OPTIMISING CIPC APPLICATION IN BOX POTATO STORES

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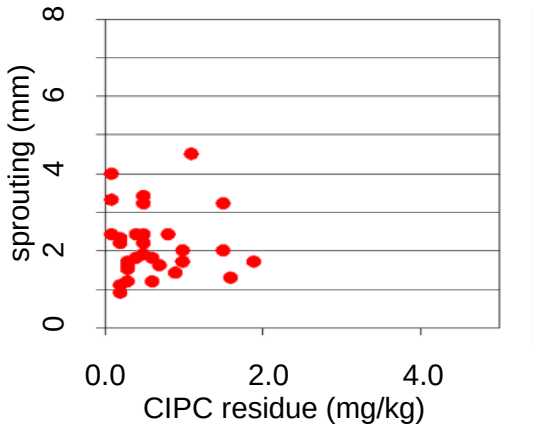
Summary: Chlorpropham (CIPC) is the most widely used sprout suppressant in potato storage and its use is currently subject to stewardship in the UK in order to reduce the risk of maximum residue level exceedance. Trials funded by AHDB were undertaken in commercial box potato stores to assess the effectiveness of adaptations to use recirculation of air/CIPC fog to improve the uniformity of application. Recommendations for the adoption of *'active recirculation'*, evaluated in these trials, have now been included on CIPC product labels for 2017/18.

INTRODUCTION

The aim of the work was to develop improved methods of CIPC application using fan assistance to recirculate the fog during application in order to achieve more uniform deposition and lower chlorpropham residues. Previous work conducted by SBCSR and the University of Glasgow (McGowan *et al.*, 2009) had successfully introduced the use of slow speed recirculation for this purpose to commercial bulk potato storage, resulting in both improved sprout control and lower chemical residues (Figure 1). Subsequent trials (Briddon *et al.,* 2013) to translate this technique to commercial box storage were only partially successful. In particular, application to passively ventilated 'overhead throw' box stores had yet to adequately address the risk of high residues. In statutory testing, MRL exceedances were still being detected in box stores. This series of trials was undertaken to take forward previous findings with the primary aim of developing solutions for these particular storage systems.

Figure 1. Use of recirculation results in a narrow range of residue concentrations and good sprout control (McGowan *et al.,* 2009)



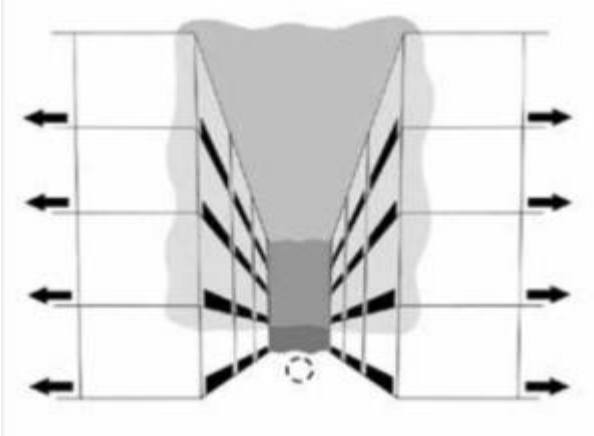
MATERIALS AND METHODS

The trial work described here was conducted in commercial box potato stores. This was deemed

necessary in order to adequately evaluate the impact of scale on the distribution of sprout suppressant. Store capacities were 900 tonnes and above. Due to the commercial nature of the stores, it was necessary to limit sample placement and removal to the times of store loading and unloading respectively.

Work was conducted over three seasons from 2013/14 to 2015/16 inclusive. At the outset of the trial, 'Be CIPC Compliant' best practice guidance recommended the use of a plenum for application of CIPC in overhead throw type stores (AHDB, 2014). The term *plenum* refers to a covered corridor (Figure 2) which bisects the main block of boxes into which the CIPC is applied. The cover largely prevents the hot-fog from rising directly into the store headspace reducing the risk of high residue levels on top boxes. This method was used in store MSF1 in 2013/14 as a benchmark for comparison. Due to the length of the store, two plenums were installed but, crucially, the store's fans were *not* used during application.

Figure 2. Mid-stack plenum design (AHDB, 2014).



Additionally, across all three years, stores were assessed following modification in a way expected to influence CIPC residue distribution, principally through the introduction of some form of active recirculation of the air/fog mixture during the application process. This was achieved primarily by slowing the main ventilation fans down to air speeds around 20-30% of their normal flow. If this wasn't possible (e.g. because use of the main fans would pull CIPC through the fridge coils), then secondary fans were added, again to run at 20-30% of normal airflow (typically 0.004-0.006 $m^3/s/t$). In each store, residue distribution was determined using netted samples of the commercial crop, selected randomly, with each net placed systematically within boxes at store loading. A typical grid showing the store layout is shown in Figure 3, with sample locations marked 'X'.

At each sampling position within the store, nets were placed on three levels (top box and bottom box plus one box approximately halfway between). Each net contained c. 10kg of potatoes. Nets were located centrally in boxes, with the top of the net just visible at the surface, to give a representative split between surface and sub-surface tubers. Nets were recovered at the time of commercial unloading of the store; this meant that storage duration could not be specifically controlled, although storage duration was recorded. Three tubers from each net were then randomly selected and analysed individually for CIPC residue concentration by a GLP laboratory (ALS, Chatteris) and 25 tubers taken randomly from the net were assessed for sprout growth (length).

Over the three seasons' work, a selection of modified box stores were assessed with the aim of achieving improved CIPC residue distribution. These ranged from simple, low-cost

modifications to overhead throw box stores to more fundamental changes, requiring complete refurbishment of the store. A range of varieties were used and stores covered both the fresh and processing potato sectors; the store types assessed in this work are shown in Table 1.

Figure 3. Typical plan of store sampling grid (nets place on 3 levels at each position shown X)

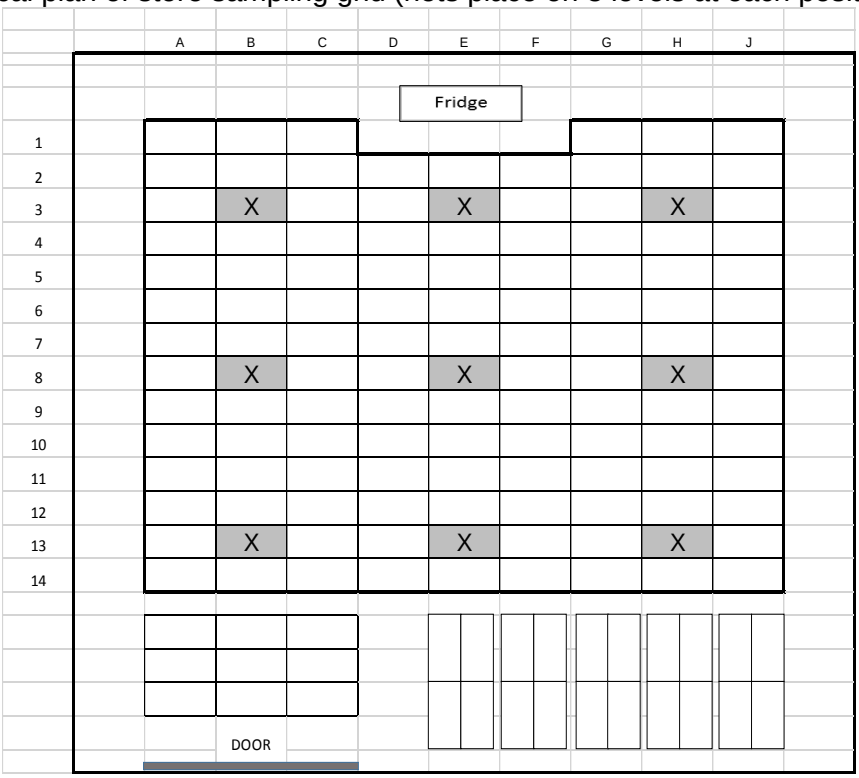


Table 1: Store types assessed in each season across the three year trial series

Store type	**Code**	**Temp**	**Active recirc-ulation?**	**Year 1** 2013/14	**Year 2** 2014/15	**Year 3** 2015/16
Passive mid-stack plenum	MSF1	Fresh	N	✓		
Positive mid-stack plenum	MSP1	Process	Y	✓		
Positive lateral flow	PLF1	Fresh	Y	✓	✓	
Positive using foam blocks	PFB2	Fresh	Y^	✓	✓	
Open suction	OSP1	Process	Y	✓		
Open suction	OSP2	Process	Y		✓	✓+ mesh
Open suction	OSP3	Process	Y			✓
Open suction	OSF1	Fresh	Y		✓	
Open suction	OSF2	Fresh	Y			✓
Open suction*	OSF3	Fresh	Y			✓

Fresh stores held at 2-3°C; process at 7-9°C; *fitted with a half-height air separator curtain; ^see text.

In store OSP2, following measurement of local airflow in the store in 2014/15, it was found that the open suction systems remained prone to biased and disproportionately high airflow in front of the refrigeration units during normal operation. A 60% mesh restrictor was added extending 25% of the full store width either side of the fridge unit to try to reduce this. Airflows with the

restrictor in place, and after its removal, were made to assess the impact.

RESULTS

Earlier work (McGowan *et al.,* 2009*,* Briddon *et al.*, 2013) showed CIPC residues with a CV% value below 100 were generally more uniform than standard application practice where ventilation was not used.

Mid-stack plenum

Application to store MSF1 resulted in a mean CIPC residue concentration of 2.9 mg/kg (SD 1.67) from a single application of 12 g/tonne. The highest concentrations of CIPC were detected in samples from middle boxes, closest to the plenum and the lowest residues (a number of boxes had residue values below 1 mg/kg), generally occurred in boxes furthest from the plenum. This demonstrates that the addition of ventilation, as in store MSP1, may help to even out any gradient.

In store MSP1, the use of a plenum with additional fans for recirculation, resulted in CIPC residue values which were relatively even (mean 2.7 mg/kg, SD 1.30, CV% 48). However, after two applications with a total dose of 26 g/tonne, there were still some boxes which had residue values which were too low (<1 mg/kg).

Whilst central plenum systems can work successfully with adequate recirculation to apply CIPC, their use requires attention to detail to eliminate localised effects and maximise the evenness of application.

Open suction (using an air separator curtain)

In 2013/14, the use of an air separator curtain coupled with low-speed recirculation of fog through open pallet apertures (Store OSP1), termed 'open suction', resulted in low CIPC residue variability (mean 1.1 mg/kg, SD 0.53, CV% 47). Although this variability may have been slightly underestimated by sampling top samples from the fifth box in stacks of six (necessitated by a variable stack height throughout the store) and overall residue levels were low, sprout control was effective (mean 1.4 mm, SD 1.29).

In 2014/15, as in the previous season, the use of an air separator curtain, together with low-speed recirculation of fog through open pallet apertures resulted in good control of CIPC residue variability and effective sprout control. This approach, in a store for the fresh potato sector (store OSF1), resulted in a mean CIPC residue concentration of 3.1mg/kg, SD 1.14, CV% 36 and in the processing sector (store OSP2) a mean residue concentration of 0.8mg/kg, SD 0.61, CV% 72. In both stores, differences in residue concentration as a result of sample position in store, was limited. Results confirmed those of 2013/14 (store OSP1).

In 2015/16, the open suction system of active recirculation resulted in low CIPC residue variability in stores holding for the fresh market, with coefficients of variation between 46% (store OSF3) and 83% (store OSP2). Variability was lowest in store OSF3, which was fitted with a half-height air separator, but this does not necessarily indicate this type of separator to be more effective, as the main block dimensions in this store were different from elsewhere, so a direct comparison cannot be made. Sprout control efficacy was very good in both stores (mean maximum sprout length <1mm) but comparisons cannot be made as, in store OSF3, the crop was also treated with spearmint oil before unloading.

Active recirculation using open suction also resulted in a moderate level of CIPC residue variability in store OSP2 but residues were generally very low (overall mean 0.1mg/kg, SD 0.13) – perhaps due to the extended storage period (68 days' storage after final application) – and this was reflected in the efficacy results. With such low residues, the coefficient of variation was unsurprisingly higher than previously observed at 121%; variation had before been in the range 36%-92%.

The addition of a mesh restrictor in this store helped to give more even distribution of air but the 60% restriction was not adequate to remove the imbalance in flow entirely (data not shown). Further work is being undertaken to refine modifications to improve uniformity.

Nevertheless, open suction systems, created by the use of air separator curtains, gave very promising results across three years' trials, with improved uniformity of residues (CV% <100). The system also has the benefit of modest conversion costs, estimated at £3-£5 per tonne.

Positive ventilation using foam blocks

In 2013/14, the use of foam blocks, inserted in alternate pallet apertures in store PFB2 (in addition to an air separator and low-speed recirculation as used in store OSP1), resulted in slightly higher but acceptable residue variability (mean 3.2 mg/kg, SD 1.84, CV% 58). Residue values in the store were generally highest in top boxes, especially at the front of the store, closest to the point where CIPC was introduced. The maximum residue measured in PFB2 (7.7 mg/kg) was less than in the other low temperature stores (9.7 and 9.3 mg/kg respectively for PLF1 and MSF1) where the position of the application port also had a significant effect. Further work was required to assess whether the additional use of the foam blocks in any format is capable of offering a significant benefit over a simple air separator curtain in this type of store.

In 2014/15, inserting foam blocks in alternate pallet apertures, in addition to an air separator curtain and use of low speed recirculation (store PFB2), did not result in a satisfactory residue distribution, with samples in the range 0.2-11.1 mg/kg from a single application of CIPC at 14 g/tonne. Considerable variation in residue concentration was evident in relation to sample box height (bottom box mean 2.9 mg/kg (SD 1.86), middle box mean 4.4 mg/kg (SD 2.00) and a top box mean of 7.5 mg/kg (SD 2.23). A similar effect of box height, with top boxes receiving a disproportionately large proportion of the total dose, although, in 2014/15, a greater application efficiency was achieved overall (mean residue 4.9 mg/kg, SD 2.78, compared with 3.2 mg/kg, SD 1.84 in 2013/14, both from an application rate at 14 g/t). Consequently, some tubers had a residue value of 10 mg/kg or greater. The use of foam blocks, in this type of store (with an air separator curtain) was not beneficial. It is considered that the backpressure on airflow, posed by the blocks, was too great and fan pressure, under low speed conditions, was insufficient to overcome this resistance and full, active recirculation did not take place. Short-circuiting of air is also a factor as this limits the amount of air reaching the end of the store furthest from the fans; observations suggest this resulted in a very low, almost undetectable, airflow at the point where CIPC fog was introduced into the store. As a consequence, fog was not drawn directly into the block of boxes and, instead, tended to rise directly up into the store headspace increasing the risk of high levels of deposition on the top surface of the stack. The use of foam blocks to retrospectively create positive ventilation in these types of store was therefore discontinued after 2014/15.

Positive lateral flow ventilation

Store PLF1 was converted to lateral suction (positive) ventilation, using the Pirie *Aspire™* system, in 2013. Previous AHDB research (Project R414) had shown this type of store results in effective application of CIPC fog, with low residue variability, using low-speed fans for

recirculation (Briddon, 2013). In this trial, the lateral suction system again performed well with a mean residue of 3.0 mg/kg (SD 1.63). Residue variability was lowest (CV% 54) of the three low temperature stores in the trial. However, it was noted that there was a marked effect of the location of the CIPC port, with particularly high values recorded in samples close to the application point.

To counteract the localised effect of the position of the fogging port observed previously, for 2014/15 the fog was introduced more centrally and the back-fill block was also connected to the main block, so that these boxes were also subject to recirculation of air and fog. These additional modifications were deemed successful as more even control of sprouting was observed. The maximum CIPC residue value in this store reduced from 9.7 mg/kg in 2013/14 to 8.4 mg/kg in 2014/15 whilst overall residue values were similar in both seasons (2013/14 mean 3.0 mg/kg, SD1.63, CV% 54; 2014/15 mean 3.1 mg/kg, SD 1.71, CV% 56). The lateral suction ventilation principle was also assessed in 2014/15 in a processing store but, due to excessive bacterial soft-rotting, results were not considered representative and are not presented. Overall a very good, even distribution of CIPC was achieved using the lateral suction system.

Proposals for the adoption of slow speed *'active recirculation'* as a standard practice for the treatment of box potato stores with CIPC were put forward by the Potato Industry CIPC Stewardship Group in March 2017 (PICSG, 2017) and have been incorporated into label recommendations for the 2017/18 season, as the industry made its final move to a pan-European maximum dose rate of 36 g/t (reduced over 5 years from 63.75g/t). No MRL exceedances occurred since February 2014 (Defra, 2017).

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