Interim Report

Efficacy of sprout suppressants either alone or in combination to control sprouting of potato

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1. Summary

The aim of the project was to investigate whether treatments using alternative sprout suppressants, or the combined use of an alternative together with CIPC, provides effective, affordable sprout control.

The trial used sprout suppressants currently registered in the UK; CIPC, maleic hydrazide (MH), ethylene and spearmint oil. In addition, the trial used the Annex 1 listed (but not currently approved for UK use) suppressant 1,4 dimethylnapthalene (DMN). The trial factorially tested the non-CIPC chemical treatments singly and in combination with CIPC for efficacy of sprout suppression. Five processing varieties were used in the trial.

Treatments with and without MH were different crops for each variety and necessarily there may have been effects of agronomy and environment that were not controlled in this particular trial.

The results demonstrated excellent sprout control by CIPC and DMN. Ethylene and spearmint oil provided statistically significant sprout suppression compared to untreated. Combinations of different treatments were more effective than each treatment alone. This was the case even with CIPC and DMN, each highly effective sprout suppressants, were statistically significantly better when used in combination.

2. Experimental section

2.1 Introduction

Sprout control is critical to the year-round supply of ware potatoes and the industry relies on Chlorpropham (CIPC), a relatively cheap and highly effective sprout suppressant. In 2014, 3.1M tonne potatoes were stored and CIPC was applied to 1.2M tonne (84% of all treated crop). These CIPC treated crops received an average of 1.86 applications each[1].

CIPC is under very severe threat of loss to the industry through regulatory review by the European Food Safety Authority[2], the outcome of which will be known in 2019. There has been sustained pressure to reduce dosage and residues through regulation and stewardship (Potato Industry CIPC Stewardship Group [PICSG]). The maximum dose has been reduced by 44% since stewardship began in 2008. During this period there were eight CIPC residue exceedances and there is great risk to the whole industry if further exceedances were to occur[3].

The aim of the project was to investigate whether treatments using alternative sprout suppressants, or the combined use of an alternative together with CIPC, provides effective, affordable sprout control. A previous AHDB Potatoes funded project (R441/R464) found much lower overall doses of CIPC were effective when used in combination with ethylene, an alternative sprout suppressant.

There are currently three registered alternative sprout suppressants to CIPC in UK. They are less effective and more costly than CIPC and may provide incomplete control (maleic hydrazide), or may have adverse effects on the processing quality of some varieties (ethylene) or may be less well accepted by the industry (spearmint oil).

There is a lack of data to support strategies based on non-CIPC or low dose CIPC combination treatments and this project aimed to address this deficiency and provide the industry with new and innovative options. The project factorially tested three non-CIPC chemical treatments and further tested these non-CIPC chemical treatments in combination with CIPC for efficacy of sprout suppression.

2.2 Material and methods

Crop, treatments and experimental design

Stocks of five processing cultivars, Innovator, Maris Piper, Performer, Royal and VR808, (tubers> 40mm) were each sourced from two independent sites, only one of which was treated in the field with maleic hydrazide (MH) [*Fazor*, MAPP 13617] at 5 kg per hectare. During storage, the ten stocks were subjected to a further eight sprout suppressant regimes and held at 9.0 °C in separate six-tonne capacity controlled environment rooms (CERs). The treatments were: 1, 4-dimethylnaphthalene (DMN), ethylene, spearmint oil and untreated, each with and without an early application of CIPC (12 g/tonne). However, the CIPC/untreated combination had a further two CIPC applications at the same dose to represent industry standard practice.

Four replicate sample nets for each of three sampling occasions were buried approximately three tubers down in MH-treated Maris Piper bulk material in fully randomised positions shared between six pallet boxes.

Store set up and control

All stores were configured for positive ventilation. Boxes were stacked tightly in three columns of two, against a plenum chamber. Pressurised air discharged from the plenum was blocked at ground level and open at the middle slot. At the opposite end of the stack, the aperture between boxes was blocked in order to force air through the crop and not through the pallet box apertures. A temperature probe was buried in each box to monitor crop temperature. Store air was recirculated through a conditioning duct for automatic refrigeration or heating as necessary. The non-CIPC treatments were held in stores never treated with CIPC sprout suppressant.

Pull down and applications

Stores were loaded on 19th October 2017 and steadily pulled down from an average temperature of approximately 15 °C to a holding temperature of 9 °C (±0.5 °C) at a rate of 0.5 °C per day. Although automatic humidification after pull-down was intended, there was a steady soft rotting problem associated with the bulk crop that was managed by an extended period without humidification. With the aid of careful sensor monitoring and visual crop inspection it never became prudent to engage automatic control.

Chlorpropham (CIPC) [*Aceto 50M*, MAPP 14134] was applied as a hot fog using a *Swingfog SN50* [*Motan*], fitted with a 1.0mm nozzle, at 12 g/tonne a.i. on 8th November 2017. Stores were switched off after warming the fridge coils to prevent any fog condensation. The plenum chamber was fogged directly with the assistance of an auxiliary fan [*Multifan TB4E50, Votermanns Ventilation BV*] used to positively assist the fog through the crop at its slowest speed setting of 0.45 m^3/s for 6 hours. After this period the clear stores were ventilated by unsealing and opening the front door for 5 minutes and then returning to automatic temperature control. The 'CIPC only' treatment was fogged at the same rate twice more on 18th December 2017 and 11th April 2018.

1,4-dimethylnaphthalene (DMN) [*DormFresh 1,4 Sight*] was applied using a *Cedax Electrofog EWH-3000* [*Xeda*], at a target product temperature of 250 °C, directly into the plenum chambers. The stores were switched off but a slow fan recirculated store air during, and for 30 minutes after, application. The stores then remained off and still for 24 hours before unsealing, venting and returning to automatic control. Starting on 1st November 2017, DMN was applied every five weeks but the dose rate gradually declined with two occasions at 20 ml/tonne, two occasions at 15 ml/tonne and finally three occasions at 10 ml/tonne.

Ethylene control was initiated on 20th November 2017, using *Restrain* ethylene generators [*ICA740, Restrain Company Ltd*] maintained and recorded by sensor units [*ICA730*]. The built in soft start programme was utilised to reduce stress thus preserving processing quality. This comprised 4 day steps at 0.1, 0.2 and 0.3 ppm followed by 2 day steps at 0.5, 1 and 2 ppm and only then the continuous target concentration of 10 ppm. Carbon dioxide concentration was monitored and stores ventilated daily if found above 0.3 %. As the generator was designed for large scale storage, ethylene fuel was diluted to 20 % by adding deionised water and physical fuel throughput reduced to the minimum 0.16 litres per day.

Spearmint oil [*Biox-M*, MAPP 16021] was also applied using the *Electrofog*, directly into the plenum chamber, at a target product temperature of 185 -190 °C. The store was switched off but a slow fan recirculated store air continuously during application and for 24 hours afterward. The store was then unsealed, vented and returned to automatic control. Spearmint was initially applied at 90 g/tonne on 20th December 2017 and subsequently every 28 days at 45 g/tonne on six further occasions.

Sampling and assessment

Samples were taken at intake (18th October 2017) and after 3, 6, and 9 months of storage (8th January, 2nd April and 2nd July 2018, respectively). For each sample, the longest sprout length was measured on all tubers of a 25 potato sub-sample. Fry colour was measured for potatoes processed as crisps for cv. VR808. It was measured for chips (French fries) for cvs. Innovator, Maris Piper, Performer and Royal.

For crisping, 300 g of slices between 1.22 and 1.47 mm thick were taken from 30 mechanically-peeled tubers and washed in water for 45 seconds. Each sample was then fried for 3 minutes in oil heated up to 177 °C at the start of frying. After frying the sample was weighed and then crisps with defects (a dark discolouration larger than a 5 mm diameter circle) removed and weighed. The remaining blemish free sample was then assessed objectively three times using a HunterLab D-9000 colour quality meter fitted with a D25-L optical sensor *[Stotto Group, Mountsorrel, Leics., UK].*

Chips were processed as single 3/8th inch square longitudinal sections from each of 20 sound tubers and fried for 90 seconds in oil heated up to 190 °C at the start of frying. The fry colour of individual strips was assessed subjectively by comparison with a USDA standard colour chart *[Munsell Color, Baltimore, Maryland, USA]* under standard artificial white light. The USDA assessment scale used for assessing chips (light to dark - 000, 00, 0, 1, 2, 3 & 4) was linearized 1 to 7 (SBCSR scale) and reported as a mean. Scores of 1 to 3 are good; scores of 4 and 5 acceptable and higher scores rejected.

In addition, 100 tubers of the ten stocks were taken at store loading for dormancy measurement. The samples were held in paper sacks in a 15°C store at a target humidity of 95% RH. Stocks were assessed approximately weekly for sprout length and the number of tubers showing sprouting at 3 mm or above recorded. Relative dormancy was represented by the number of days taken for half of the tubers to cross the 3 mm sprout threshold.

Important dates for applications and sampling are shown in Appendix 1 Study Diary.

Maleic hydrazide residue analysis

For each variety twelve tuber samples were taken from untreated, ethylene treated and from CIPC treated stores after 9 months storage. The samples were analysed for total maleic hydrazide residue by ALS (Chatteris, PE16 6QZ).

Statistical analysis

Statistical analyses were performed using Microsoft Excel 2016. The statistical significance threshold was set at 5% or less and a single factor parametric Analysis of Variance (ANOVA) was used. Graphs were additionally compiled in MS Excel from resulting descriptive statistics. For all varieties, ANOVA was conducted as single factor for sprout suppressant with mean longest sprout [4 replicates of 25 tubers] as variable. Post-hoc t-test comparisons were applied to investigate significant differences ($P<0.05$) in the ANOVA.

3. Results

***Note:** It is important to remember that treatments with and without maleic hydrazide (MH) are different crops and there may be effects of agronomy and environment that were not controlled in this particular trial.

3.1 Dormancy

The dormancy of tubers of each variety with and without MH treatment was assessed and the results are shown in Table 1. There was at least a 19 day difference in sprouting in store at 15 ^{o}C between untreated and MH-treated crops.

Table 1. Mean days to sprouting at 15^{o} C for tubers of each variety with and without MH*

Variety	Mean days to sprouting (3mm)
Innovator - MH	19.6
Innovator + MH	43.3
M. Piper - MH	18.6
M. Piper + MH	38.3
Performer - MH	46.5
Performer + MH	91.9
Royal - MH	26.2
Royal + MH	57.2
VR808 - MH	37.6
VR808 + MH	68.0

3.2 Tuber sprouting

Sprouting was assessed as the length of the longest sprout at approximately 3 monthly intervals. The results for Innovator, Maris Piper, Performer, Royal and VR808 are shown in Tables 2-6, respectively. An estimate of variation within the data set is shown as standard deviation (sd) for the 9 month sampling occasion.

Maris Piper had the longest sprouts and Performer showing the least sprouting. All treatments significantly reduced sprouting compared with untreated (Appendices 2.1-3). DMN controlled sprouting (average <4mm) effectively in all varieties for the duration of the trial (9 months), CIPC also controlled sprouting particularly in the more dormant varieties Performer, Royal and VR808. Both DMN and CIPC were generally significantly more effective sprout suppressants than spearmint or ethylene at any sampling occasion.

Combination treatments increased efficacy (Tables 2-6). These effects can also be observed as the average sprouting of all varieties (Figure 1). The statistical significance of treatments increased with storage duration (sprouting) and at 9 months.

With the caveat expressed above*, MH treatment also appeared to be effective in reducing sprouting in all varieties at 3 months storage and a useful effect persisted to 9 months storage for Maris Piper and VR808. Combination treatments increased efficacy (Tables 2-6). These effects can be observed as the average sprouting of all varieties (Figures 1 and 2).

A comparison between treatments using the overall sprouting dataset (all varieties, sampling occasions and both MH treatments) per treatment was carried out. There were statistically significant differences ($P<0.05$) in sprout length between treatments (Appendix 2, Table1). CIPC and DMN together were more effective suppressants than either CIPC or DMN alone. In this current trial, DMN was more effective than CIPC alone. Both DMN and CIPC were more effective than either ethylene or spearmint oil. There were no statistically significant differences between ethylene or spearmint oil treatments

Table 2a: Innovator, length of longest sprout at each sampling occasion

	sampling occasion (months)			
Treatment	3	6	9	sd. (9 months)
Untreated	20.5	56.7	52.1	19.5
CIPC	2.0	8.8	15.5	15.6
Ethylene	10.2	19.9	19.9	8.6
Spearmint Oil	9.7	28.9	36.0	15.2
DMN	1.8	2.6	3.8	5.6
CIPC + Ethylene	2.0	5.0	11.6	9.5
CIPC + DMN	0.7	0.5	1.3	2.7
CIPC + Spearmint	0.9	7.1	7.1	10.7

Table 2b: Innovator+MH, length of longest sprout at each sampling occasion

	sampling occasion (months)			
Treatment	3	6	9	sd. (9 months)
Untreated + MH	6.0	21.8	18.3	24.6
CIPC + MH	0.6	1.3	2.2	5.8
Ethylene + MH	1.9	6.8	7.7	5.6
Spearmint Oil + MH	0.9	7.0	8.7	11.6
DMN + MH	0.7	1.2	1.1	1.1
CIPC + Ethylene + MH	0.3	1.6	4.0	4.6
CIPC + DMN + MH	0.1	0.2	0.4	0.5
CIPC + Spearmint + MH	0.3	2.4	3.2	7.3

Table 3a: Maris Piper, length of longest sprout at each sampling occasion

	sampling occasion (months)			
Treatment	3	6	9	sd (9 months)
Untreated	40.3	71.6	78.7	39.9
CIPC	2.8	9.8	15.5	23.4
Ethylene	16.5	24.7	23.1	16.2
Spearmint Oil	21.7	35.2	55.7	28.9
DMN	2.7	1.6	1.4	2.9
CIPC + Ethylene	1.7	2.3	3.2	4.6
CIPC + DMN	0.3	0.1	0.0	0.1
CIPC + Spearmint	1.8	2.3	9.2	20.2

Table 3b. Maris Piper +MH, length of longest sprout at each sampling occasion

	sampling occasion (months)			
Treatment	3	6	9	sd. (9 months)
Untreated + MH	3.9	10.7	10.3	8.5
CIPC + MH	0.6	1.3	0.8	1.0
Ethylene + MH	1.6	4.1	4.1	2.9
Spearmint Oil + MH	0.9	2.8	4.3	9.5
DMN + MH	0.5	0.4	0.2	0.4
CIPC + Ethylene + MH	0.3	0.5	0.4	0.6
CIPC + DMN + MH	0.1	0.0	0.0	0.2
CIPC + Spearmint + MH	0.0	0.0	0.0	0.1

Table 4a: Performer, length of longest sprout at each sampling occasion

	sampling occasion (months)			
Treatment	3	6	9	s.d. (9 months)
Untreated	5.0	34.7	45.4	18.8
CIPC	0.4	1.6	2.5	6.7
Ethylene	1.3	17.4	23.5	6.5
Spearmint Oil	0.7	15.3	34.5	16.6
DMN	0.2	0.4	0.6	0.5
CIPC + Ethylene	0.2	1.7	5.7	8.1
CIPC + DMN	0.2	0.0	0.0	0.1
CIPC + Spearmint	0.0	0.7	1.2	4.4

Table 4b: Performer+MH, length of longest sprout at each sampling occasion

	sampling occasion (months)			
Treatment	3	6	9	s.d. (9 months)
Untreated + MH	0.8	16.1	14.5	9.9
CIPC + MH	0.1	1.8	1.9	4.7
Ethylene + MH	0.4	6.3	8.8	6.4
Spearmint Oil + MH	0.0	4.6	8.6	11.2
DMN + MH	0.0	0.1	0.1	0.3
CIPC + Ethylene + MH	0.0	0.3	5.4	5.7
CIPC + DMN + MH	0.0	0.0	0.0	0.1
CIPC + Spearmint + MH	0.0	0.3	1.9	4.4

Table 5a: Royal, length of longest sprout at each sampling occasion

	sampling occasion (months)			
Treatment	3	6	9	s.d. (9 months)
Untreated	11.9	81.2	84.6	51.3
CIPC	1.0	2.7	1.6	2.5
Ethylene	2.7	17.9	31.4	15.6
Spearmint Oil	2.9	28.7	54.1	24.2
DMN	0.9	1.6	1.2	0.9
CIPC + Ethylene	1.0	1.7	3.0	7.8
CIPC + DMN	0.4	0.7	0.2	0.4
CIPC + Spearmint	0.4	0.6	0.5	0.7

Table 5b: Royal +MH, length of longest sprout at each sampling occasion

	sampling occasion (months)			
Treatment	3	6	9	s.d. (9 months)
Untreated + MH	2.4	28.5	26.2	39.1
Ethylene + MH	0.4	8.6	8.6	8.9
Spearmint Oil + MH	0.8	10.9	19.0	18.5
DMN + MH	0.3	1.1	1.2	0.6
CIPC + Ethylene + MH	0.3	1.6	3.3	4.7
CIPC + DMN + MH	0.1	0.3	0.4	0.6
CIPC + Spearmint + MH	0.2	1.5	1.3	2.6

Table 6a: VR808, length of longest sprout at each sampling occasion

	sampling occasion (months)			
Treatment	3	6	9	s.d. (9 months)
Untreated	10.7	39.5	55.4	26.08
CIPC	0.9	1.3	1.4	4.98
Ethylene	1.2	10.0	11.1	7.16
Spearmint Oil	0.7	15.0	23.7	13.64
DMN	0.7	0.9	0.6	0.75
CIPC + Ethylene	0.4	1.4	1.7	2.80
CIPC + DMN	0.0	0.1	0.0	0.17
CIPC + Spearmint	0.7	2.1	0.7	0.48

Table 6b: VR808 + MH, length of longest sprout at each sampling occasion

	sampling occasion (months)			
Treatment	3	6	9	s.d. (9 months)
Untreated + MH	2.0	3.0	2.4	3.60
CIPC + MH	1.1	1.1	0.9	1.00
Ethylene + MH	1.3	1.6	2.1	2.06
Spearmint Oil + MH	0.9	1.5	1.9	4.30
DMN + MH	0.8	0.5	0.5	0.54
CIPC + Ethylene + MH	0.9	1.3	0.9	0.65
CIPC + DMN + MH	0.5	0.1	0.0	0.20
CIPC + Spearmint + MH	0.3	0.8	0.4	0.53

Figure 1. Length of longest sprout, average of all varieties, for without MH treatment at 3, 6 and 9 months.

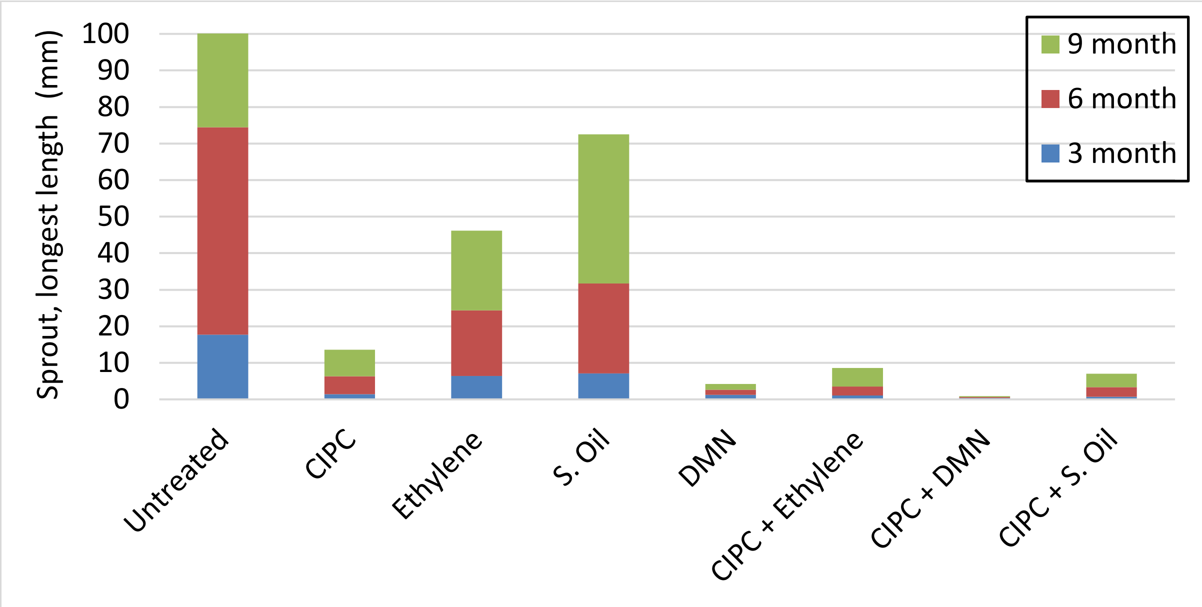
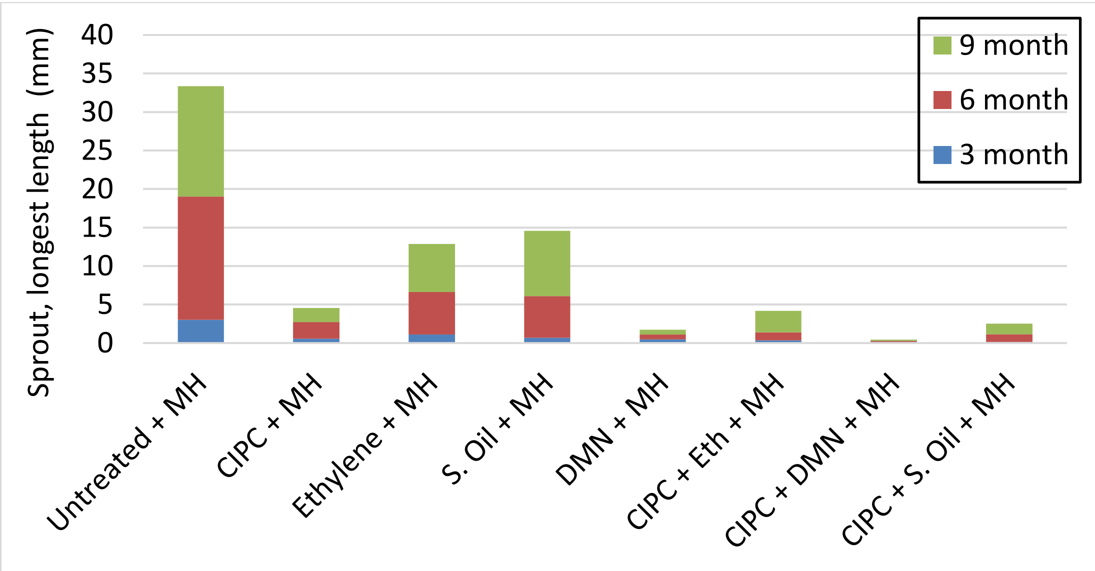


Figure 2. Length of longest sprout, average of all varieties, for each with MH treatment at 3, 6 and 9 months.



3.3 Processing quality

French fry

Fry colours were assessed against a scale of SBCSR units which relate to USDA standard categories as shown in Table 7. An SBCSR score up to 3.9 would be considered commercially acceptable. Innovator, Maris Piper, Performer and Royal were processed as French fries and the results for fry colour shown in tables 8-11.

Table 7: French fry USDA standards - SBCSR units comparison table.

SBCSR units	1	2	3	4	5	6	7
USDA Standard colours	000	00	0	1	2	3	4

For Innovator, Performer and Royal the darkest fry values were generally found when ethylene was a treatment although, apart from with Performer, the effect was small and inconsistent. The magnitude of the effect would not have caused a rejection on the grounds of fry colour. No other treatment or combination of treatments had any consistent effect on fry colour. There was a significant decline in fry colour at 9 months with all but two stocks having average fry colour SBCSR values of greater than 3.9.

MH appears to be associated with lighter fry colours (Table 12) but this may be due to different crops being used in this trial.

Table 8: Innovator, French fry colour (SBCSR units) after 3, 6 and 9 months storage

	Storage period (months)					
	3		6		9	
Treatments	fry colour (SBCSR)	s.d.	fry colour (SBCSR)	s.d.	fry colour (SBCSR)	s.d
Untreated	3.1	0.2	3.4	0.4	4.6	0.7
CIPC	3.0	0.4	3.4	0.1	5.2	0.3
Ethylene	3.4	0.2	3.4	0.2	4.9	0.3
Spearmint Oil	2.8	0.4	3.3	0.1	4.9	0.2
DMN	3.1	0.1	3.6	0.1	5.8	0.6
CIPC + Ethylene	3.1	0.2	3.7	0.0	5.5	0.5
CIPC + DMN	3.1	0.1	3.5	0.2	5.4	0.8
CIPC + Spearmint	3.2	0.2	3.3	0.2	5.9	0.1
Untreated + MH	3.1	0.2	2.3	0.1	4.1	0.3
CIPC + MH	3.0	0.4	2.2	0.1	4.8	0.4
Ethylene + MH	3.4	0.2	2.7	0.1	4.6	0.4
Spearmint Oil + MH	2.8	0.4	2.6	0.2	4.4	0.4
DMN + MH	3.1	0.1	2.5	0.3	4.5	0.3
CIPC + Ethylene + MH	3.1	0.2	2.9	0.2	4.8	0.4
CIPC + DMN + MH	3.1	0.1	2.4	0.3	4.9	0.8
CIPC + Spearmint + MH	3.2	0.2	2.5	0.2	4.6	0.3

Table 9: Maris Piper, French fry colour (SBCSR units) after 3, 6 and 9 months storage

	Storage period (months)					
	3		6		9	
Treatments	fry colour (SBCSR)	s.d.	fry colour (SBCSR)	s.d.	fry colour (SBCSR)	s.d.
Untreated	2.8	0.3	2.8	0.3	4.4	0.5
CIPC	2.8	0.4	2.4	0.3	4.1	0.6
Ethylene	3.0	0.2	2.8	0.3	4.4	0.5
Spearmint Oil	2.7	0.3	2.6	0.2	3.9	0.4
DMN	3.0	0.1	2.4	0.2	4.3	0.5
CIPC + Ethylene	2.8	0.3	2.7	0.4	4.7	0.5
CIPC + DMN	2.9	0.4	2.7	0.5	4.1	0.7
CIPC + Spearmint	2.5	0.3	2.4	0.1	4.1	0.4
Untreated + MH	2.4	0.3	2.3	0.3	3.6	0.5
CIPC + MH	2.4	0.3	2.2	0.1	3.8	0.6
Ethylene + MH	2.7	0.3	2.3	0.1	4.6	0.2
Spearmint Oil + MH	2.5	0.4	2.3	0.1	3.8	0.4
DMN + MH	2.4	0.3	2.2	0.2	4.1	0.3
CIPC + Ethylene + MH	2.6	0.5	2.5	0.3	4.6	0.4
CIPC + DMN + MH	2.6	0.3	2.3	0.1	3.8	0.3
CIPC + Spearmint + MH	2.7	0.2	2.3	0.1	4.1	0.4

Table 10: Performer, French fry colour (SBCSR units) after 3, 6 & 9 months storage

	Storage period (months)					
	3		6		9	
Treatments	fry colour (SBCSR)	s.d.	fry colour (SBCSR)	s.d.	fry colour (SBCSR)	s.d.
Untreated	3.3	0.1	3.3	0.1	4.6	0.2
CIPC	3.2	0.2	3.1	0.1	4.4	0.5
Ethylene	3.4	0.3	3.6	0.3	4.5	0.5
Spearmint Oil	3.3	0.4	3.1	0.2	4.3	0.1
DMN	3.2	0.1	3.2	0.2	4.2	0.6
CIPC + Ethylene	3.5	0.4	3.6	0.2	4.5	0.3
CIPC + DMN	3.3	0.1	3.3	0.4	4.5	0.4
CIPC + Spearmint	3.4	0.5	3.0	0.5	4.4	0.4
Untreated + MH	2.2	0.1	2.5	0.3	3.2	0.3
CIPC + MH	2.3	0.1	2.3	0.2	3.4	0.5
Ethylene + MH	2.9	0.3	2.5	0.2	3.8	0.3
Spearmint Oil + MH	2.3	0.2	2.2	0.2	3.7	0.4
DMN + MH	2.2	0.0	2.6	0.4	3.5	0.5
CIPC + Ethylene + MH	2.7	0.3	2.6	0.3	4.0	0.1
CIPC + DMN + MH	2.3	0.0	2.3	0.2	3.4	0.5
CIPC + Spearmint + MH	2.4	0.4	2.2	0.0	3.7	0.5

Table 11: Royal, French fry colour (SBCSR units) after 3, 6 and 9 months storage

	Storage period (months)					
	3		6		9	
Treatments	fry colour (SBCSR)	s.d.	Fry colour (SBCSR)	s.d.	fry colour (SBCSR)	s.d.
Untreated	3.3	0.0	3.4	0.3	4.4	0.6
CIPC	3.3	0.3	3.2	0.2	4.4	0.5
Ethylene	3.5	0.3	3.3	0.1	4.0	0.5
Spearmint Oil	3.2	0.3	3.3	0.2	4.4	0.2
DMN	3.4	0.2	3.4	0.2	4.4	0.6
CIPC + Ethylene	3.6	0.2	3.4	0.2	4.4	0.1
CIPC + DMN	3.4	0.2	3.3	0.1	4.2	0.4
CIPC + Spearmint	3.3	0.1	3.4	0.3	4.1	0.5
Untreated + MH	2.3	0.3	2.2	0.1	3.4	0.6
CIPC + MH	2.2	0.0	2.2	0.1	3.7	0.5
Ethylene + MH	2.3	0.3	2.5	0.3	3.8	0.5
Spearmint Oil + MH	2.3	0.3	2.3	0.1	3.6	0.5
DMN + MH	2.2	0.0	2.2	0.1	3.4	0.2
CIPC + Ethylene + MH	2.2	0.1	2.4	0.3	3.8	0.6
CIPC + DMN + MH	2.3	0.5	2.3	0.1	3.7	0.4
CIPC + Spearmint + MH	2.1	0.0	2.2	0.1	3.8	0.5

Table 12: Average French fry colour (SBCSR units) across all treatments for each variety after 3, 6 and 9 months storage.

	Storage period (months)					
	3 Months		6 Months		9 Months	
Variety		+ MH		+ MH		+ MH
Innovator	3.1	2.2	3.4	2.5	5.3	4.6
Maris Piper	2.8	2.5	2.6	2.3	4.2	4.1
Performer	3.3	2.4	3.3	2.4	4.4	3.6
Royal	3.4	2.2	3.3	2.3	4.3	3.6

Processing for crisp

VR808 was processed as crisps and the results for fry colour and defects are shown in tables 13 and 14. At three months storage all Hunter L values were very acceptable at > 63.3 with an average of 65.4. The lowest values were generally found when ethylene was a treatment, a more marked effect at 6 months storage with the +MH stock when Hunter L values were <60. Fry colour values for both stocks and for all treatments were poor at 9 month storage. The percentage of total fry defects was particularly high for the +MH stock at 9 months storage (Table 14).

Table 13: VR808, crisp fry colour (Hunter L) after 3, 6 and 9 months storage

	Storage period (months)					
	3		6		9	
Treatment	Hunter L	SD	Hunter L	SD	Hunter L	SD
Untreated	64.9	1.7	62.8	1.7	56.6	3.2
CIPC	65.7	1.4	63.9	1.1	57.2	1.3
Ethylene	65.9	1.4	63.0	0.8	57.3	3.7
Spearmint Oil	64.9	1.7	62.9	2.2	59.9	2.7
DMN	65.8	1.3	63.6	1.7	57.3	2.7
CIPC + Ethylene	63.3	1.4	62.8	1.3	56.0	1.9
CIPC + DMN	65.9	1.6	64.8	2.0	56.7	3.0
CIPC + Spearmint	65.8	2.5	63.0	1.7	58.6	1.8
Untreated + MH	67.2	1.3	62.6	2.9	55.9	2.5
CIPC + MH	66.8	1.4	61.9	2.7	53.9	1.4
Ethylene + MH	63.3	2.8	59.3	1.4	56.1	0.5
Spearmint Oil + MH	64.4	2.5	63.3	1.7	55.6	0.5
DMN + MH	65.5	2.2	61.4	1.4	56.4	2.3
CIPC + Ethylene + MH	63.5	1.6	58.3	2.8	54.3	2.5
CIPC + DMN + MH	67.3	1.5	63.2	1.0	55.6	1.0
CIPC + Spearmint + MH	66.0	0.8	62.8	1.5	56.9	2.4

Table 14:VR808, crisp total defects after 3, 6 and 9 months storage

	Storage period (months)					
	3		6		9	
Treatments	%	SD	%	SD	%	SD
Untreated	7.8	10.6	4.5	2.5	12.6	11.0
CIPC	6.6	7.9	1.2	1.4	10.7	5.5
Ethylene	9.9	10.0	3.4	1.9	22.6	9.8
Spearmint Oil	4.3	5.0	1.8	2.8	17.0	11.0
DMN	6.1	8.3	4.0	3.2	27.2	3.7
CIPC + Ethylene	6.4	4.2	3.6	5.5	31.0	7.1
CIPC + DMN	4.3	5.6	5.9	3.1	21.0	8.2
CIPC + Spearmint	2.1	1.7	4.0	2.2	12.6	9.0
Untreated + MH	10.0	7.6	11.8	6.0	72.6	27.5
CIPC + MH	3.3	4.3	0.4	0.8	47.0	22.5
Ethylene + MH	8.8	6.2	6.8	7.9	88.0	6.5
Spearmint Oil + MH	8.2	5.1	2.0	1.4	84.4	10.5
DMN + MH	8.0	11.9	6.3	8.1	89.9	8.0
CIPC + Ethylene + MH	7.7	6.2	12.0	5.1	69.8	29.5
CIPC + DMN + MH	4.0	5.0	5.8	8.5	83.8	2.5
CIPC + Spearmint + MH	9.7	10.0	0.9	1.9	61.2	19.2

Some internal sprouting was observed in cv. Innovator, a variety known to be susceptible to the condition[4], after 9 months storage (Table 15).

Table 15: Internal sprouting in Innovator, effect of treatments at 9 months storage.

Treatment	% internal sprouting	s.d.
Untreated	22.0	2.3
CIPC	19.4	7.2
Ethylene	41.0	17.1
Spearmint Oil	47.0	10.5
DMN	20.0	10.3
CIPC + Ethylene	3.0	2.0
CIPC + DMN	1.0	2.0
CIPC + Spearmint	6.4	4.6
Untreated + MH	1.1	2.0
CIPC + MH	1.0	2.0
Ethylene + MH	11.3	8.3
Spearmint Oil + MH	9.0	3.8
DMN + MH	3.0	2.0
CIPC + Ethylene + MH	3.0	3.8
CIPC + DMN + MH	1.0	2.0
CIPC + Spearmint + MH	2.0	4.0

3.4 Maleic hydrazide residue

The levels of total maleic hydrazide residues found on the different varieties are shown in Table 16. The residues ranged from 1.1 – 21 mg/kg. There was no apparent effect of store treatment on the MH residue after nine months storage.

Table 16: Maleic hydrazide residues found in each variety after 9 months storage.

Variety	Store Treatment	mg / kg	average
Innovator	CIPC	20	16.7
	Ethylene	14	
	Untreated	16	
Maris Piper	CIPC	11	10.2
	Ethylene	8.7	
	Untreated	11	
Performer	CIPC	7	9.9
	Ethylene	13	
	Untreated	9.7	
Royal	CIPC	6	5.1
	Ethylene	8.3	
	Untreated	1.1	
VR808	CIPC	15	17.0
	Ethylene	15	
	Untreated	21	

4. Discussion

The aim of this ongoing project was to investigate whether treatments using alternative sprout suppressants, or the combined use of an alternative together with CIPC, provided effective, affordable sprout control.

One of the treatments investigated was maleic hydrazide (MH). Unfortunately, in the 2017-18 season, it was not possible to obtain stocks of the same crop both with and without MH treatment. This has affected interpretation of the results due to potential differences in agronomy and environment between the stocks of a variety. This will be rectified in the second year's work. In this trial there were clear differences in dormancy with and without MH treatment, in every case dormancy at 15°C was longer with MH treatment.

Total maleic hydrazide residues were measured at the completion of the storage period (Table 16). There did not appear to be a correlation between average residue value for each variety and the number of days to 50% sprouting at 15°C (Table 1).

A previous AHDB Potatoes funded project[5] found a much lower overall dose of CIPC was effective when used in when in combination with ethylene; this was observed again in this trial for varieties Innovator, Maris Piper and Performer at 9 months storage. This effect is not found when the overall data of all varieties, sampling occasions and MH treatments are used for comparison. Combinations of different treatments were generally more effective than each treatment alone. This was the case with either CIPC or DMN, each highly effective sprout suppressants singly, which were statistically significantly better when used in combination. The effectiveness of treatments were, in increasing order of efficacy, untreated, ethylene or spearmint oil, CIPC, DMN, CIPC and DMN. The use of different stocks affected the ability to include a direct comparison of MH across treatments; nevertheless it may not be a co-incidence that sprouting was very significantly reduced for all varieties with MH treatment.

The relative dormancy of varieties was a factor in the efficacy of sprout suppressants with DMN controlling all varieties very well.

The fry colour of stocks treated with MH was lower than for those stocks not treated (Table 12). This effect could not be attributed to MH treatment in this particular trial. Other studies that included an a assessment of fry colour following MH treatment have not observed a consistent or significant effect[6,7]. Fry colour for all variety, stocks and treatments worsened markedly after 9 months' storage (Table 12) and for some stocks would have been commercially unacceptable.

In the earlier study R441/R464, ethylene treatment had a slightly adverse effect on frying quality of some processing varieties. In this trial, ethylene was often associated with darker fry colours but generally, apart from with cv. Performer, the effects were small and inconsistent.

5. Conclusions

Combinations of sprout suppressants were demonstrated to be more effective than the use of a single treatment alone. It also seemed highly likely that combinations including MH will prove to be effective sprout suppressant strategies, although this could not be categorically shown in this work.

Further evaluations are being undertaken in the second year of this AHDB–funded trial in the 2018/19 season.

6. References

1. Barker A, Garthwaite DG, Parish G (2015) Pesticide Usage Survey Report 266, Potato Stores in the UK 2014.
2. http://onlinelibrary.wiley.com/doi/10.2903/j.efsa.2017.4903/epdf and EFSA Q-2014-00916
3. M. Storey, A. Cunnington & A. Briddon (2017) Optimising Chlorpropham use through stewardship. EAPR Triennial Conference, Versailles, France. 9-14 July.
4. http://web.hzpc-holland.com/teeltbeschrijving/Innovator_c_en_french%20fries.pdf
5. R441/R464 Project reports AHDB Potatoes 2017.
6. Gichohi E. G. and Pritchard M. K. (1995). Storage temperature and maleic hydrazide effects on sprouting, sugars, and fry color of Shepody potatoes. American Potato Journal, 72, Issue 12, pp 737–747.

7. Caldiz D. O., Fernandez L. V. and Inchausti M. H. (2001). Maleic hydrazide effects on tuber yield, sprouting characteristics, and french fry processing quality in various potato (Solanum tuberosum L.) cultivars grown under Argentinian conditions. American Journal of Potato Research, 78, pp 119–128.

Appendix 1: Study treatment diary

Date	Event	
19 October 2017	loading and pull- down initiated	from 15oC
31 October 2017	holding temperature achieved	9^oC
01 November 2017	DMN applied (first)	20 ml/t
08 November 2017	CIPC applied (first)	12 g/t
20 November 2017	ethylene initiated	soft start
06 December 2017	DMN applied (second)	20 ml/t
09 December 2017	Ethylene holding target achieved	10 ppm
18 December 2017	CIPC applied (second)	12 g/t
20 December 2017	Spearmint oil applied (first)	90 ml/t
08 January 2018	**Sampling occasion 1**	
10 January 2018	DMN applied (third)	15 ml/t
17 January 2018	Spearmint oil applied (second)	45 ml/t
14 February 2018	DMN applied (fourth)	15 ml/t
14 February 2018	spearmint applied (third)	45 ml/t
14 March 2018	Spearmint oil applied (fourth)	45 ml/t
21 March 2018	DMN applied (fifth)	10 ml/t
02 April 2018	**Sampling occasion 2**	
11 April 2018	CIPC applied (third)	12 g/t
11 April 2018	Spearmint oil applied (fifth)	45 ml/t
25 April 2018	DMN applied (sixth)	10 ml/t
09 May 2018	Spearmint oil applied (sixth)	45 ml/t
30 May 2018	DMN applied (seventh)	10 ml/t
06 June 2018	Spearmint oil applied (seventh)	45 ml/t
02 July 2018	**Sampling occasion 3**	

Appendix 2: Post hoc t-test comparison of treatments.

Table Appendix 2, P values for length of longest sprout.
The comparison was made for each treatment using the entire dataset which comprised all varieties, all sampling occasions and both MH treatments.

Treatments	CIPC	DMN	Ethylene
Ethylene	0.0003	0.000001	-
S. Oil	0.0003	0.0001	ns
DMN	0.009	-	-
CIPC + Ethylene	ns	-	-
CIPC + S. Oil	ns	-	-
CIPC + DMN	0.0004	0.00003	-