



## **Final Report**

# **The Use of CIPC Vapour to Control Sprouting in Commercial Potato Stores**

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## 1. SUMMARY

The use of chlorpropham (CIPC) as a sprout suppressant is currently causing concern in GB. Although recently reviewed as part of the European regulatory process (EC 91/414), additional controls are being implemented in GB, by the Potato Industry CIPC Stewardship Group, under an action plan, agreed with the Advisory Committee on Pesticides. Additional controls include statutory equipment testing, and improved training of operators. The aim of the action plan is to limit 'anomalous' residue values, in excess of the Maximum Residue Level (MRL, 10 mg/kg).

The amount of CIPC that can be applied in GB (63.75 g/tonne on potatoes for processing) is greater than that used elsewhere in Europe, and is greater than that used in 'example fogging' operations in the EC 91/414 review process. While the Stewardship Group is succeeding at improving CIPC application in GB, by implementing additional controls, contingency plans must be available should greater restrictions be placed on the use of this critical sprout suppressant (Erasmus, 2008).

Application of CIPC as a vapour represents an opportunity to control sprouting at much lower rates than currently used in hot-fogging and also overcomes some of the other problems associated with conventional application of this chemical, such as formation of 3-chloroaniline and losses from pressurisation of stores during hot-fogging.

The amount of CIPC applied, and the amount that can be 'recovered' do not concur, with values around 50% unaccounted for. In GB, applications are currently permitted up to 63.75 g/tonne over a season on potatoes for processing and 36 g tonne<sup>-1</sup> on potatoes for the fresh market.

The current method of applying CIPC (hot fog) introduces the chemical in the form of fine particles (around 5µm in size) which become attached to tubers and store fabrics. Over time, CIPC particles volatilise, with the vapour transferring to eyes and controlling sprout growth.

Although an effective means of controlling sprout growth, particles attached to tuber surfaces constitute CIPC deposits and contribute to CIPC residue levels. Tuber CIPC residue levels are frequently in excess of the amount required for sprout control. Control of sprouting is possible by direct application of CIPC vapour. By releasing vapour directly into the store there is scope for considerable reductions in the amount of CIPC used.

The overall goal of this project was to identify suitable sources, which would release (CIPC) vapour in stores in a controlled manner and to investigate mechanisms for delivering vapour to tubers. Previous research (Cunnington *et al*, 2006) has shown that CIPC in the vapour phase can, with appropriate air movement, be delivered in sufficient quantity to prevent sprouting. In this way it is possible for chemical use to be reduced 100 fold over a storage season.

Experimental work at SBEU investigated optimum air speeds for delivering CIPC vapour to crop. At low air speeds (0.03-0.04m<sup>3</sup>/s/t) CIPC vapour distributed gradually and only penetrated a 3m bulk pile after an extended period. Increasing airspeed (0.16-0.17 m<sup>3</sup>/s/t) resulted in more rapid distribution with significant residues within 3 days.

Source trials carried out at SBEU demonstrated the suitability of gel releasing matrices in creating CIPC vapour over relatively long treatment periods. All sources tested produced vapour and resulted in residue values being detected on the tubers.

During the course of the preliminary experimental work at GU it had been found that the vapour concentration of CIPC varied with temperature, as would be expected, and humidity. However, the latter aspect had not been controlled in previous projects (such as R258) and its implications are crucial to the understanding of the use of CIPC vapour in stores. These changes will have a variety of effects on the amount of CIPC passing the stored potatoes and therefore adhering to the tuber so further understanding of these effects must be elucidated. Although there is little to no information in the literature on this, there are comparable studies on the absorption of organic vapours onto sand (Goss, 1992) and also studies on the effects of temperature and humidity on ecotoxicology of chemicals (Viswanthan and Krishna Murti, 1989).

Further development of CIPC vapour, as a commercial treatment, requires a better understanding of the fundamental mechanisms involved.

## 2. INTRODUCTION

To maintain potato quality throughout a storage season, currently several applications of CIPC sprout suppressant are frequently required. Such applications are made as a hot-fog with an excess of CIPC, in particulate form, being introduced to stores. A proportion of this CIPC becomes attached to tubers and effects sprout control. CIPC attached to tubers also, however, contributes to CIPC residue levels. The distribution of CIPC is difficult, especially in the absence of positive ventilation, and here, in particular, there is an increased risk of exceeding the statutory MRL of 10 mg kg<sup>-1</sup>. Difficulties associated with application of CIPC have been acknowledged by the regulatory authorities, and additional restrictions have been introduced on the use of this chemical in an attempt to control anomalous residue values. Changes are being implemented by the Potato Industry CIPC Stewardship Group ([www.potato.org.uk/cipc](http://www.potato.org.uk/cipc)) and are being monitored by the Advisory Committee on Pesticides.

An alternative means of applying CIPC is in the vapour form. Using this approach, the CIPC source is held separate from the tubers, but it is formulated in a way that makes CIPC vapour easily available to circulating air. This approach has several merits:

1. A more even coverage of tubers should be possible with the chemical distributing as a vapour rather than an airborne particulate.
2. Less chemical is required (up to c. 1/100) as the vapour source is held separate from the tubers and supplied as required.
3. The absence of particulates reduces the risk of exceeding the MRL (due to the relatively high dose a single particle contains).
4. There is scope for 'residue control' with ventilation of crops resulting in more rapid losses of the chemical due to its higher surface area when applied as a vapour.
5. Potential for significant reductions in losses of CIPC which occur as a result of pressurisation of stores during hot-fogging.
6. Potential for reduction in 3-chloroaniline residue levels. 3-chloroaniline is a thermal breakdown product of CIPC generated during hot-fogging.
7. Potential reduction in environmental burden (especially wash water) as the CIPC vapour source is held separate from the crop.

If successful, the development of CIPC vapour formulations would result in less chemical being used over a storage season, with lower residues on the crop and a significantly lower impact of CIPC use on the environment.

Previous levy-funded work (Project R258) assessing the potential of vapour release resulted in effective sprout control of crops with residues in excess of 1mg/kg. A high rate of decline of residue levels during airing of crops was also noted (c.80% after 3 months of storage).

The aim of this work is to develop a formulation which is an effective CIPC vapour source and to conduct testing to allow the potential for commercialisation of CIPC vapour application to be assessed.

### 3. EXPERIMENTAL SECTION

#### 3.1 Pilot-scale trials

##### 3.1.1 Materials and methods

In this trial, crop was treated with CIPC vapour using four formulations:  
*MSS CIPC 5G*: a registered, granular CIPC formulation (Whyte/UPL)  
A coded, liquid CIPC formulation (Certis Europe)  
Agar/CIPC gel developed at Glasgow University  
A coded, powder CIPC formulation (PinNip Inc., USA)

Crop was held in 2m x 0.3m diameter pipes. Pipes, containing potatoes, were located on a manifold that was supplied with clean (CIPC-free) air from a store where CIPC had not previously been used (Figures 1 & 2). Air was drawn, using fans, through the crop at a rate of approximately  $0.02\text{m}^3 \text{ s}^{-1} \text{ t}^{-1}$ .



FIGURE 1. MANIFOLD, SUPPLIED WITH CLEAN AIR FROM A CIPC UNTREATED STORE, FOR SUPPLYING AIR TO 4 'PILES' OF POTATOES.



FIGURE 2. TWO METRE BY 0.3M ID PIPE CONTAINING C. 60 KG POTATOES. THE VAPOUR SOURCE WAS LOCATED ABOVE THE MANIFOLD, IN THE BOTTOM 50CM SECTION OF PIPE.

The vapour source was located in the bottom 50cm of each pipe. The method of presentation of sources to the airstream is shown in Figure 3. Solid formulations (A & D) were held in fine cotton pouches, to prevent particulate CIPC from escaping. The gel and liquid formulations were exposed directly to the airstream, after application to capillary matting in the case of the liquid formulation (B). Formulations A, B and D were used at rates that made 3g of CIPC available for volatilisation. A similar 'application rate' for the gel formulation would have required an excessive number of gels (30) so this formulation was used at a lower rate of 0.3g of available CIPC (3 gels). Gels were inspected during the trial and were replaced after 31 days when there was evidence of shrinkage. There was no evidence that vapour release was affected.

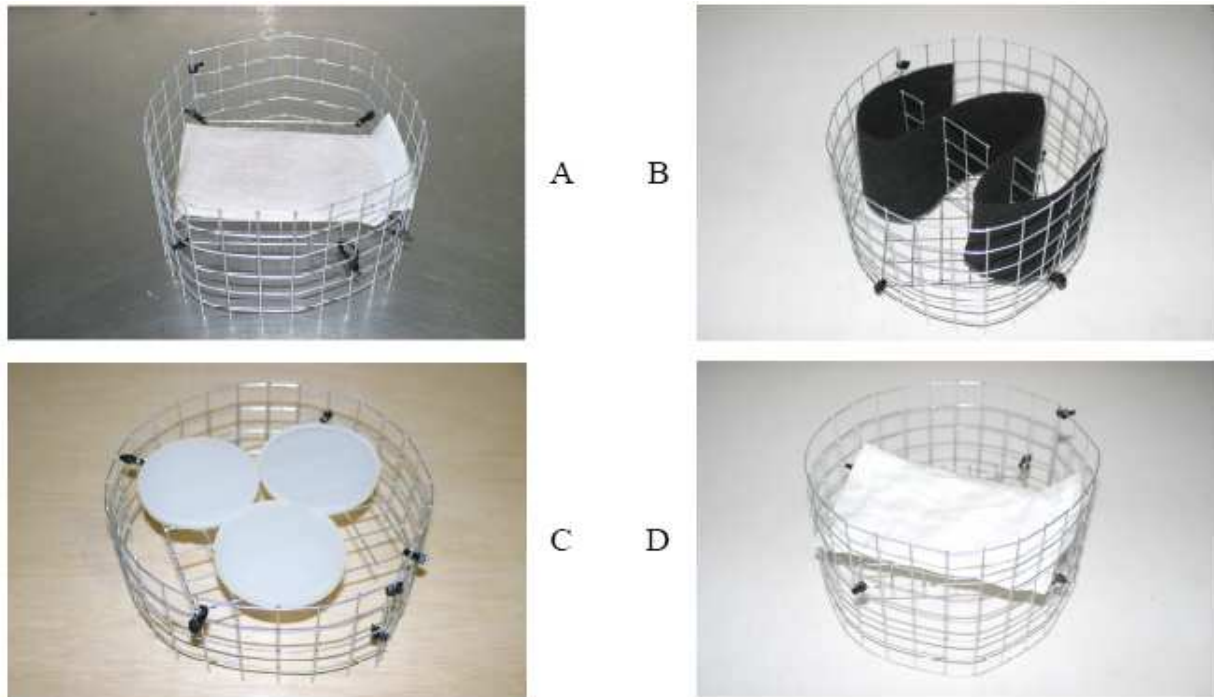


FIGURE. 3. PRESENTATION OF SOLID (A & D), LIQUID (B) AND GEL (C) CIPC VAPOUR SOURCES.

CIPC vapour concentration and airflow rate was measured amongst tubers, within the pipe. The CIPC residue levels of 3 individual tubers were measured at the conclusion of the trial at each of four heights (0 m, 0.5 m, 1.0 m and 1.5 m). The testing/exposure of source D was started 6 days after the other treatments. Consequently initial vapour assessment was carried out at day 4 with subsequent sampling at days 8, 22 and 36. Unloading took place on the same day as the other pipes which was actually day 50 for this treatment.

### 3.1.2 Results

CIPC vapour concentrations, measured at 0.1m and 1.0m heights in the pipes, are shown in Figure 4. Results at unloading are not shown as they were extremely high ( $\geq 0.6 \mu\text{g/l}$ ) for all formulations. This is thought to be due to contamination by particulate CIPC. Sources A, B and D showed no significant difference at either of the heights throughout the trial up to day 42. In contrast, source C showed significantly higher values at 100 mm after 3, 7 and 28 days.



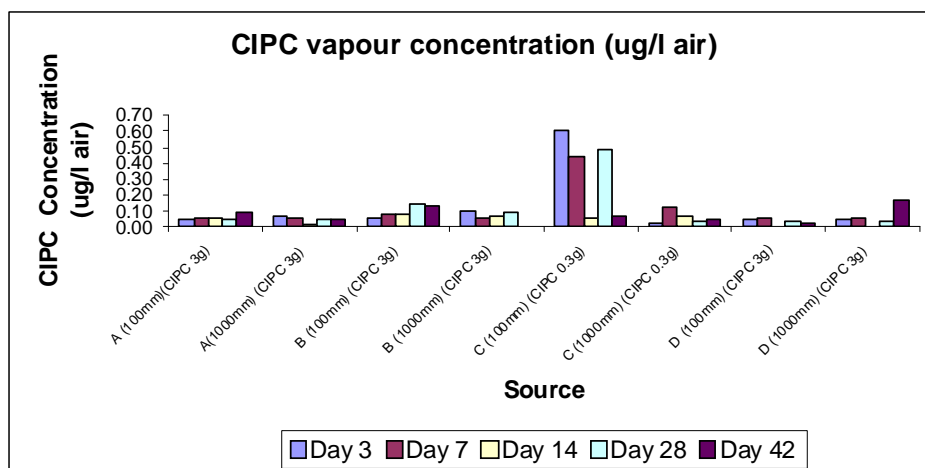


FIGURE. 4. VAPOUR LEVELS FROM CIPC SOURCES IN PILOT TRIAL.

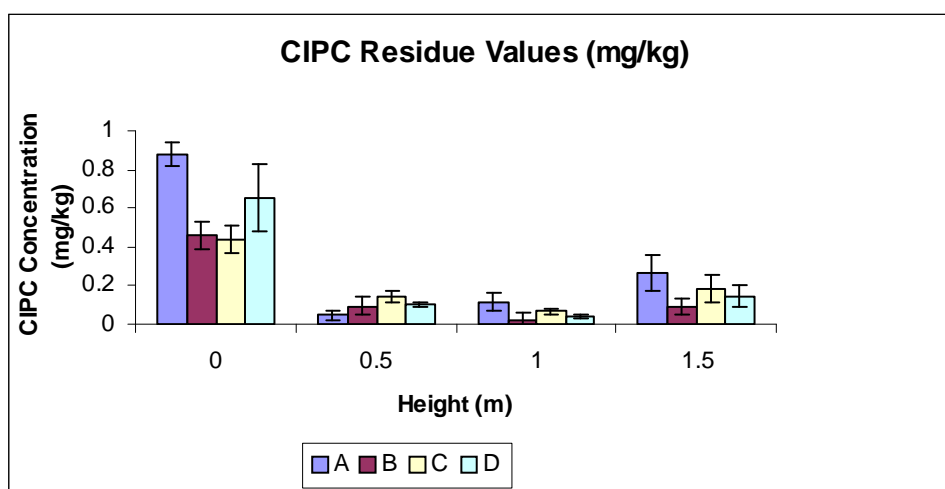


FIGURE. 5. TUBER CIPC RESIDUE VALUES AT CONCLUSION OF PILOT TRIAL.

CIPC residue values at the conclusion of the trial are shown in Figure 5. All of the sources resulted in CIPC residues on tubers. Values were generally highest, around 0.6 mg/kg, at the bottom of the pipe (0 m) where air and vapour entered the 'pile'. Residue values were low, around 0.1 mg/kg at 0.5 m and 1.0 m and increased again at 1.5 m to around 0.2 mg/kg. Although the gel formulation generated significantly higher CIPC vapour concentrations on a number of occasions at the 100 mm sampling height, this was not reflected in the tuber residue results.

### 3.1.3 Discussion and conclusions

A successful system was developed for assessment of CIPC sources on a larger scale than the laboratory trials. The results showed that liquid, solid and gel sources released vapour, but only the gel formulation (D) did so at the expected concentration under the environmental conditions (high RH 95-99% and 10°C). These higher vapour concentrations were attained with 10% of the available CIPC, demonstrating the efficiency of the gel at releasing vapour. Further work is required to understand the effects of airflow and humidity on vapour movement and longevity of the source materials.

## 3.2 Evaluation of the effect of airflow rate on CIPC residue distribution when applied as vapour

### 3.2.1 Material and methods

Treatments were loaded into individual 12 tonne capacity Controlled Environment (CE) stores operating at 10°C (air temperature) and a mbient RH for the duration of the study. Tubers were placed inside vertical plastic tubes (*Agritwin* non-perforated drainage pipe – Polypipe Civils). Each pipe was 3200mm long with a 600mm diameter. The set-up of pipes is shown in Figure 6. To facilitate filling and sampling each pipe was cut into sections and the joins sealed with tape. The pipe was filled with potatoes to a height of 3000mm leaving a 200mm headspace between the top of the crop and an auxiliary fan, drawing air through the crop at various rates. Each pipe contained approximately 550kg of tubers. Axial flow fans (600mm diameter, *Multifan* 4VF1042A – Vostermans Ventilation, Holland) were used in all treatments except for the passive ventilation treatment. Where fitted, the auxiliary fan operated continuously for the duration of the treatment. The duration and airflow rate of treatments is shown below:

- Treatment 1: High airflow (air flow  $\sim 0.16$  m<sup>3</sup>/s/t - CER36) for 3 days
- Treatment 2: High airflow (air flow  $\sim 0.17$  m<sup>3</sup>/s/t - CER35) for 19 days
- Treatment 3: Low airflow ( $\sim 0.03$  m<sup>3</sup>/s/t - CE34) for 19 days
- Treatment 4: Low airflow ( $\sim 0.04$  m<sup>3</sup>/s/t - CE32) for 88 days
- Treatment 5: Control (passive ventilation - CER 31) for 19 days



FIGURE 6. SET-UP OF PIPES IN AIRFLOW RATE TRIAL.

The treatments were designed not only to offer a repeat of the previous experiment (3 day and 19 day treatments) but to also extend this to include a longer-term treatment. The duration of this longer-term treatment was calculated to give a total volume of air similar to that of the 19 day “high speed” treatment:

Total volume 19 days at high speed =  $0.16 \text{ m}^3/\text{s/t} \times 60\text{s} \times 60\text{m} \times 24\text{h} \times 19\text{d} = 262656\text{m}^3$

Total volume 88 days at low speed =  $0.04 \text{ m}^3/\text{s/t} \times 60\text{s} \times 60\text{m} \times 24\text{h} \times 88\text{d} = 304128\text{m}^3$

The CIPC source for this experiment was from background contamination of the store. All stores were treated (empty) within 1 week prior to the experiment (using a conventional Swingfog SN-50 fogger), after initial testing indicated differences in the concentration of CIPC vapour in stores.

CIPC vapour samples were collected on Tenax traps and analysed at Glasgow University.

### 3.2.2 Results

Figures 7 and 8 show CIPC vapour concentrations initially and after fogging (zero time) in each of five stores.

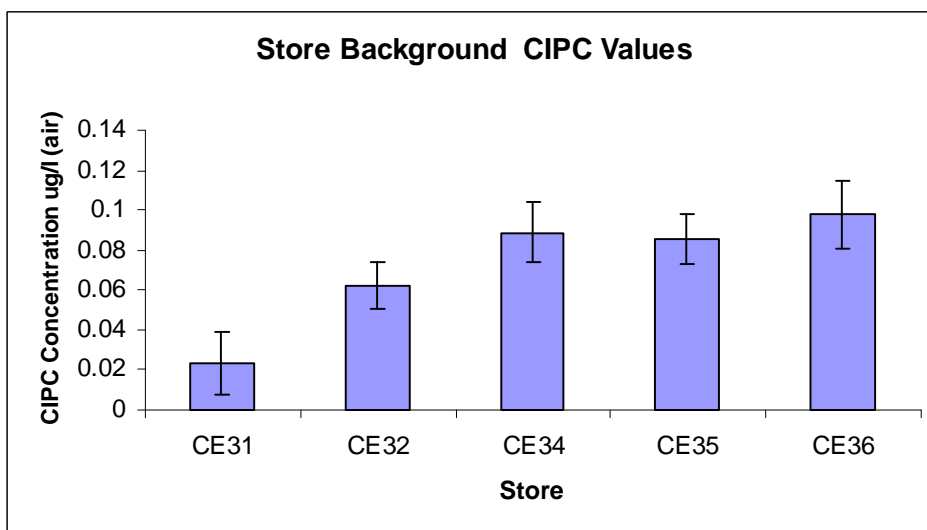


FIGURE 7. BACKGROUND CIPC CONCENTRATIONS MG/L (AIR)

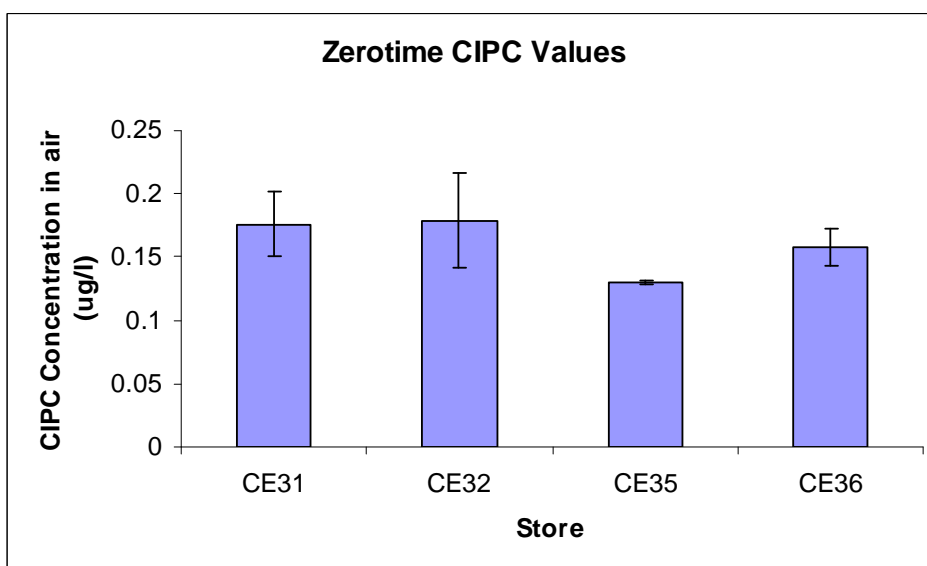


FIGURE 8. CIPC CONCENTRATIONS MG/L (AIR) AFTER FOGGING OF STORES.

Vapour samples were taken at 0, 1, 3, 10, 19, 34, 52, 72 and 88 days, depending on the duration of the store trial. Figure 9 shows the vapour concentrations at each of the time points.

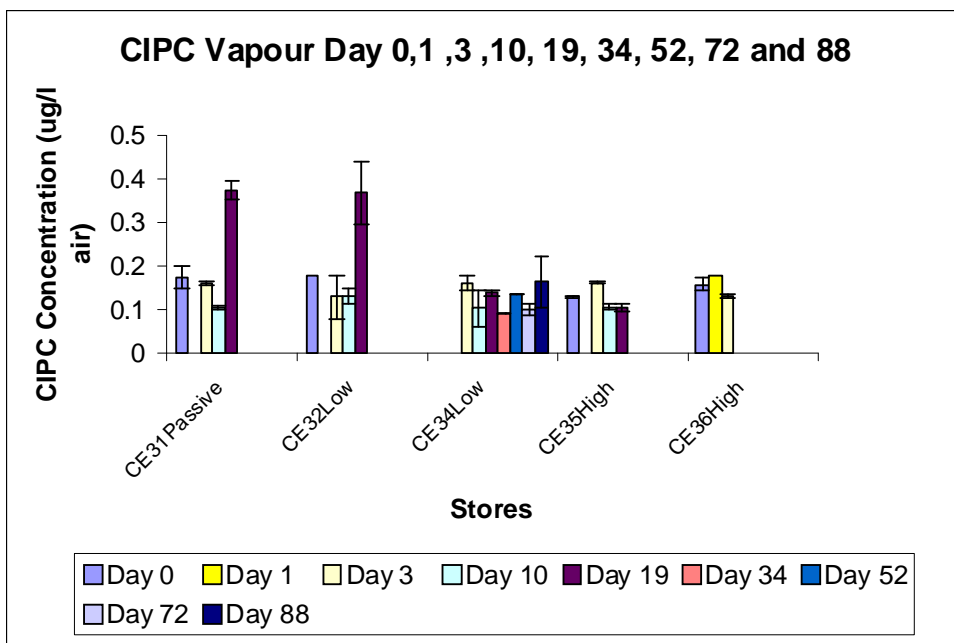


FIGURE 9. CIPC CONCENTRATIONS MG/L (AIR) IN EACH STORE.

Saturated CIPC vapour pressure was reached by day 1 (considered to be 0.11µg/l of air at 25°C) and maintained throughout the 88 days of the trial. This occurred in all the treatments.

3-chloroaniline, a breakdown product of CIPC, was detected in the vapour phase in all stores. Figure 10 shows the values for 3-chloroaniline found in each store, which were low relative to its saturated vapour pressure (468µg/l at 20°C).

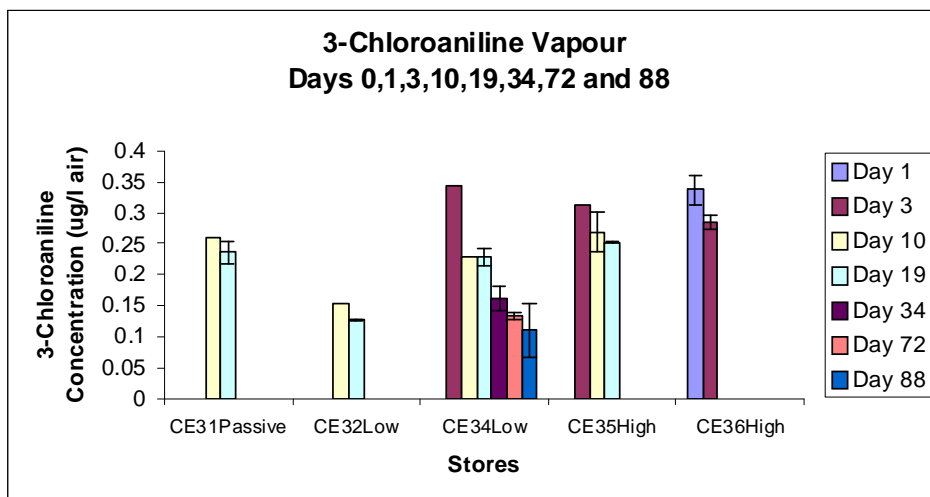


FIGURE 10. VAPOUR CONCENTRATIONS OF 3-CHLOROANILINE IN EACH STORE.

Store	Time (days)	Airflow (m <sup>3</sup> /s/t)	Height (m)	CIPC residue (mg/kg)
CE36	3	0.16	0	5
CE36	3	0.16	2.5	1.2
CE35	19	0.17	0	8.8
CE35	19	0.17	2.5	5.1
CE32	19	0.03	0	7.8
CE32	19	0.03	2.5	1.2
CE31	19	passive	0	5.2
CE31	19	passive	2.5	0.1
CE34	88	0.04	0	12.3
CE34	88	0.04	2.5	5.4

TABLE 1. TUBER CIPC RESIDUE RESULTS

CIPC residue results are shown in Table 1. In all cases the level of tuber residues was greater at 0m than 2.5m. However, it was only with passive air that the CIPC level dropped below 1mg/kg.

At the end of each storage period tubers were removed (from heights of 2-2.5m) and assessed for sprout growth (length of longest sprout) during storage at 10°C in a CIPC untreated store. Results are shown in Figure 11.

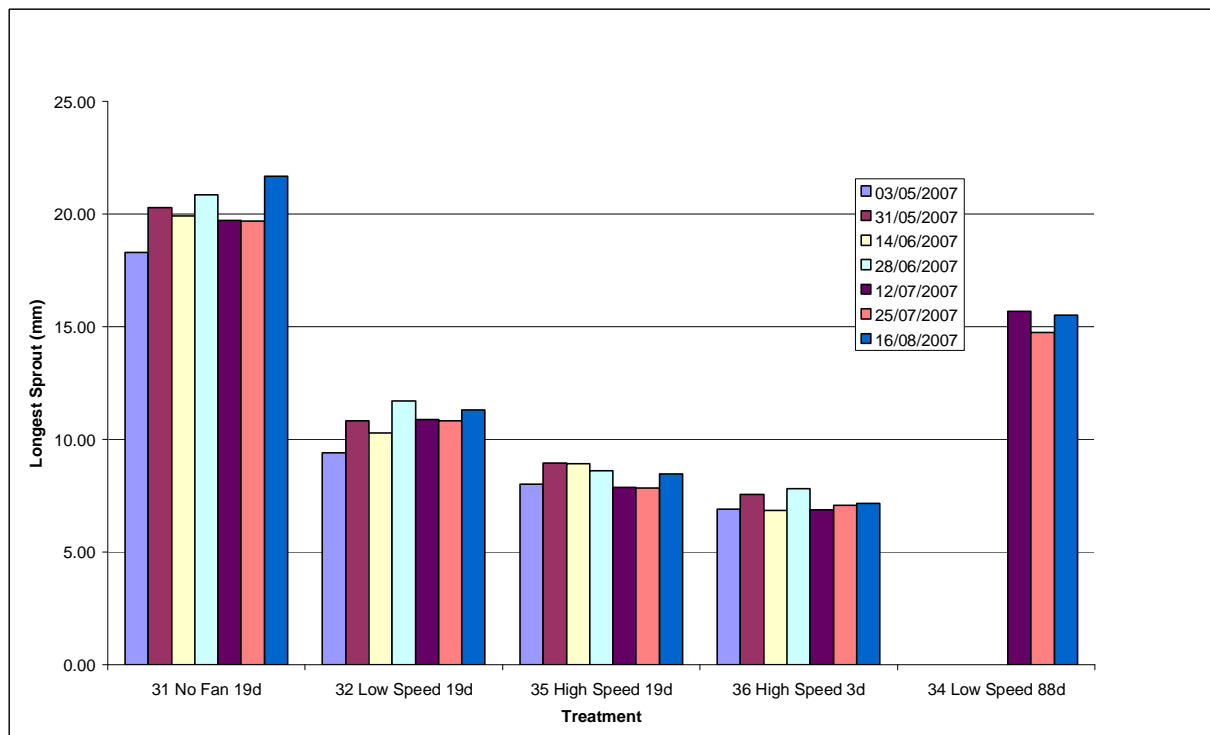


FIGURE 11. SPROUT GROWTH (LENGTH OF LONGEST SPROUT, MM) OF SAMPLES DURING STORAGE AFTER RECIRCULATION TREATMENTS.

Low levels of sprouting were evident in the crop (cv Amora) at the start of the study. In the passive ventilation (no fan) treatment, sprout growth occurred during the CIPC exposure period as evidenced by the excessive sprout length (c.18mm) at the start of efficacy assessment (after CIPC exposure period). Sprout growth of this treatment continued during storage under 'CIPC free' conditions. Sprout growth was most effectively restricted in high air speed treatments. No further growth of these treatments took place during storage in 'CIPC free' conditions.

Figure 12 shows the change in CIPC levels recovered from tuber peel between the end of the treatment period and the sample's removal from the subsequent efficacy trial. The time in days refers to the period of treatment with saturated CIPC vapour. The second (red) figure refers to the length of the efficacy trials in CIPC-free storage in weeks.

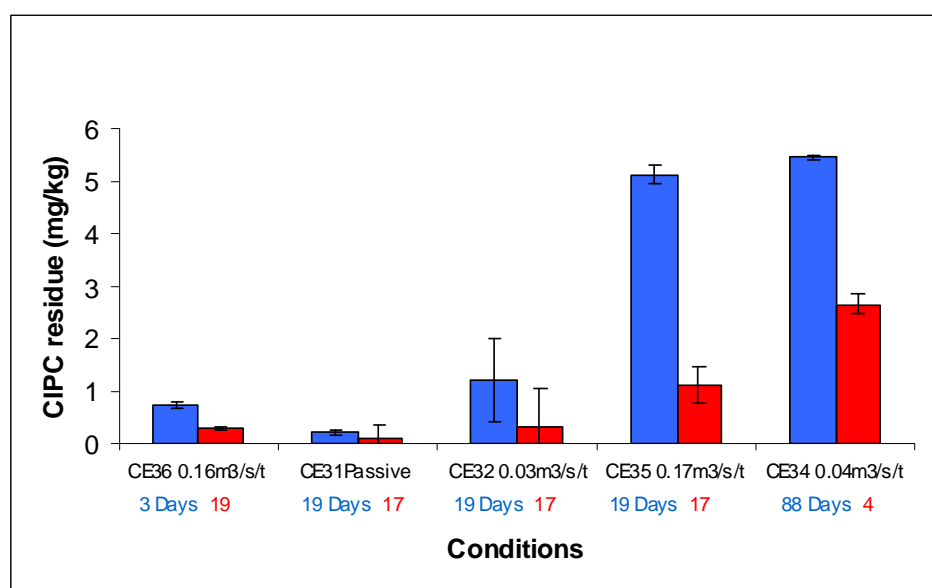


FIGURE 12. CIPC RESIDUE LEVELS AFTER EFFICACY TRIALS.

### 3.2.3 Discussion

With passive airflow, only low levels of CIPC reached the tubers, measured at 0.1 mg/kg at a height of 2.5 m at 19 days after treatment. Sprouting data indicate such levels are insufficient to inhibit further sprout growth.

At low airflows (0.03-0.04m<sup>3</sup>/s/t) after 19 days, reasonable levels of CIPC reached the tubers at the bottom end of the stack but these levels did not permeate up the stack. However, after 88 days, the levels increased resulting in 5mg/kg being detected at 2.5m. Although sprout growth was restricted during storage in a CIPC-free store, there was an increase in sprout length between the 19 day and 88 day lots at the end of recirculation treatments. This is likely to be as a result of the more gradual distribution of CIPC at modest air speeds, allowing sprout growth to proceed for a longer period.

At high airflows (0.16-0.17m<sup>3</sup>/s/t) after 3 days, the levels at 2.5m were 1.2 mg/kg. However, after 19 days the level had risen to 5.1 mg/kg. The rapid distribution of CIPC in these treatments resulted in the most effective control of sprouting during recirculation and in subsequent storage.

## 3.3 Evaluation of the effect of airflow duration on CIPC residue distribution when applied as vapour

### 3.3.1 Distribution

In this trial, for the first time, CIPC vapour concentration and airflow were measured within the crop stack. These are important parameters as they play a critical role in the delivery of the active substance, from source, to the target. This led to a much better understanding of the processes occurring amongst tubers. The general principles of this trial were as carried out in year 1 except that airflow rate remained constant and time of sampling was the only variable.

#### 3.3.1.1 Material and methods

Treatments were loaded into individual 12-tonne capacity Controlled Environment (CE) stores operating at 10°C (air temperature) and 95% RH for the duration of the study. Tubers were loaded into vertical plastic tubes (*Agritwin* non-perforated drainage pipe, Polypipe Civils). Each pipe was 3200mm long with a 600mm diameter. To facilitate loading and sampling, each pipe was cut into sections and the joins sealed with tape. The pipe was filled with potatoes to a height of 3000mm leaving a 200mm headspace between the top of the crop and a fan, drawing air through the crop. Axial flow fans (*Multifan* 4VF1042A, 600mm diameter, Vostermans Ventilation, Netherlands) were used in all treatments except for the passive ventilation treatment. Where fitted, the fan operated continuously for the duration of the treatment. The duration and airflow rate of treatments is shown below. Each pipe contained approximately 550kg of tubers.

CIPC vapour-contaminated air was supplied continuously at 0.01-0.02m<sup>3</sup>/s/t. Airflow measurements were taken within the pipe at 0.5, 1.5 and 2.5 m at intervals throughout the trial.

Pipes were unloaded, and samples obtained as follows:

- Treatment 1: Sampling at 3 days (CER 31)
- Treatment 2: Sampling at 19 days (CER 32)
- Treatment 3: Sampling at 80 days (CER 33)

CIPC vapour level was measured at days 0, 1, 3, 10 & 19 days, from sampling positions within pipes at 0.5, 1.5 and 2.5 m. Treatment 3 assessed fortnightly after this, until unloading.

Tubers for CIPC residue analysis were removed at unloading with three replicates from 0 m, 0.5 m, 1 m, 1.5 m, 2 m, 2.5 m and 3 m heights within each column. Tubers were taken from the centre of the tube.

#### 3.3.1.2 Results

Three days after the start of trial, headspace CIPC vapour concentration was consistently higher than the concentration within pipes (Figure 13b). Thereafter, headspace and in-pipe concentrations were similar (Figs. 13c and 13d). During extended treatment, over a period of 80 days, CIPC vapour levels reduced both in the headspace and within the pipe (Figure 14).



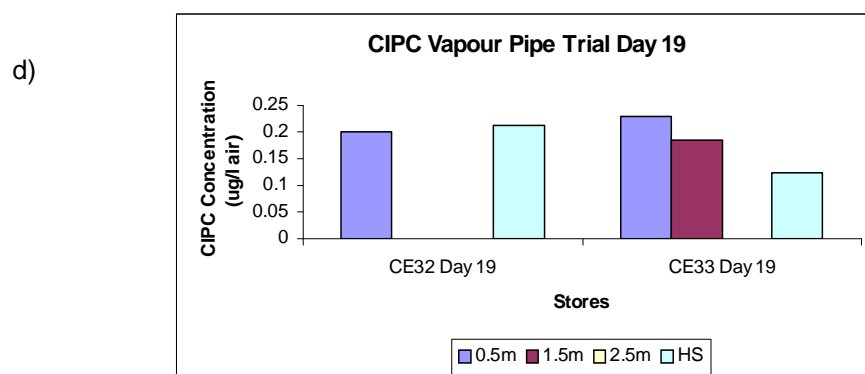
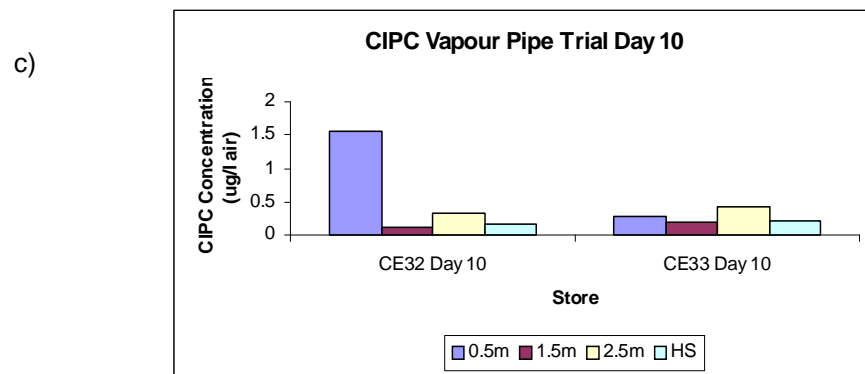
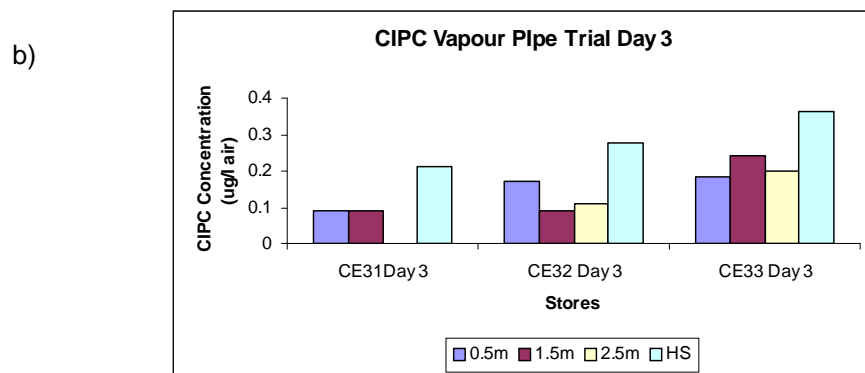
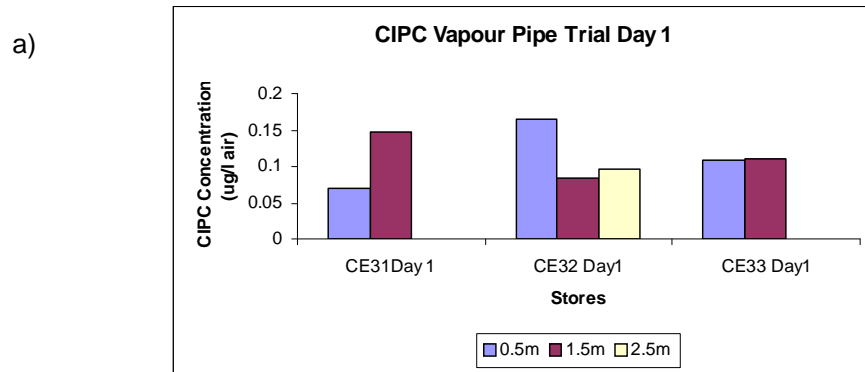


FIGURE 13. CIPC VAPOUR LEVELS AT (A) 1, (B) 3, (C) 10 AND (D) 19 DAYS WITHIN PIPES AND THE STORE HEADSPACE (HS).

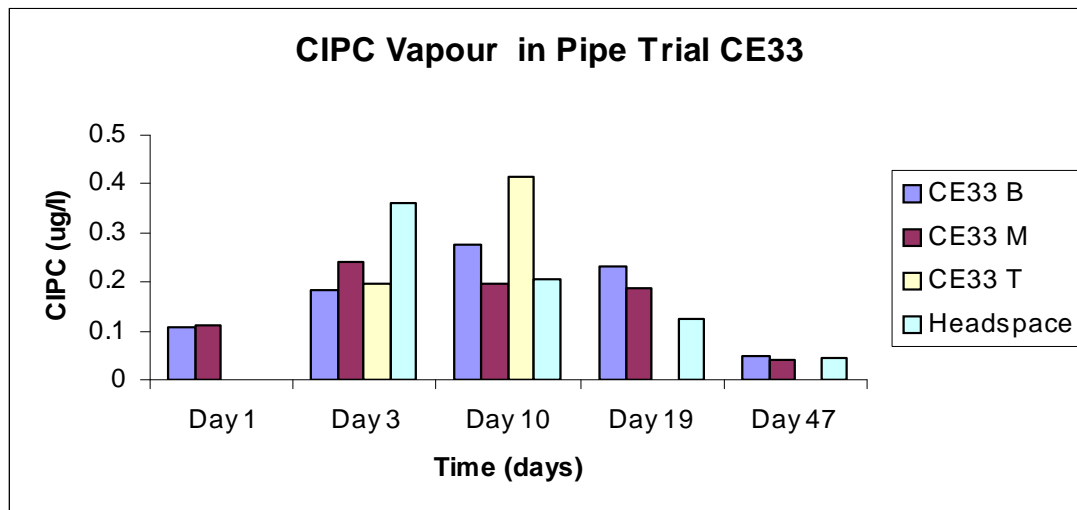


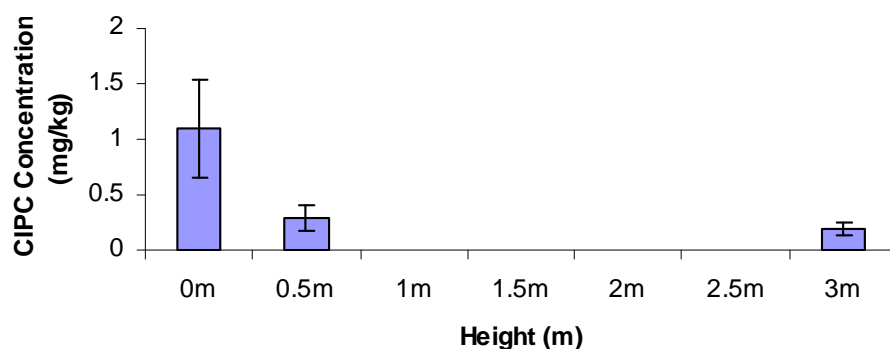
FIGURE 14. CIPC VAPOUR CONCENTRATIONS IN CER 33 (80 DAY TREATMENT).

CIPC residue results are shown in Figure 15. Results at 3 days show that CIPC was deposited at 0m and 0.5m, and on samples at the top of the pipe (3 m), but was not detectable on tubers at sample heights in the range 1-2.5 m. Greater attachment of CIPC on top tubers has been noted throughout the vapour pipe trials. Airflow modelling of the system has shown that changes in air speed/pressure due to factors such as pipe geometry and crop porosity, mean there is a tendency for air speed to drop at this point. This probably resulted in the accumulation of CIPC vapour at the top of the pipe.

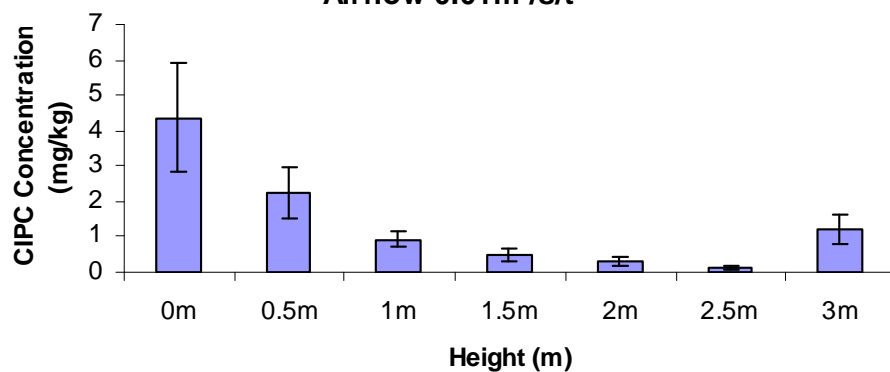
At day 19, there was an overall increase in CIPC levels, and it was detected at all levels. Residue values remained relatively high in samples from 0m and in tubers at the top of the pipe (3m).

CIPC residue values, at day 80, showed a more even distribution. This 'evening-out' of distribution occurred as a result of an increase in mean concentration on tubers at heights of 0.5 m up to 3 m and a reduction in concentration on samples from the 0 m level. The reduction in residue concentration at the base of the pipe suggests a change may have taken place in the equilibrium conditions. This is probably a result of a reduction in the vapour concentration entering the pipe due to the reduced CIPC level in the headspace later in storage. This result, which has been observed previously with vapour-applied CIPC, suggests a strong propensity for redistribution which is not associated with the chemical when applied using traditional, hot-fog methodology as a particulate.

**CIPC Residues at Day 3 (CE31)**  
**Airflow 0.01m<sup>3</sup>/s/t**



**CIPC Residues at Day 19 (CE32)**  
**Airflow 0.01m<sup>3</sup>/s/t**



**CIPC Residues at Day 80 (CE33)**  
**Airflow 0.01m<sup>3</sup>/s/t**

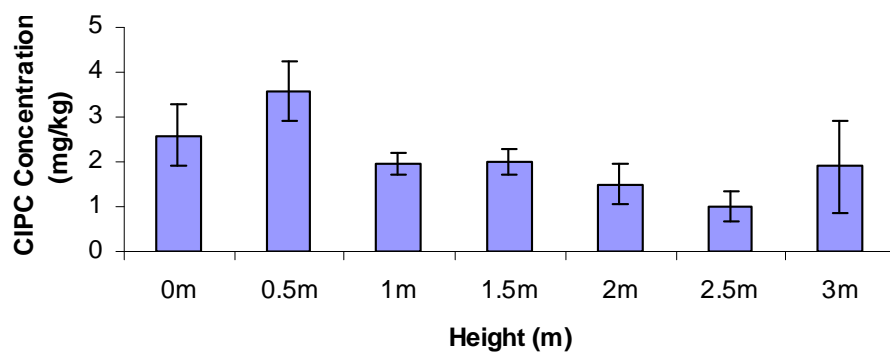


FIGURE. 15. CIPC RESIDUE CONCENTRATION AFTER (A) 3, (B) 19 AND (C) 80 DAYS.

### **3.3.1.3 Discussion**

The results from this work show, for the first time, how CIPC vapour levels in the store headspace differed initially from the within-pipe vapour concentration but equilibrate over time to reach similar levels. It also showed that the levels decreased in all cases by day 47. It is unclear why this occurred as fogging the stores prior to the experiment was expected to provide an 'excess' of CIPC for the entire trial.

The distribution of residual CIPC on tubers was similar to that seen in previous work and demonstrated that contact time is crucial to reach effective levels to prevent sprouting. Evidence was also obtained of a more dynamic nature to the CIPC active, when was applied as a vapour compared with particulate, with significant reductions in residue level also occurring over time.

This trial shows conclusively that CIPC does not have to be added at high concentrations as a solid to be an effective sprout suppressant. Supply of low levels of CIPC vapour, allowing these to accumulate and redistribute gradually, was effective at reducing the quantity of CIPC required by 50-100 fold.

## **3.3.2 Redistribution**

### **3.3.2.1 Materials and methods**

Redistribution of CIPC was assessed using vapour treated material sampled at 19 days (Treatment 2) in the distribution trial detailed above (Section 3.4.1).

Tubers from three positions (heights of 0-5cm, 100cm and 200cm) were used giving material with an anticipated range of concentrations to act as a source of CIPC vapour.

Sufficient tubers were transferred to form a two-tuber deep layer in the base of separate 300mm diameter pipes. These were covered with a single tuber buffer/discard layer and an additional 50cm layer of 'untreated' tubers. Airflow was set at 0.01-0.02 m<sup>3</sup>/s/t with clean, CIPC uncontaminated air for a timed period of approximately 43 days (Figure 16).



FIGURE 16. LAYOUT OF PLENUM WITH THREE PIPES CONTAINING SAMPLES AND SUPPLIED WITH CLEAN AIR, AS USED IN CIPC REDISTRIBUTION TRIAL.

### 3.3.2.2 Results

CIPC vapour samples were taken twice during the 43-day trial (Table 2). Levels were variable and, possibly, there was some form of particulate CIPC contamination where very high values were recorded.

	Tubers from	0–5 cm Pipe A	100cm Pipe B	200cm Pipe C
12 <sup>th</sup> June 2008	Source air	0.036		
	Source	0.034	0.042	0.014
	10cm above	0.052	0.000	0.055
	40cm above	0.021	0.013	0.136
14 <sup>th</sup> July 2008	Source air	0.567		
	Source	2.098	1.542	1.494
	10cm above	0.106	0.946	1.466
	40cm above	1.835	1.086	0.060

TABLE 2. CIPC VAPOUR CONCENTRATION ( $\mu\text{G/L}$  AIR) DURING REDISTRIBUTION EXPERIMENT.

CIPC residue values at the end of the redistribution experiment are shown in Figure 16 and Table 3. Results show that CIPC vapour is desorbed, and transferred up the stack albeit at a very low rate. Higher concentrations of CIPC in the source material resulted in higher concentrations of CIPC attaching to untreated tubers.

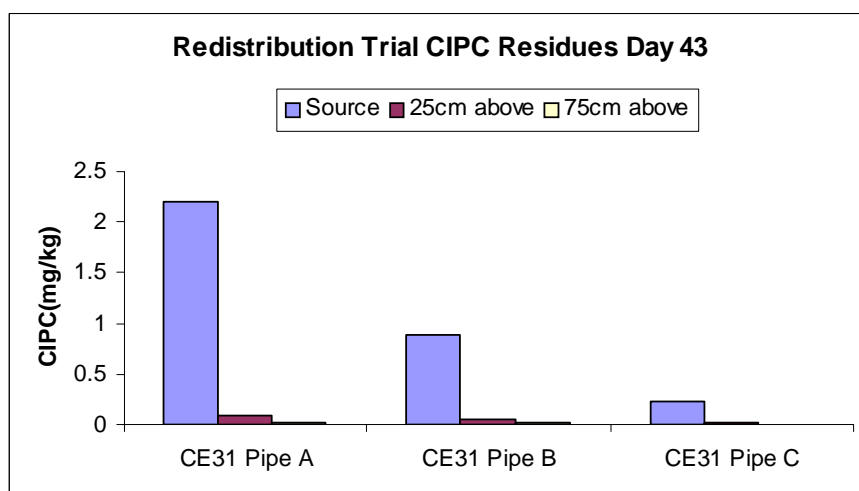


FIGURE 17. CIPC RESIDUE LEVELS AT THE CONCLUSION OF THE REDISTRIBUTION TRIAL.

	CE31 Pipe A	CE31 Pipe B	CE31 Pipe C
Source	2.20	0.88	0.24
25cm above	0.10	0.06	0.02
75cm above	0.02	0.02	0.00

TABLE 3. CIPC RESIDUE LEVELS (MG/KG) AT THE CONCLUSION OF THE REDISTRIBUTION TRIAL.

### 3.3.2.3 Discussion

Some re-distribution of CIPC occurred from the vapour treated source crop to the untreated target crop, though residue levels were largely retained. This is a positive result as retention of residue is required for sprout control. Although the magnitude of residues on the target crop remained small ( $\leq 0.10$  mg/kg), given the small volume of the source crop, and the relatively large volume of the target, this still thought to represent redistribution on a scale greater than that occurs with CIPC applied conventionally. Results confirm changes in CIPC residue levels, when applied as a vapour, can be obtained by changing the equilibrium conditions to which tubers are exposed.

It can be concluded that CIPC vapour is effectively adsorbed to tuber surfaces and can subsequently be desorbed by changing the equilibrium conditions to which tubers are exposed.

## 4. CONCLUSIONS

The experimental work carried out demonstrates that there is scope for the treatment of stored potatoes using CIPC in the vapour phase alone. Currently, CIPC is applied in Great Britain almost universally in particulate form (as a hot fog) with these particles becoming attached to tubers, which then act as vapour sources. This approach is particularly problematic, because the excess of product that is supplied is measured as a CIPC residue on tubers.

As well as containing a relatively high concentration of active substance, CIPC in particulate form is long-lived with a decline rate of only around 1 ppm per month (G. Kleinkopf, 2004), making the risk of exceeding the MRL more likely.

### 4.1 Distribution

In laboratory and small-scale trials, there has been evidence of uneven distribution of residue levels (and consequently efficacy) from vapour-applied CIPC. The affinity of potatoes for CIPC vapour was shown in earlier levy-supported work (Cunnington *et al*, 2006). A critical air speed is required to move the CIPC through tubers, to ensure even residues of CIPC. This is acceptable for bulk and positively-ventilated box store scenarios. However, in passively-ventilated box stores the system is likely to need, at the very least, many more point sources of CIPC but, if the final step is limited by convective airflow, then it may simply not be a suitable technique for this type of store.

The application in terms of bulk and box storages will obviously vary, and both cases require extensive research and development on detailed air movement, surface interactions and CIPC vapour release characteristics before such systems could be utilised in commercial stores. Results show, however, that in bulk and positively ventilated box stores, the technique has great potential and, given further work to develop it, is likely to be successful.

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