Taking control of pome fruit residues

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Taking control of pome fruit residues

Final report for the project AP99042
(January 2000-December 2001)

W.S. Washington

Department of Natural Resources and Environment,
Agriculture Victoria, Knoxfield

April 2002
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Scope of Report

This report summarises work conducted in Australia during January 2000 –
December 2001 by a national team to investigate reasons for the occurrence of DPA
residue contraventions in pome fruit and develop and implement extensions strategies
to overcome these violations. The project also aimed to develop appropriate disposal
guidelines for used post-harvest chemicals and to develop a training manual of best
practice use of post-harvest drenches for pome fruit.

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1. Media summary

Superficial scald is an important disorder of many apple and pear cultivars during long-term storage. At present, susceptible fruit are treated with the anti-oxidant diphenylamine (DPA) to prevent scald. However, recent national surveys have detected small numbers of apple samples with residues of DPA exceeding the Australian maximum residue limit (MRL). Our study aimed to find out why these DPA residue violations occurred, and to develop extension materials and activities to prevent further residue problems.

Our study recorded dip practices and determined dip and fruit concentrations of DPA sampled from packing sheds around Australia. Analysis of data from 50 sheds and for 11 apple and pear cultivars highlighted a number of important issues, which must be addressed to minimise residue problems. These are summarised in the best practice manual "Guidelines for post harvest drenching of apples and pears". (Refer to www.nre.vic.gov.au/agvic/fhd/publications/dpa-use-guidelines.pdf) It is recommended that all shed operators:

• Refer to the best practice manual for a checklist of important issues when planning DPA treatments
• Do not use off-label rates of DPA and always follow the product label
• Mix new DPA dips thoroughly before use, especially with high dip rates
• Take care to top-up old dips accurately
• Where possible avoid the use of high DPA rates (above 640ml product /100L).

Other technology transfer activities included: interactive workshops with growers, presentations, industry publications, a poster, and newspaper articles. Draft national guidelines for disposal of used post-harvest dip have also been prepared, but are not yet approved.

Recommendations for future work include:

• More training in best practice for shed operators.
• Increased levels of residue testing of fruit to increase shed operator awareness and ensure that DPA violations do not occur.
• More specific Quality Assurance programs to ensure that shed operators use correct rates and procedures during post-harvest treatment of fruit
• More research to find reliable scald control methods with reduced, or zero, use of DPA
• Obtaining national consensus and implementation of draft disposal guidelines
• Work with DPA manufacturers/suppliers to revise the product labels in line with the findings of this project

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2. Technical summary
Superficial scald is a disorder which results in skin browning during, and after, long-term storage on many apple and pear cultivars. At present, treating susceptible fruit after harvest with the anti-oxidant diphenylamine (DPA) prevents scald. However, recent national surveys have detected small numbers of apple samples with residues of DPA exceeding the Australian maximum residue limit (MRL). As these residue violations could have major implications for trade, our study aimed to find out why these DPA residue violations occurred, and to develop extension materials and activities to prevent further residue problems.

Methods: Two hundred and eighty dip and fruit samples were collected from 50 packing sheds in 6 states around Australia. Information on shed dipping practices was also collected. In Victorian sheds fruit and drench was sampled three times during the life of the same dip in order to study the effect of new, old and top-up dips on fruit and dip residues of DPA. An analytical laboratory determined DPA residues. Data was collated, plotted and analysed to determine any important trends.

Results and outcomes: We found that a significant proportion of Granny Smith, Lady Williams and Red Delicious fruit had DPA residues that exceeded the MRL for apple, when fruit were sampled immediately after treatment. Residues in all samples of 6 other apple cultivars were less than the MRL for apple. Similarly, residues found in all pear samples did not exceed the MRL for pears. (Note that treated fruit are normally stored for long periods before marketing, during which time DPA residues decline significantly).

High DPA residues were often associated with:
1). Application of high, off-label rates of DPA to Lady Williams fruit.
2). Imperfect mixing of DPA in newly prepared dip tanks, especially where high rates were used.
3). Inadequate methods used when topping-up old dips.
4). Use of high rates (above 640ml product/100L) of DPA.

Procedures that are important in avoiding residue violations are summarised in the best practice manual “Guidelines for post harvest drenching of apples and pears”.

While some cases of high fruit residues could be related to inadequate post-harvest practices, our results indicate that the Australian MRL of 5mg/kg for apples may be too low for the (high) registered use rates of DPA on some cultivars, when compared with similar data from the USA. Limited data for the cultivar Pink Lady indicated that it takes up DPA more readily than the cultivars Red Delicious, Granny Smith, Lady William and Fuji. Insufficient data was collected for the other cultivars sampled in this study to draw any conclusions about their DPA uptake.


Draft national guidelines for disposal of used post-harvest dip have also been prepared. These are not yet approved because newly prepared AVCARE guidelines for disposal of agricultural and veterinary chemicals have taken precedence and are currently being examined by regulatory organisations.

Recommendations include:
- More workshops and training in best practice for shed operators, combined with more residue testing to ensure that DPA violations do not occur and to increase awareness of the issue.
- More specific Quality Assurance programs to ensure that shed operators use correct rates and procedures during post-harvest treatment of fruit.
- Consideration should be given to adjusting the MRL for DPA in apples to account for the high rates required for scald control on highly susceptible cultivars grown in regions liable to scald.
- More research to find reliable methods for scald control with reduced, or zero, use of DPA.
- Research to develop data for use of DPA on new cultivars should be supported by the chemical suppliers.
- Obtaining national consensus and implementation of draft disposal guidelines.
- Work with DPA suppliers to revise the product labels in line with the findings of this project.

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3. Introduction

The Australian Apple and Pear Industry produces a crop of about 500,000 tonnes per annum, worth an estimated fresh farm gate value of $499 million (ABS Year Book, 1999). Much of this crop is susceptible to the physiological disorder known as superficial scald. Scald appears as a brown discolouration on the fruit surface during and after long term storage of fruit. This discolouration makes fruit unmarketable. The anti-oxidant diphenylamine, or DPA, is an important post-harvest treatment that is currently applied to many apple and pear cultivars to prevent scald.

DPA is usually applied as a drench or dip to fruit soon after harvest and before storage. It has been used to prevent scald for several decades in many countries, including Australia and the USA. Two products containing DPA are available to the Australian industry: Chemley No-Scald DPA (distributed by E.E. Muir and Sons Pty Ltd) and Campbell DPA 310 Scald Inhibitor (distributed by Colin Campbell Chemicals Pty Ltd).

The issue of chemical residues in pome fruit is an important issue to consumers both locally and overseas. Adverse publicity could lead to major reductions in markets for fruit that are associated with such residues. As a result, the residue issue has potential to significantly impact the pome fruit industry.

Possible ways to reduce or avoid the use of DPA include the following: avoid long-term storage of susceptible fruit to reduce the risk of scald; only long-term store cultivars of fruit which are not susceptible to scald; use forecasting systems to predict which fruit are at risk of developing scald; use ultra-low oxygen storage to minimise the risk of scald and allow reduced rates of DPA; use vegetable oils as anti-scald treatments. Unfortunately, although these and other alternatives to DPA are being developed, none are yet available commercially, and at present none have the efficacy and ease of use of DPA.

Since 1997 the National Residue Survey of AFFA has detected a small proportion of apple samples with DPA residues which exceed the Australian maximum residue limit (MRL). In addition, a further higher proportion of samples had residues less than, but close to, the MRL. Trace-back investigations failed to clearly identify a simple cause for these excessive residues. In response to this situation, the AAPGA has decided to take a pro-active approach to preventing further contraventions of the MRL for DPA and requested a project to address this and other issues relating to disposal of used post-harvest chemicals. The project AP99042 aimed to:

1. Determine reasons for DPA contraventions and develop and implement extension strategies to overcome these violations,
2. Develop a Best Practice training manual for use of DPA and other post-harvest treatments for use in workshops around Australia
3. Develop national guidelines for disposal of used post-harvest chemicals
4. Collate, evaluate and research residue and efficacy data for new fruit cultivars (subject to funding by the co-operating chemical suppliers)
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4. National targeted sampling of fruit and dip solution

Introduction
A targeted sampling of apple and pear fruit and post-harvest DPA dip solutions was carried out in 6 states around Australia. Sampling under standardised conditions aimed to establish objective data on fruit residues and associated dip concentrations. Key packing sheds and high-risk cultivars of fruit were sampled to determine the reasons for the occurrence of DPA residues above the MRL in some fruit samples.

Methods

Boxes, plastic bags and courier forms as used by the National Residue Survey (NRS) of Agriculture, Fisheries and Forestry -Australia (AFFA) for routine testing of produce for residues were obtained from the NRS. These were sent to co-operators (usually a district horticulturalist, post-harvest researcher or an extension officer with the state Department of Agriculture) in each state. A standardised sampling procedure was developed and supplied to all co-operators. Fruit and corresponding dip samples (140 of each) were taken immediately after fruit treatment in commercial packing sheds in each state. For each sample, 10 fruit were taken from the top of the bin after that bin of fruit had been treated with DPA either by drenching or dipping the bin immediately after harvest. Fruit were allowed to drain and were substantially dry before sampling. Drench was sampled in a 100 ml glass bottle from drench tanks which had been pumped for several minutes. Samples were sent via courier to the testing laboratory within 1-2 days of collection.

Note that fruit were sampled immediately after treatment, and before normal storage and marketing practices. Because there is no with-holding period for DPA treated fruit, testing of residues immediately after treatment is appropriate. It was also necessary in order to obtain consistent data from different sheds around Australia.

Residue testing method. The analytical laboratory stored drench samples at 4°C until testing, while fruit samples were stored at -20°C. Drench samples were tested by high-pressure liquid chromatography (HPLC), while whole fruit samples were analysed by gas chromatography, with suitable standards used in both cases.

In Victoria only, 3 samples from the same dip were taken at each shed. The first was from freshly prepared dip, the second from used dip immediately before topping-up, and the third from the same dip immediately after top-up.

Fruit and dips were sampled throughout the post-harvest treatment season, which corresponds to the harvest period for the mid- and late season cultivars of apple in Australia, from February 29th to June 6th 2000.

Sampling was directed mainly at cultivars of apple and pear, which have the greatest risk of high DPA residues. These are cultivars which are most susceptible to scald (and which are therefore treated in the highest rates of DPA); or cultivars which may absorb more DPA than others (due to physical characteristics such as a russetted skin or an open calyx which may allow dip to enter the core of the fruit). The highest risk cultivars of apple are Granny Smith, Red Delicious and Lady William. Buerre Bosc
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pear, which has a naturally russetted skin, is also considered to be at higher risk than other cultivars.

Other apple cultivars were also sampled in order to get information on possible residue levels which may result from dipping those cultivars, some of which are new or minor in importance and are not listed on the DPA product labels.

Information on rates applied, drench application methods and other details of the post-harvest treatment were recorded for each sample.

Results and Discussion

A total of 280 fruit and dip samples were taken from 50 different packing sheds (Table 1). This was made up of 132 from Victoria, 38 from Tasmania, 40 from Queensland, 24 from NSW, 40 from South Australia and 6 from Western Australia. Two hundred and forty-two samples were apple fruit and dip taken from all states, while 38 pear fruit and dip samples were taken from Victoria and South Australia.

Table 1. Number of fruit and corresponding dip samples tested for DPA residues. Samples were taken from a total of 53 packing sheds from 29th February to 6th June 2000.

<table>
<thead>
<tr>
<th>State</th>
<th>Total</th>
<th>Fruit</th>
<th>Dip</th>
</tr>
</thead>
<tbody>
<tr>
<td>Victoria</td>
<td>132</td>
<td>66</td>
<td>66</td>
</tr>
<tr>
<td>Tasmania</td>
<td>38</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td>Queensland</td>
<td>40</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>New South Wales</td>
<td>24</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>South Australia</td>
<td>40</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Western Australia</td>
<td>6</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td><strong>total</strong></td>
<td>280</td>
<td>140</td>
<td>140</td>
</tr>
</tbody>
</table>

Shed data collected

In the 50 sheds sampled, the most common treatment systems were single and two-tiered (one, or two, bins at a time) drenchers. A small number of sheds used immersion dip tanks, while one large shed used a triple tiered drencher (treating three bins at a time). Pre-washing before treatment was common in Victoria and South Australia, but was not noted in sheds from other states. The time delay between pre-washing and DPA treatment ranged from 1-10 minutes (usually 1-3 minutes).

Tank volumes ranged from 300-2900 L with most between 1000-2000 L. DPA treatment rates ranged from 325 - 3700 mg DPA a.i./L, equivalent to 100 - 1200 ml DPA product per 100 litres. While the upper rates listed on the product labels are equivalent to this maximum, some cultivars (eg. Lady Williams) were often treated at rates higher than those specified on the label. Lady Williams was also the cultivar that had the highest proportion of samples with residues exceeding the MRL.
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Three fungicides were used (iprodione, carbendazim and imazalil), occasionally all together but more often alone or in combination. Many sheds did not use any fungicide. Drench treatment times ranged from 5-192 seconds, with most being in the range of 20-45 seconds. Fruit temperatures ranged from 8-25 °C at time of treatment.

**Combined apple and pear results**

Figure 1. plots the shed operators intended DPA concentration in the dip tank against the measured dip tank concentration. The straight line indicates the expected relationship, which would be that intended concentrations plotted against measured concentrations were identical. As can readily be seen, more points lie below the line than above it, indicating that measured concentrations were more often actually less than the operator intended. This occurred even with freshly prepared dips. However, a significant number of samples showed the opposite ie. the shed operator intended to get a lower dip concentration than was actually measured by our sampling of the dip. It is not clear why this data was so variable. Possible factors include poor mixing of DPA in tanks, inaccurate measurement of DPA rates and/or water volumes or incorrectly calibrated tanks.

![Figure 1. Actual versus growers intended DPA concentration in dip tanks, and line showing the expected relationship between the two.](image)

As expected, a positive relationship exists between the measured dip tank concentration and the residue in fruit treated in that dip (Figure 2a). Fruit DPA
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residues increase as the dip tank concentration increases. This relationship remains when apple data only is plotted (Figure 2b), but is not as obvious when pear data is plotted (Figure 2c). This probably relates to the smaller number of pear samples taken (19) compared to apple samples (121). No MRL violations occurred when fruit were treated with 2 g active ingredient (a.i.)/L DPA or less, irrespective of cultivar.

NOTE: DPA concentrations throughout this report are listed as grams (g) active ingredient (a.i.)/L. This is equivalent to 310 x g a.i./L of DPA concentrate per 100L, as the Australian DPA products contain 310g/L diphenylamine.
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Figure 2. DPA concentrations in dip tanks and DPA residues in fruit treated in those dips, for a) all apple and pear samples, b) all apple samples, and c) all pear samples.
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Victorian results from new, old and top-up samples

Sampling in Victorian sheds was from three stages in the life of the one dip — newly prepared dips, old dips (about 50 bins of fruit treated), and immediately after topping-up the old dip. Graphed data from new, old and top-up sampling for apples are shown in Figures 3a, 3b and 3c. Although statistical analysis of this data indicates there is no difference between the three lines, there is an indication that data for the new dip is different from the other two. The fitted line for new dips appears flatter and, especially at high rates may be better represented by a curve.

This suggests that newly prepared dips may not mix as readily as most operators assume, especially at high DPA concentrations. Complete mixing may only occur after many bins of fruit have been treated, and as a consequence may result in uneven treatment rates when fruit are treated early in the life of the dip, and higher rates when fruit are treated later in the dip life. The latter case may occur in some sheds, where dip concentrations are tested during the preparation of a fresh dip using a titration test kit. It is possible that in some cases initial testing during the dip preparation may indicate low DPA concentrations (due to poor mixing), and shed operators may add more DPA (above the label recommendation) which may eventually result in a higher dip concentration than was originally intended.

Discussions with the representatives of DPA suppliers indicate that satisfactory mixing is an issue, and they are planning to review the mixing directions as part of a revised product label. Despite the lack of statistically significant differences between the three data sets (new, old and top-up samples,) a larger sample may show significant differences between the data sets, adding support to the idea of incomplete mixing.

Results from all states

a). Apple.

Figure 4. shows the distribution of DPA residues found in apple fruit from our sampling during the year 2000. Although most samples are below the Australian MRL of 5 mg/kg, a significant proportion are above the MRL, and a long “tail” indicates that some samples had residues as high as 9-10mg/kg, when sampled immediately after treatment and before storage.

Similar data collected from the USA, shown in Figure 5. (from a table in an FAO/WHO Joint Meeting on Pesticide Residues document -1984, from Pennwalt, 1984), indicates that residues were generally much lower than in our study. Only one sample from the US data exceeded 5 mg/kg, and all were well under the USA MRL for DPA in apples of 10 mg/kg. These results probably reflect the greater difficulty that many Australian growers have in controlling superficial scald, due to adverse growing conditions and scald susceptible cultivars. Because of this higher scald risk, DPA is registered in Australia for use on apples at rates up to 3.6 g/L (3620 mg/L), while in the USA it is registered for use on apples at a maximum rate of 2 – 2.2 g/L (2000-2200 mg/L). (Johnson 1997). The paradox is that although Australia has a much higher registered use rate for DPA, our MRL is one half that approved in the USA.
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Figure 3. Apple fruit DPA residue versus dip concentration for three ages of dip: a) new, b) old and c) top-up dips sampled from apple packing sheds in Victoria
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Figure 4. DPA residues in apple fruit from 47 sheds in Australia (n=121, 9 cultivars, 1-2 days after treatment, in 2000).

Figure 5. DPA residues in apple fruit from 40+ sheds in USA (n=87, 5 cultivars, 3-8 days after treatment, in 1984).

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More than three-quarters of the 242 apple fruit and dip samples were made up of the cultivars Granny Smith, Red Delicious, Fuji and Lady Williams (Table 2). Only small numbers of Pink Lady, Sundowner, Jonagold, Braeburn and Golden Delicious were sampled.

Table 2. Summary of the fruit DPA residue test results in 2000

<table>
<thead>
<tr>
<th>Fruit type</th>
<th>Cultivar</th>
<th>Number of samples tested</th>
<th>% greater than 50% MRL but less than MRL</th>
<th>% violation of MRL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apple</td>
<td>Granny Smith</td>
<td>39</td>
<td>56</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>Lady Williams</td>
<td>14</td>
<td>50</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>Red Delicious</td>
<td>31</td>
<td>65</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Fuji</td>
<td>19</td>
<td>32</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Pink Lady</td>
<td>8</td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Sundowner</td>
<td>3</td>
<td>66</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Jonagold</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Braeburn</td>
<td>2</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Golden Delicious</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>other</td>
<td>2</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>All apples</td>
<td>121</td>
<td>54</td>
<td>16</td>
</tr>
</tbody>
</table>

Pear

|          | Packham           | 10                       | 10                                       | 0                  |
|          | Beurre Bosc       | 9                        | 33                                       | 0                  |
|          | All pears         | 19                       | 21                                       | 0                  |

Sixteen percent of apple fruit samples were above the Australian MRL of 5 mg/kg when sampled immediately after DPA treatment (Table 2). A further 54% had residues greater than half but less than the MRL, making a total of nearly 70% with residues greater than half the MRL. Lady Williams was the cultivar with the highest proportion exceeding the MRL (36%), followed by Granny Smith (26%) and Red Delicious (13%).

Individual apple cultivar results

Red Delicious. Dip tank concentrations were in the range of the label directions for this cultivar (2-3.1g active ingredient (a.i.)/L, equivalent to 640-1000ml product per 100L, as the Australian DPA products contain 310g/L diphenylamine), or lower, except for two samples which were higher than the label maximum. Despite this, the MRL violations for this cultivar occurred in fruit treated in lower concentrations of DPA (Figure 6), indicating that excessive dip concentrations were not the issue for Red Delicious. Because this cultivar has an open calyx, it is possible that the high fruit residues were associated with pooling of the drench in the calyx and penetration into the core via the open calycine sinus.
Figure 6. DPA concentration in dip tanks versus the corresponding DPA residue in fruit for 8 cultivars of apple sampled from sheds in 6 states
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Lady Williams. The most significant issue for this cultivar was that dip tank concentrations were usually higher than the label recommendation (Figure 6). Most (12 out of 14) samples were from Victoria where the maximum recommended drench concentration is about 1.50 g a.i./L. Nine of the fourteen samples were treated in drench that was significantly higher than this dip concentration (Figure 6) and all violations occurred when fruit were treated at high dip concentrations.

Fuji. Although all use of DPA on Fuji is off-label, all the samples except one were treated in low (< 2g a.i./L) concentrations and no fruit residue violations occurred. The slope of the fitted line for Fuji and Lady William is steeper than that for GS and RD (Figure 6), indicating that the former cultivars take up DPA more readily.

Granny Smith. Dip tank concentrations were all found to be in the range of the label directions for Granny Smith (2-3.6g active ingredient (a.i.)/L, equivalent to 640-1170ml product per 100L), or lower. Therefore the violations which occurred were not due to higher dip concentrations than recommended for fruit to be stored in normal Controlled Atmosphere storage. The relatively flat slope of the fitted line (Figure 6) indicates that this cultivar, like Red Delicious, does not take up DPA as readily as some other cultivars such as Pink Lady and Fuji.

Pink Lady. As with cultivar Fuji, DPA use is off-label for Pink Lady. Data show that all users applied DPA at very low rates (less than 1 g a.i./L), and no MRL violations were detected. However, the steep slope of the fitted line (Figure 6) indicates that Pink Lady takes up DPA much more readily than any of the other cultivars sampled. Extrapolation of the regression line indicates that MRL violations could occur at dip concentrations as low as 1.5g a.i./L. Although this is based on a relatively small amount of data, it indicates the potential for MRL violations where cultivars differ in their ability to absorb DPA.

The other cultivars were sampled in very low numbers. Rates used were generally low (< 2 g a.i./L) except for two applications at about 3.2g a.i./L to Sundowner, and no MRL violations were found. Insufficient data was collected for Jonagold, Braeburn, Sundowner and Golden Delicious to draw any conclusions.

b). Pear.

Of the 38 pear fruit and dip samples, 20 were the cultivar Packham and 18 were the cultivar Buerre Bosc (Table 2). No pear fruit samples were above the MRL of 7 mg/kg, and only 21% of samples had residues greater than half the MRL. Three out of the four in this category were Buerre Bosc. Figure 7. shows the distribution of DPA residues found in pear fruit during our study in 2000. All samples were well below the Australian MRL of 7 mg/kg. Thirty-three percent of Buerre Bosc fruit had residues greater than half the MRL, while only 10% of Packham fruit had such residues (Figure 8).
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Figure 7. DPA residues in pear fruit from 8 sheds in Australia (n=19, 2 cultivars, 1-2 days after treatment, in 2000).
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Figure 8. Dip tank DPA concentration versus corresponding fruit DPA residue for 2 cultivars of pear sampled from sheds in 2 states
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Trace-backs
Trace-backs of MRL violations and analysis of the data were completed in order to determine possible causes of these violations. Results of the trace-back investigations are summarized in Table 3. These investigations were conclusive for the 5 samples of Lady Williams fruit, which were all treated with (high) off-label rates of DPA. Top-up procedures also appeared to be at fault for 4 of the 5 Lady William samples having over-MRL residues.

Trace-back investigations for all other MRL violations were inconclusive. Other possible factors in the remaining residue violations were: long drench times, pooling of drench liquid in calyxes of fruit, slow drying of fruit after drenching at low temperatures and the presence of wetters in the fungicides which were components of some dips. The last explanation seems unlikely as many other samples were treated in similar mixtures of DPA and fungicides but resulted in fruit residues under the MRL.

The results from the trace-backs highlight the difficulty of investigating possible flaws in a drenching procedure that was carried out several months before the trace-back investigation. It also emphasises the need for improved recording systems and/or more specific QA requirements for vital post-harvest operations such as drenching fruit.
Table 3. Summary of trace-back results for apple samples where MRL violations were detected

<table>
<thead>
<tr>
<th>State</th>
<th>Shed</th>
<th>Cultivar</th>
<th>No. of samples</th>
<th>Trace-back explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Victoria</td>
<td>A</td>
<td>GS</td>
<td>3</td>
<td>? (Possible) long drench time, and inadequate top-up procedure</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>LW</td>
<td>2</td>
<td>Off label (high) DPA rates used and top-up procedure inadequate</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>LW</td>
<td>2</td>
<td>Off label (high) DPA rates used and top-up procedure inadequate</td>
</tr>
<tr>
<td>Tasmania</td>
<td>D</td>
<td>RD</td>
<td>1</td>
<td>? (Possible) pooling of drench in calyx of fruit; slow drying of drench on fruit due to low temperature</td>
</tr>
<tr>
<td>South Australia</td>
<td>E</td>
<td>LW</td>
<td>1</td>
<td>Off label (high) DPA rates</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>GS</td>
<td>1</td>
<td>? (Possible) long drench time</td>
</tr>
<tr>
<td>New South Wales</td>
<td>G</td>
<td>GS</td>
<td>1</td>
<td>?</td>
</tr>
<tr>
<td>Queensland</td>
<td>H</td>
<td>RD</td>
<td>1</td>
<td>? (Possible) long drench time; wetters in fungicides</td>
</tr>
<tr>
<td></td>
<td>I</td>
<td>GS</td>
<td>3</td>
<td>As above</td>
</tr>
<tr>
<td></td>
<td>J</td>
<td>RD</td>
<td>1</td>
<td>As above</td>
</tr>
<tr>
<td></td>
<td>K</td>
<td>RD</td>
<td>1</td>
<td>? (Possible) wetters in fungicides increasing uptake of DPA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GS</td>
<td>1</td>
<td>? (Possible) long drench time; wetters in fungicides</td>
</tr>
<tr>
<td>Total</td>
<td>11</td>
<td>3</td>
<td>19</td>
<td></td>
</tr>
</tbody>
</table>
5. Best practice training manual for use of DPA and post-harvest treatments

The manual was developed from resources including Tugwell and James (1999) "Guidelines for apple and pear post-harvest treatments", the book by Little and Holmes (2000) "Storage Technology for Apples and Pears", the Orchard Pest and Disease Handbook 2000-2002, Victoria – all regions & South Australia, 10th edition, and other sources. Feedback was obtained from the project steering committee, from members of the project team in each state, and from growers from the Australian Apple and Pear Growers national conference at a presentation/workshop at Stanthorpe in August 2001.

The steering committee was made up of officers of the DNRE Victoria, representatives of the two chemical resellers involved with the two products available in Australia and the AAPGA Industry Development Manager. Membership comprised of some or all of the following mix of NRE and industry representatives: W. Washington (project leader), Robert Holmes (team leader post-harvest pathology), Vicki Bates (NRE extension), Val Hilton and, prior to July 2001, Jessica Purbrick (AAPGA Industry Development Managers), Ron Allison (E.E.Muir and Sons), Geoff Derrick (Colin Campbell Chemicals), Ruth McGowan (Chemical Standards Officer), Catherine Hollywell (Director Chemical Standards), Mark Collins (NRE extension), Jim Stranger (Regional Chemical Standards Officer), David Williams (Principal Scientist Perennial Horticulture), Trevor Plowman, (National Residue Survey) and others as required.

Hard copies of the manual were produced for a workshop in November, and a revised edition was produced in December 2001 (Appendix 1). This version is also available on the Internet at the following web site and can be printed directly from this address.

6. National guidelines for the disposal of used post-harvest dip

Introduction

Post-harvest dip and drench materials, containing DPA and the fungicides iprodione, carbendazim and/or imazalil (the fungicides are used to prevent the development of storage rots such as blue mould), are used in large volumes during the harvest season. These dips are subject to contamination by dirt/leaves etc and degradation as bins of fruit are treated. R.Holmes (pers.comm.) estimates that each year throughout Australia approximately 1 million L of dip or drench liquid containing DPA and/or fungicides has to be disposed of after drenching pome fruit. These dips are routinely dumped and replaced by fresh dip in order to maintain the appropriate concentration of active ingredients and to minimise the effect of dirt and build-up of fungal spores which can reduce scald and rot control. National guidelines for the safe disposal of used post-harvest dip are therefore urgently required to deal with the large volumes of dip material which are used each year.

Dip disposal guidelines.

“Apple and Pear Industry guidelines for the disposal of spent post harvest dip” have been drafted and circulated for comment. They are based on an earlier document: Environment Protection Authority (Victoria) Information Bulletin “Interim guidelines for the disposal of waste fungicide produced by apple and pear growers”, Publication 645, April 1999. Our current draft guidelines are specifically for the post-harvest issue of disposal of used DPA and fungicides after application to apples and pears intended for long-term storage. Our guidelines have not been endorsed by the Victorian EPA, Environment Australia or by other state regulatory bodies.

Since we began to develop these guidelines, AVCARE (the National Association for Crop Production and Animal Health) has produced a confidential draft document including “A review of current procedures for disposal of dipping solutions listed in Australia and overseas” and a draft brochure “Disposal of Plant Protection dipping solutions”. The draft AVCARE guidelines, which consider all animal and plant protection products used as dips, have been circulated to all State authorities for comment.

Following the circulation of the AVCARE draft guidelines, the Dips Disposal Contact Group of the Registration Liaison Committee (RLC)/Environment Australia have produced a discussion paper – Draft Guidelines for the disposal of Dipping Solutions. This is an attempt to get national agreement on the dip disposal issue. The Environment Australia draft guidelines are in the process of being circulated nationally for comment and feedback. Until national agreement has been reached re- these AVCARE guidelines then our specific guidelines cannot be distributed.

Report to DNRE Chemical Standards Branch on orchard residues associated with disposal of used post-harvest dip

A short study was completed which examined the chemical residues found in soil resulting from the disposal of spent post-harvest dip in orchards in Victoria. This was done to
Taking control of pome fruit residues

provide some data on the likely soil residues from what are probably the most common practices for disposal of used dip. Support for this work was obtained from the Agriculture and Food Initiative of the DNRE.

Copies of this report have been supplied to the Chemical Standards Branch of the Victorian DNRE, to Environment Australia, to E.E. Muir and Sons Pty Ltd and Colin Campbell Chemicals Pty Ltd.

Publication details of the report are:


An outline of some of the findings are included below:

Results indicate that residues of chemicals in spent post-harvest dip solutions are readily detected from orchards in both southern and northern Victoria after disposal in the orchard. Disposal methods included: 1). discharged onto previously untreated orchard headlands; 2). routinely discharged onto orchard tracks; 3). routinely discharged onto the same area of orchard headland, or 4). routinely discharged into a long open drain.

The first two disposal methods are those currently suggested in the Victorian EPA bulletin “Interim guidelines for the disposal of waste fungicides produced by apple and pear growers”; publication 645, April 1999, for disposing of spent dip. The results of the residue/time study indicate that residues of DPA and the fungicides carbendazim and iprodione do in fact decline significantly even over the cooler autumn-winter period. It is likely that rates of decline would be greater over the hotter months of the year, when UV levels, temperatures and probably biological activity of soils is higher.

Decay of the fungicide carbendazim appears to be slower than that of DPA and iprodione in this study. Carbendazim is reported to be quite stable between pH 5-7, although it is subject to hydrolytic and microbial degradation in soil. By contrast, iprodione is much more rapidly degraded at the same pH range, and is also subject to microbial degradation. DPA is apparently rapidly degraded in active sewage sludge, and is sensitive to photolysis.

Imazalil was not detected in soil or dip samples from any of the orchards, and was not used by any of the sheds in the orchards studied. Despite this, it is used by some packing sheds where resistance of rot pathogens to benzimidazole fungicides (such as carbendazim) is a problem. It is reported to be quite stable in soil, more so than the other compounds in this study (with the exception of calcium).

More detailed studies are needed to determine breakdown over time for several typical locations and disposal systems around Victorian orchard districts. This should provide a good indication of how suitable the various disposal possibilities are.
7. Technology Transfer

Each year of the project an article was produced for Pome Fruit Australia, the national journal of the pome fruit industry in Australia. Other articles were prepared for other industry magazines, newspapers and state Department publications for growers. The best practice manual was prepared and used in several interactive workshops with grower groups, and to increase its availability to the industry it was modified and placed on the Internet in a form which could be readily down-loaded and printed out by interested parties. A poster suitable for use in the packing shed was also produced and supplied to most packing sheds which treat pome fruit with DPA.

8.1 Extension activities:

"Take control of DPA residues" presentation at AAPGA Conference workshop, Rizzato Brothers, Stanthorpe, Queensland, 9th August 2001


"Best practice workshop for postharvest dipping of apples and pears" IHD Knoxfield, run jointly with Colin Campbell Chemicals and DNRE, 21st January 2002,

8.2 Publications:

Workshop manual:


Industry publications:


Taking control of pome fruit residues


Newspaper/newsletter articles:


Poster

“Correct use of DPA” E.E.Muir and Sons

Questionnaire

“Taking control of DPA residues – Questionnaire”, 1 page. Used at Stanthorpe workshop, August 2001

Reports

Milestone reports for the project AP99042 “Taking control of pome fruit residues”

8. Recommendations

Recommendations arising from this project include:

- More workshops and training in best practice for shed operators.
- Increased levels of residue testing to ensure that DPA violations do not occur. This testing will also increase shed operator awareness of the residue issue, as most operators are not aware of the potential problem with high residues.
- More specific Quality Assurance programs to ensure that shed operators use correct rates and procedures during post-harvest treatment of fruit.
- In the short term consideration should be given to adjusting the MRL for DPA in apples to account for the high rates required for scald control on highly susceptible cultivars grown in regions liable to scald.
- More research to find reliable methods for scald control with reduced, or zero, use of DPA.
- Research to develop data for use of DPA on new cultivars should be supported by the chemical suppliers.
- Obtaining national consensus and implementation of draft disposal guidelines.
- Work with DPA manufacturers/suppliers to revise the product labels in line with the findings of this project.
Guidelines for postharvest drenching of apples and pears
Guidelines for postharvest drenching of apples and pears

- Natural Resources and Environment, Victoria
- Australian Apple and Pear Growers Association Inc
- National Residue Survey, Agriculture Fisheries and Forestry Australia
- Horticulture Australia Ltd

December 2001
Guidelines for postharvest drenching of apples and pears

CHECKLIST

Before the drenching season
• Measure the drench reservoir tank or use a water meter to calculate the tank volume.

• Make sure the drench tank is of sufficient size (ideally 1500-2000 L).

• Check that DPA flow rate is sufficient (normally 1000 L per minute per bin).

• Make a chart for quantities of DPA and fungicide required for the different varieties you will treat.

• Prepare a system to measure drench liquid volume for top-ups (e.g., calibr dip-stick).

• Make sure that a competent and trained staff member will always be in charge of the drench preparation and topping up.

• Have enough measuring jugs and a white board available to record quantities added to drench.

• Make sure that there is an automatic cut-off for the drench pump which stops the drench shower when the bin conveyor is full.

• Make sure that there is sufficient draining time (3-4 min) between a chlorine or water pre-wash and the DPA treatment.

Preparing the drench and treating fruit
• Read and follow all information on the product labels.

• Pre-mix DPA by adding a small amount of water to the DPA, then add to tank.

• Add fungicides one at a time.

• If using calcium, dissolve it in water and add it to the drench, last.

• Mix drench thoroughly before treating fruit (run pump and agitator for at least 5 minutes).

• Do not treat fruit for too long (ideally 10-30 seconds).

• If fruit or drench temperatures are colder than 15°C or hotter than 30°C, contact your reseller before drenching.
Taking control of pome fruit residues

- Test drench strength regularly.
- Follow safety precautions as detailed on the DPA product label.

Topping up
- After treating 50 bins test drench strength.
- Measure top-up volumes accurately, do not estimate.
- Make sure that pre-washed fruit do not dilute the drench.
- Keep the system free from leaves and other debris to maintain effectiveness of the drench and to avoid build up of fungal spores.
- Do not top-up more than three times.

Be aware of factors which can cause excessive DPA residues

Fungicides
- What rot control strategy will you use? Consider the risk potential of each variety, use of hygiene practices and fungicides (if any).
- Each product will have specific use information. Read the entire label.

Calcium
- Do you need calcium in the drench? Liquid and granular forms of calcium available which may improve the quality of apples after storage.

Disposal
- Have you an appropriate disposal method for spent drench solution? Consult local authorities such as EPA, water authorities, Agriculture Department and resellers.

Possible alternatives to DPA
- Have you considered alternatives to DPA for scald control? eg. only long term store varieties which have a low risk of developing scald; ultra-low oxygen storage; use vegetable oils as anti-scald treatments; forecast risk of fruit.

DPA labels
- Have you read and do you understand the current DPA product label?
Guidelines for postharvest drenching of apples and pears

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Appendix – DPA product labels (not included in PDF file)
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December 2001

This manual is part of the project AP99042 "Taking control of pome fruit residues" funded by the Australian Apple and Pear Growers Association, the National Residue Survey of Agriculture, Fisheries and Forestry, Australia (AFFA), Horticulture Australia Limited, and the Department of Natural Resources and Environment, Victoria.

Disclaimer
The advice provided in this manual is intended as a source of information only. The State of Victoria and its officers do not guarantee that the manual is without flaw of any kind or is wholly appropriate for your purposes and therefore disclaims all liability for any error, loss or other consequence which may arise from you relying on any information in this manual.
Taking control of pome fruit residues

1. Introduction

Superficial scald is a cold storage disorder affecting many apple and pear varieties. It is a browning of the skin, caused when the skin cells die. It may appear during storage, but more usually following storage, because its development is accelerated at warmer temperatures. It is affected by fruit variety, harvest maturity, weather conditions and fertilizer use.

Fruit varieties vary in their susceptibility to scald. Table 1 lists the susceptibility of common apple and pear varieties.

Table 1. Fruit susceptibility to superficial scald

<table>
<thead>
<tr>
<th>Fruit type</th>
<th>Highly susceptible</th>
<th>Moderately susceptible</th>
<th>Slightly susceptible</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apple</td>
<td>Granny Smith, Lady Williams, Red Delicious</td>
<td>Sundowner, Jonathan, Firmgold, Fuji</td>
<td>Golden Delicious, Gala, Pink Lady</td>
</tr>
<tr>
<td>Pear</td>
<td>Packham's Triumph</td>
<td>Josephine, Buerre Bosc, Winter Nelis</td>
<td></td>
</tr>
</tbody>
</table>

Susceptibility to scald increases in growing conditions that are hot, dry and sunny. Fruit are most susceptible before they reach the maturity for commercial harvest and susceptibility declines over the normal harvest period. However, riper fruit with lower susceptibility to scald may be unsuitable for long term storage. Fruit are more susceptible when grown under a high nitrogen regime and less susceptible when grown under a high calcium regime.

Scald can be effectively controlled by treating fruit with the antioxidant Diphenylamine (DPA). DPA is currently the most effective treatment and it is available in two products, Campbell DPA 310 Scald Inhibitor™ and Chemley No Scald DPA™. DPA is most effective when applied within a few days after harvest and is most commonly applied by dipping or drenching fruit in bins. The level of DPA needed to control scald depends on the fruit maturity, storage time and the susceptibility of the variety.

The incidence of bitter pit, fruit softening, scald and rot in stored fruit can be reduced by a number of field and postharvest practices, including raising fruit calcium levels with postharvest drenches of calcium.

Storage rots are also affected by the amount of inoculum (the number of fungal spores), the fruit susceptibility as influenced by nutrition and maturity, the storage conditions, cultivar characteristics, fruit skin damage and the effectiveness of any post-harvest fungicide treatments.

This manual covers key aspects of postharvest drenching of apple and pear fruit.

Note: Always refer to the current product label attached to the product before use.
2. **Before the drenching season**

2.1 **How to measure the drench reservoir tank and calculate its volume**

Knowing the tank volume is critical for the application of correct strength DPA. The volume of rectangular sided tanks can be easily calculated from the tank dimensions (see below). Tanks with irregular dimensions can be measured using a water flow meter. Be sure to include any large pipes etc., which are filled with drench solution, in the calculation. The volume of pipework can be calculated from the internal diameter (i.d.) and the length which contains liquid. Pipe volume (litres) = 0.314 x internal radius$^2$ (cm) x length (m).

![Diagram of a rectangular tank showing dimensions: Length, Width, Height, and Fill line.]

Volume = length (L) x width (W) x height (H)

Tank capacity = Volume (m$^3$) x 1000 litres

Example: Drench tank has the dimensions

Length 2.0 m, Width 1.0 m, Height 1.5 m

Volume = L x W x H

= 2 x 1 x 1.5 m$^3$

= 3 m$^3$

Tank Capacity (litres) = Volume (m$^3$) x 1000

= 3 x 1000

= 3000 litres

2.2 **Ensure drench tank is sufficient size**

The usual tank volume is 1500 to 2000 L. Dilution of DPA associated with fruit throughput is faster when the tank size is small. When the reservoir is large, the amount of times the total volume of the drench is pumped through is less. This lowers the risk of the DPA emulsion breaking down due to the mechanical agitation of pumping. If the tank is small, the lost volume of drench needs to be replaced more frequently to avoid air being sucked into the pump.
2.3 Ensure DPA flow rate is sufficient (normally 1000L/min per bin)

A pumping rate of 1000 litres/minute is required to adequately cover all fruit in a bin in 30 seconds. In a double tiered drench system the pumping rate should be doubled to 2000 L/minute, and in a triple tiered system the rate should be 3000 L/minute. Tank size needs to increase with increased pumping rate. Drenches (in a recycling drench system) should be able to be pumped for up to 200 minutes without causing any significant drop in DPA strength.

2.4 Make a chart for quantities of DPA, fungicide and calcium required to drench the different varieties you will treat.

This should indicate the amounts required for preparing a new drench and also for topping-up the drench after various volumes have been lost.

To prevent high residue levels of DPA in fruit receiving post-harvest treatments, the DPA concentration of drenches should be varied according to the susceptibility of the variety being treated. Also note that rates of DPA can be reduced if fruit are to be stored under ultra-low oxygen Controlled Atmosphere (C.A.) - see product label.

It is critical that top-up volumes are measured and not assumed.

### Determining DPA Requirements

To calculate the quantity of DPA concentrate required to make up drenches of various tank sizes, the following formula can be used.

\[
\text{Litres of DPA Concentrate} = \frac{\text{Drench strength (ml/100Litres)}}{1000} \times \frac{\text{Tank capacity (litres)}}{100}
\]

Example: The tank capacity is 1350 litres, required drench concentration for Granny Smith grown in the Goulburn Valley and stored in conventional C.A. is 1170 ml/100 Litre (from product label).

Required quantity of DPA in litres is: \((1170/1000) \times (1350/100) = 15.8 \text{ Litres}\)
**EXAMPLE ONLY:**

Table 1. Chart for preparing and topping up DPA and other drench components, for three varieties of apples grown in Queensland, NSW, Victoria only (*note that higher rates may be required for fruit grown in the Goulburn Valley, Victoria-see product label*). Fruit to be stored in air or C.A. at 3% oxygen only.

<table>
<thead>
<tr>
<th>Water volume (litres)</th>
<th>Granny Smith</th>
<th>Lady William</th>
<th>Red Delicious</th>
<th>Calcium chloride (kg)</th>
<th>Rovral Aquaflo (litres)</th>
<th>Bavistin FL (litres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>12.80</td>
<td>6.80</td>
<td>12.80</td>
<td>40</td>
<td>2.0</td>
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<td>1700</td>
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<td>34</td>
<td>1.7</td>
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<td>1600</td>
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<tr>
<td>1500</td>
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<td>1400</td>
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<td>1300</td>
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<td>26</td>
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<td>0.65</td>
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<td>1200</td>
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<td>7.68</td>
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<td>1.2</td>
<td>0.60</td>
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<td>5.76</td>
<td>18</td>
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<td>800</td>
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<td>2.72</td>
<td>5.12</td>
<td>16</td>
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<td>0.40</td>
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<td>2.38</td>
<td>4.48</td>
<td>14</td>
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<td>0.35</td>
</tr>
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<td>12</td>
<td>0.6</td>
<td>0.30</td>
</tr>
<tr>
<td>500</td>
<td>3.20</td>
<td>1.70</td>
<td>3.20</td>
<td>10</td>
<td>0.5</td>
<td>0.25</td>
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<td>1.28</td>
<td>0.68</td>
<td>1.28</td>
<td>4</td>
<td>0.2</td>
<td>0.10</td>
</tr>
<tr>
<td>100</td>
<td>0.64</td>
<td>0.34</td>
<td>0.64</td>
<td>2</td>
<td>0.1</td>
<td>0.05</td>
</tr>
</tbody>
</table>
Taking control of pome fruit residues

2.5 Prepare a system to measure drench volume for top-ups (eg. calibrated stick)

To make sure that drenches are topped up accurately a calibrated measuring stick (or calibrations on the tank) should be made. The person responsible for operating the drench must be aware of the markings on the stick and their relationship to the volume left in the drench. This ensures that correct concentrations of DPA and other chemicals are maintained when topping up. A flow meter on the filling hose would be an equally effective way to determine the top-up volume.

2.6 Ensure that a competent staff member will always be in charge of the drench preparation and topping up

Mixing and topping up drench liquid is a critical operation and there is little margin for error. Staff in charge of these operations must be capable of consistent accuracy and should be adequately trained in measurement of volumes and calculation of quantities.

2.7 Ensure sufficient measuring jugs and a white board or similar are available

The harvest season is a hectic time and it is helpful to have aids to keep tally of bin throughput, number of top-ups and chemical quantities added. It is recommended that there are sufficient measuring jugs available to measure out all the DPA concentrate required at one time (eg three 3 litre jugs could be used to measure out 8 litres of DPA at one time). A whiteboard or similar should be available so that quantities are checked off as they are added. This procedure should avoid the uncertainty that could occur if the operator is called away during the preparation or topping up of a drench tank.

2.8 Ensure that there is an automatic cut-off for the drench when the bin conveyor is full

If the drench continues to operate after the bin line is full there is an increased risk of over exposure of the fruit to the DPA mix. This can result in fruit burn and DPA residue problems.

2.9 Ensure draining time between pre treatment chlorine or water wash and the DPA treatment is sufficient (3-4 min)

It is important that fruit is allowed sufficient drainage time (3-4 minutes) before drenching to prevent dilution of the DPA drench solution. If chlorine compounds are carried through to the DPA drench they will break down the DPA and scald will not be controlled. To minimise the chances of this happening-

- Ensure fruit is well drained before drenching
- Only use registered chlorine and chloro-bromo compounds at the label rates
- Use a chlorine monitoring and metering device to ensure the correct chlorine concentration in the water
- Use chlorine test strips to ensure there is no chlorine remaining on the fruit surface before DPA treatment.

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3. Preparing a new drench and fruit treatment

3.1 Premix DPA in a small amount of water and add to tank
To ensure that DPA is mixed throughout the tank it should be pre-mixed in a bucket with water and then added to the tank. It is important to add water to the DPA, and not DPA to water, when pre-mixing. If DPA is added straight to the tank it can sink to the bottom and not mix properly causing uneven concentration of DPA in the drench.

3.2 Add fungicides one at a time if required
Reactions between fungicides can occur if they are mixed together as concentrates. Therefore, it is important that fungicides are added to the drench separately. This will make sure that they are most effective in controlling storage rots. Rovral and similar products may lose their effectiveness if the drench pH is above 7. As a result a pH buffering agent may be required. Some fungicides have a resistance warning and a resistance strategy should be followed to maximise rot control.

3.3 If using calcium, dissolve it in water and add it to the drench, last

3.4 Mix drench thoroughly before treating fruit (run pump and agitator for at least 5 min)
All drenches should be agitated prior to use or whenever a delay occurs between drenching bins. This ensures that concentrations of DPA and fungicides are evenly distributed throughout the tank.

3.5 Avoid treating fruit for too long (ideally 10-30 seconds)
Fruit should be treated for at least 10 seconds to ensure uptake of DPA, but beware that longer treatment times can lead to excess DPA residues in fruit. Slow drying of fruit will also increase DPA uptake - ensure bins are adequately drained before stacking on other bins. This will help prevent undesirable residues from occurring.

3.6 Fruit or drench temperatures
For optimal treatment with DPA, fruit should be at a temperature between 15-30°C before drenching. DPA uptake, and resulting residues, may be too high when fruit and drench temperatures are high. This may also increase the incidence of skin injury, characterised by a dull muddy brownness, which affects most of the surface area of non-coloured varieties. In red varieties the red colour loses clarity and becomes "inky".

Fruit temperature can also lead to increased residues, therefore, locate drench tanks where they will be shaded and remain fairly cool. Contact your reseller if the drench temperature exceeds 30°C.

3.7 Test drench strength regularly
It is important that the strength of the drench is monitored and maintained at the label rates. If the strength is too high then residue problems will arise. Testing of drench tank strength can be done using test kits or by the titration method as a service from chemical resellers. Contact your DPA supplier for details before the season begins.

3.8 Observe safety precautions as detailed on the DPA product label
Copies of the DPA product labels are located in the appendix.
4. Topping-up drenches

4.1 After treating 50 bins test drench strength
DPA emulsions can lose their effectiveness with throughput of fruit. This may become significant in a system with a 1000 L tank after about 50 bulk bins have been drenched, although with current DPA formulations this is not usually the case. One potential problem can occur with the "breaking" of the emulsion with the DPA separating out as very fine crystals. The effective end of the emulsion is seen in a drench system when the drench loses its milky appearance and tiny DPA crystals can be seen. Another problem can occur with dilution from drenching of wet fruit from pre-washing. Pre-washing with chlorinated water can also reduce the effectiveness of DPA as the chlorine can breakdown the DPA.

The age of a drench or dip is not critical - what is most important is the amount of agitation or time a drench is pumped. Current DPA labels indicate that the product is stable for 200 minutes pumping. Leaving a drench/dip to stand will not have any marked effect on the emulsion, however, if it is to be left for more than a day it should be covered to prevent dust entering and reduce evaporation.

4.2 Measure top-up volumes accurately, do not estimate
Topping up of drench tanks is usually required after 50 bins of fruit have been drenched per 1000 Litres. Record volume lost and top-up accordingly. Refer to top-up chart prepared pre-season.
Do not top-up more than 2-3 times, replace the drench if more top-ups are required. Very dusty fruit should be hosed down before drenching.
Replace drench solutions that are older than 2 weeks irrespective of the number of bins treated.
Keep drench tanks covered and out of sunlight when not in use. Avoid bare iron surfaces - hot galvanise or use an epoxy resin on the interior surfaces of drench tanks.
Tanks should have some form of agitation to avoid excessive settling

4.3 For pre-washed fruit ensure that drench does not become diluted.
Sufficient draining time is required before drenching fruit that has been pre-washed. This will make sure that DPA concentrations don’t become too low for adequate scald control. At least 3 minutes time between pre-washing and drenching is usually adequate

4.4 Keep the system free from leaves and other debris to avoid build up of fungal spores
The number of fungal spores that are found in the drench will increase if plant material and other debris are allowed to build up. This will make storage rot control more difficult, even with the use of fungicides. It also may reduce the effectiveness of anti-scald treatments.

4.5 Do not top-up more than three times
It is important that the entire drench solution is replaced after topping up has taken place on three occasions. The drench can start to break down at this point and its effectiveness in controlling scald is greatly reduced. Leaves, debris and dust also build up and can reduce the effectiveness of anti-scald treatments and can by contaminating fruit with fungal spores, increase rot development.
Taking control of pome fruit residues

5. Factors which can lead to excessive DPA residues or damage to fruit

Table 2. Factors which can lead to excessive DPA residues, their cause and possible solution

<table>
<thead>
<tr>
<th>factor</th>
<th>background</th>
<th>solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>inappropriate rates</td>
<td>using off-label rates</td>
<td>check and use label rates</td>
</tr>
<tr>
<td></td>
<td>this can also occur when 2 or more varieties are being harvested and drenched at the same time, and all are</td>
<td>use smaller drench tank volumes to allow for more changes in drench tank; operate 2 drench</td>
</tr>
<tr>
<td></td>
<td>treated with the same drench</td>
<td>tanks to allow simultaneous treatment of 2 cvs which have different DPA requirements; arrange</td>
</tr>
<tr>
<td></td>
<td>new cultivars not on label</td>
<td>for drenching at another shed which has appropriate equipment</td>
</tr>
<tr>
<td>incorrect top-up</td>
<td>drench volume is lost after treating fruit</td>
<td>more research needed</td>
</tr>
<tr>
<td>long drench time</td>
<td>bins moving too slowly through drench</td>
<td>accurately measure volume lost and top-up with label rate for that volume</td>
</tr>
<tr>
<td></td>
<td>bins banking up under drench</td>
<td>adjust bin speed</td>
</tr>
<tr>
<td>russetted, sunburnt or bruised</td>
<td>DPA moves into damaged skin at a faster rate</td>
<td>check that automatic cut-off of drench is working</td>
</tr>
<tr>
<td>fruit</td>
<td></td>
<td>do not treat</td>
</tr>
<tr>
<td>high temperature fruit and/or</td>
<td>DPA is absorbed more rapidly at high temperatures</td>
<td>check with distributor if fruit or drench temperatures are &gt;30°C</td>
</tr>
<tr>
<td>drench</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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### Table 2 (Continued)

<table>
<thead>
<tr>
<th>factor</th>
<th>background</th>
<th>solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>breaking of the DPA emulsion</td>
<td>DPA emulsion can break with prolonged pumping. This can lead to uneven residues on fruit and inconsistent scald control</td>
<td>check drench condition regularly, especially after 200 minutes (total) pumping</td>
</tr>
<tr>
<td>slow drying of fruit after drenching</td>
<td>continued DPA absorption occurs while fruit remains wet</td>
<td>ensure fruit dries as soon as possible before storing</td>
</tr>
<tr>
<td>fungicide or calcium in the drench</td>
<td>fungicide and calcium formulations may contain additional wetting agents which enhance uptake</td>
<td>only use products which are known to be compatible with DPA</td>
</tr>
<tr>
<td>entry of drench into core via open calyx</td>
<td>cultivars such as Red Delicious and others with an open calyx channel can have this problem</td>
<td>use DPA on-line or other scald control measures</td>
</tr>
<tr>
<td>pooling of drench in calyx or stem depression</td>
<td>excess DPA can be absorbed where this occurs</td>
<td>gently tilt or agitate the bin to displace excess drench</td>
</tr>
<tr>
<td>type of storage (ultra-low O2 or conventional CA)</td>
<td>fruit to be stored in ultra-low oxygen storage must not be treated with rates for conventional CA</td>
<td>follow product label</td>
</tr>
<tr>
<td>contamination of untreated fruit with DPA</td>
<td>fruit not intended to be treated in DPA can pick up detectable residues of DPA from contact with the packing line, with wooden bins or from vapour movement of DPA from nearby treated fruit if such fruit is held in the same cold room</td>
<td>thoroughly clean the packing line and fruit bins before packing untreated fruit; replace brushes or any parts which cannot be adequately cleaned; do not store untreated fruit in the same cool room as treated fruit</td>
</tr>
</tbody>
</table>
There are a number of fungi that cause postharvest rot in pome fruit. Important rots are Blue mould caused by species of *Penicillium*, Mucor rot caused by *Mucor piriformis*, Anthracnose rots (including Bitter rot, Target rot and Ripe spot) caused by several fungi including *Gloeosporium* species and Grey mould rot caused by *Botrytis cinerea*. These rots can infect through wounds, via lenticels or directly through the fruit skin. Apple cultivars with an open sinus between the calyx and the core (e.g. Red Delicious) are prone to Mouldy core. This can develop from infections by various fungi initiated at any stage of fruit development or postharvest.

Many conditions in the orchard and postharvest environments have an influence on the incidence of rots. These include:

- The number of spores in the drench liquid (can be reduced by minimising leaf litter and other debris and by using clean bins)
- The susceptibility of the fruit tissue to fungal attack which is in turn greatly influenced by fruit maturity, nutritional status and rough handling
- The storage duration, temperature and atmosphere
- Varietal characteristics of the apples or pears
- Fruit shape and drenching practices
- The effectiveness of fungicidal treatments, both pre- and post-harvest
- wet weather before harvest and harvesting fruit when wet
- contamination of fruit bins with orchard soil

Rot control can be influenced by attention to the above practices. In particular it is important to follow good hygiene to remove sources of infection from the storage shed. Use of fungicides should only be a part of an overall plan to minimise rots in stored fruit. Table 3 lists currently registered fungicides available for post-harvest use to help reduce problems of fruit rotting in storage.
Taking control of pome fruit residues

Table 3. Fungicides approved for postharvest use on apples and pears

<table>
<thead>
<tr>
<th>Group</th>
<th>Activity group</th>
<th>Trade name</th>
<th>Active ingredient</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Benzimidazole</td>
<td>4 Farmers carbendazim 500 fungicide WP</td>
<td>carbendazim 500 g/kg</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BASF Bavistin FL Systemic Fungicide</td>
<td>carbendazim 500 g/L</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Boomer 500 WP fungicide</td>
<td>carbendazim 500 g/kg</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Campbell Goldazim 500SC systemic fungicide</td>
<td>carbendazim 500 g/L</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Chemag carbendazim 500 SC fungicide</td>
<td>carbendazim 500 g/L</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Farmoz Howzat SC systemic fungicide</td>
<td>carbendazim 500 g/L</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Spin Flo systemic fungicide</td>
<td>carbendazim 500 g/L</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tecto 90 fungicide</td>
<td>thiabendazole 900g/kg</td>
</tr>
<tr>
<td>B</td>
<td>Dicarboximide</td>
<td>Farmoz Civet Aquaflo fungicide</td>
<td>iprodione</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rovral Aquaflo fungicide</td>
<td>iprodione</td>
</tr>
<tr>
<td>C</td>
<td>Demethylation inhibitor (DMI)</td>
<td>Campbell Magnate 750 WG fungicide</td>
<td>imazalil sulphate 750 g/kg</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dow Agrosciences imazalil 750 SP fungicide</td>
<td>imazalil sulphate 750 g/kg</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Farmoz Imazagard 750 WSP fungicide</td>
<td>imazalil sulphate 750 g/kg</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fungaflo 500 EC Janssen fungicide EC</td>
<td>imazalil 500 g/L</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fungaflo 750 WSP Janssen fungicide</td>
<td>imazalil sulphate 750 g/kg</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fungazil 500 EC fungicide</td>
<td>imazalil 500 g/L</td>
</tr>
</tbody>
</table>

Notes:
*Always refer to the product label before use.*

If export is intended check chemical registration/use requirements of importing countries.

To achieve the required control spectrum, especially where fungicide resistance occurs, products of more than one group may need to be used together. Products with a resistance warning should have a resistance management strategy on the label. Tank mix chemicals only where compatibility has been established (check labels). Rovral and similar products may lose their effectiveness if the drench pH is above 7. As a result a pH buffering agent may be required. Suppliers can provide further information.
7. Calcium

The calcium content of fruit has a large effect on its quality, particularly on the quality after cold storage. Low calcium levels in apples are associated with bitter pit, both on the tree and during storage, and with breakdown and softening during storage. Raising the calcium levels in apples and pears, by tree sprays and/or postharvest drenches, decreases bitter pit, softening and the storage disorders breakdown, superficial scald and rot.

Rates of calcium:
Fruit from healthy or young trees - commercial grade calcium chloride can be used at up to 3 kg/100 litres of drench
Fruit from older or less vigorous trees - more sensitive to lenticel spotting, commercial grade calcium chloride can be used at up to 2.5 kg/100 litres of drench
STOPIT - liquid calcium chloride is as effective as the commercial grade or flaked calcium chloride when used at a rate of up to 1.3 L / 100 L of drench.
Check compatibilities with other drench chemicals before use.
Never add concentrates to concentrates - dilute all chemicals in water before adding to "multimix" drenches
Remember calcium can cause injury to susceptible varieties ie lenticel spotting on Jonathans

8. Disposal of used drench

Consult local authorities such as EPA, water authorities, Agriculture Department and resellers.

National guidelines for the disposal of waste post-harvest drenches are in the process of being developed and approved by all states.

The Victorian Environment Protection Agency (EPA) has an information bulletin "Interim guidelines for the disposal of waste fungicides produced by apple and pear growers" publication 645, April 1999 which outlines procedures for the disposal of waste post-harvest drench.

9. Possible alternatives to DPA

Work is underway at IHD, Knoxfield and interstate to investigate the effectiveness and suitability of alternative scald controls. Possible ways to reduce or avoid the use of DPA include the following:
• Avoid storing fruit long-term to avoid the risk of scald
• Only long-term store cultivars of fruit which are not susceptible to developing scald
• Use forecasting systems to predict which fruit are at risk of developing scald
• Use ultra-low oxygen storage to minimise the risk of scald and allow reduced DPA rates
• Use vegetable oils as anti-scald treatments
10. Safety
For safe handling of DPA refer to the product label.

11. Further reading


Appendix- DPA product labels (not included in PDF file)

Note that these are copies of the current registered labels as of December 2001, however as labels are always subject to revision, always read and carefully follow the label directions on the product container.