9.93**	11.95
CIPC	**1.41**	1.35	**2.96**	3.22
Ethylene	**1.73**	3.00	**6.44**	8.18
Mint Oil	**0.26**	1.35	**0.25**	0.80
DMN	**0.15**	0.39	**0.41**	1.08
Orange Oil	**1.08**	2.51	**3.29**	3.54
Ethylene + Mint Oil	**0.72**	0.85	**2.48**	2.95

Maris Piper	MH+	SD	MH -	SD
Untreated	**3.54**	3.24	**11.23**	8.42
CIPC	**1.20**	0.80	**1.29**	0.72
Ethylene	**2.33**	4.67	**2.41**	2.01
Mint Oil	**0.08**	0.27	**0.05**	0.22
DMN	**0.10**	0.36	**0.13**	0.39
Orange Oil	**1.04**	0.55	**1.21**	0.65
Ethylene + Mint Oil	**1.29**	1.11	**1.59**	1.22

Melody	MH+	SD	MH -	SD
Untreated	**1.11**	1.20	**1.52**	1.28
CIPC	**0.36**	0.67	**0.43**	0.79
Ethylene	**0.25**	0.56	**0.47**	0.78
Mint Oil	**0.05**	0.50	**0.15**	0.46
DMN	**0.03**	0.22	**0.10**	0.34
Orange Oil	**0.36**	0.61	**0.35**	0.82
Ethylene + Mint Oil	**0.15**	0.48	**0.20**	0.49

Nectar	MH+	SD	MH -	SD
Untreated	**0.66**	0.73	**1.57**	1.23
CIPC	**0.29**	0.50	**0.50**	0.77
Ethylene	**0.18**	0.44	**0.21**	0.43
Mint Oil	**0.03**	0.17	**0.31**	0.53
DMN	**0.02**	0.14	**0.14**	0.43
Orange Oil	**0.04**	0.20	**0.17**	0.43
Ethylene + Mint Oil	**0.28**	0.71	**0.03**	0.22

Sprouting (longest sprout): – 9 months storage

King Edward	MH+	sd	MH -	sd
Untreated	**6.11**	13.08	**15.69**	18.80
CIPC	**1.11**	1.73	**2.79**	2.90
Ethylene	**3.07**	5.41	**5.17**	5.53
Mint Oil	**0.20**	0.43	**0.30**	0.69
DMN	**0.29**	0.48	**0.31**	1.19
Orange Oil	**1.33**	1.80	**3.52**	2.97
Ethylene + Mint Oil	**1.51**	1.11	**2.36**	2.71

Maris Piper	MH +	sd	MH -	sd
Untreated	**4.35**	3.70	**23.41**	9.66
CIPC	**1.30**	0.73	**1.23**	0.97
Ethylene	**2.14**	1.75	**2.82**	2.26
Mint Oil	**0.00**	0.00	**0.01**	0.10
DMN	**0.04**	0.20	**0.00**	0.00
Orange Oil	**1.29**	0.73	**1.63**	0.75
Ethylene + Mint Oil	**1.56**	1.17	**1.57**	1.34

Melody	MH +	sd	MH -	sd
Untreated	**1.11**	2.69	**2.12**	3.17
CIPC	**0.50**	0.69	**0.69**	1.60
Ethylene	**0.26**	0.54	**0.12**	0.41
Mint Oil	**0.09**	0.29	**0.10**	0.39
DMN	**0.03**	0.18	**0.05**	0.23
Orange Oil	**0.18**	0.46	**0.32**	0.64
Ethylene + Mint Oil	**0.21**	0.43	**0.08**	0.27

Nectar	MH +	sd	MH -	sd
Untreated	**0.86**	0.64	**4.53**	5.66
CIPC	**0.47**	0.50	**0.75**	0.69
Ethylene	**1.00**	0.68	**1.12**	1.53
Mint Oil	**0.43**	0.52	**0.83**	0.57
DMN	**0.04**	0.20	**0.14**	0.35
Orange Oil	**0.79**	0.52	**0.97**	0.58
Ethylene + Mint Oil	**0.37**	0.56	**0.73**	1.85

B. Sprouting following shelf life storage

Sprouting (longest sprout): shelf life following 3 months storage

King Edward	MH +	sd	MH -	sd
Untreated	**1.96**	2.07	**12.09**	6.96
CIPC	**1.66**	1.40	**2.52**	2.17
Ethylene	**3.21**	2.91	**11.64**	6.34
Mint Oil	**2.10**	2.14	**5.97**	5.53
DMN	**1.22**	0.84	**2.81**	2.06
Orange Oil	**2.74**	2.50	**12.24**	5.58
Ethylene + Mint Oil	**2.62**	3.48	**9.46**	5.30

Maris Piper	MH +	sd	MH -	sd
Untreated	**5.22**	4.00	**15.57**	5.60
CIPC	**0.95**	0.67	**0.80**	0.74
Ethylene	**5.45**	3.62	**14.60**	5.04
Mint Oil	**5.02**	3.77	**9.71**	6.39
DMN	**2.85**	2.18	**5.64**	3.78
Orange Oil	**5.42**	3.55	**15.77**	4.90
Ethylene + Mint Oil	**4.14**	3.01	**10.25**	5.44

Melody	MH +	sd	MH -	sd
Untreated	**3.79**	1.93	**7.41**	3.76
CIPC	**0.96**	0.78	**1.06**	0.83
Ethylene	**3.98**	2.11	**6.75**	3.63
Mint Oil	**2.89**	1.69	**4.63**	2.65
DMN	**1.98**	1.30	**4.71**	3.15
Orange Oil	**4.15**	2.95	**6.24**	3.51
Ethylene + Mint Oil	**2.86**	1.73	**3.54**	2.71

Nectar	MH +	sd	MH -	sd
Untreated	**1.45**	2.12	**5.36**	4.43
CIPC	**1.09**	1.03	**0.95**	0.78
Ethylene	**1.78**	1.69	**6.06**	4.49
Mint Oil	**1.06**	0.94	**3.25**	4.39
DMN	**1.18**	0.97	**2.05**	1.86
Orange Oil	**2.07**	1.50	**6.53**	4.73
Ethylene + Mint Oil	**1.26**	1.32	**2.33**	2.53

Sprouting (longest sprout): shelf life following 6 months storage

King Edward	MH +	SD	MH -	SD
Untreated	**3.19**	4.89	**13.15**	9.09
CIPC	**1.75**	1.46	**2.92**	2.25
Ethylene	**2.65**	2.92	**10.05**	7.43
Mint Oil	**1.81**	1.73	**4.72**	2.37
DMN	**0.96**	0.57	**1.10**	0.59
Orange Oil	**2.73**	2.14	**7.06**	3.27
Ethylene + Mint Oil	**2.23**	1.45	**5.31**	3.26

Maris Piper	MH +	SD	MH -	SD
Untreated	**3.87**	3.14	**12.36**	7.24
CIPC	**1.20**	0.55	**1.42**	0.85
Ethylene	**4.28**	2.56	**8.64**	3.43
Mint Oil	**1.43**	1.07	**1.95**	1.42
DMN	**1.34**	0.57	**1.83**	0.77
Orange Oil	**3.34**	1.53	**6.03**	2.59
Ethylene + Mint Oil	**2.35**	1.49	**3.79**	2.52

Melody	MH +	SD	MH -	SD
Untreated	**2.97**	1.31	**6.10**	2.46
CIPC	**1.14**	1.03	**1.02**	0.55
Ethylene	**3.55**	1.87	**5.09**	2.16
Mint Oil	**2.74**	1.16	**4.76**	1.69
DMN	**1.93**	0.93	**2.98**	1.35
Orange Oil	**2.69**	1.27	**4.13**	1.64
Ethylene + Mint Oil	**2.58**	0.88	**3.06**	1.34

Nectar	MH +	SD	MH -	SD
Untreated	**2.26**	1.77	**7.59**	3.17
CIPC	**0.81**	0.49	**1.52**	1.09
Ethylene	**2.04**	1.02	**6.45**	2.67
Mint Oil	**1.55**	1.08	**5.56**	2.24
DMN	**1.99**	1.32	**4.97**	1.83
Orange Oil	**1.47**	0.83	**6.22**	2.70
Ethylene + Mint Oil	**1.63**	1.22	**3.76**	1.68

Sprouting (longest sprout): shelf life following 9 months storage

King Edward	MH +	SD	MH -	SD
Untreated	**6.72**	12.79	**17.06**	15.48
CIPC	**1.28**	1.48	**2.26**	2.65
Ethylene	**3.49**	4.51	**10.12**	4.84
Mint Oil	**1.09**	0.92	**3.30**	1.90
DMN	**0.10**	0.33	**0.49**	0.61
Orange Oil	**1.95**	1.89	**6.28**	2.86
Ethylene + Mint Oil	**1.75**	1.34	**5.14**	2.84

Maris Piper	MH +	SD	MH -	SD
Untreated	**4.19**	3.77	**24.44**	8.55
CIPC	**1.05**	0.73	**1.49**	1.34
Ethylene	**2.47**	1.65	**6.14**	3.18
Mint Oil	**0.76**	0.67	**1.56**	1.42
DMN	**0.57**	0.56	**0.87**	0.54
Orange Oil	**1.95**	0.74	**3.40**	1.79
Ethylene + Mint Oil	**1.50**	0.86	**3.10**	2.26

Melody	MH +	SD	MH -	SD
Untreated	**1.67**	1.51	**4.89**	3.18
CIPC	**1.35**	0.81	**3.73**	3.19
Ethylene	**2.61**	1.56	**5.90**	3.06
Mint Oil	**2.09**	1.19	**2.91**	1.86
DMN	**0.59**	0.92	**1.27**	1.42
Orange Oil	**1.24**	1.02	**2.31**	1.62
Ethylene + Mint Oil	**1.82**	1.09	**2.95**	1.87

Nectar	MH +	SD	MH -	SD
Untreated	**2.65**	2.90	**17.65**	5.12
CIPC	**0.89**	0.53	**2.25**	1.90
Ethylene	**2.54**	3.02	**13.31**	4.32
Mint Oil	**1.72**	1.12	**12.78**	3.88
DMN	**1.94**	0.99	**6.54**	2.74
Orange Oil	**1.75**	1.21	**10.20**	3.80
Ethylene + Mint Oil	**1.68**	1.70	**9.67**	3.65