Spraying apples:

Sprayers and sprayer performance

Optimisation, coverage, volumes, chemical rates

David Manktelow
freshLearn Ltd
Spraying is simple but achieving effective pest and disease control requires a series of correct decisions

- Right time
- Right chemical
- Right rate
- Hit the target
- Cover the target
The #1 Spraying Problem? Is a failure to accurately **direct** spray to the target canopy

1800 l/ha for big trees used on small trees on mounds
20% sprayed under, 40% sprayed over
Output distributions for different canopies?

**Multi-leaders**
- 2/3 of the output
- From the top 1/3 of the nozzles
- To the top 1/3 of the trees

**Single leaders**
- 2/3 of the output
- From the top 1/2 of the nozzles
- To the top 1/2 of the trees
Different nozzlings suit different canopies

2/3 of spray from top 1/3 of nozzles to top 1/3 of tree as appropriate for the multileader shown on the LHS

2/3 of spray from top 1/2 of nozzles to top 1/2 of tree as appropriate for the single leader tree shown on RHS
Deposit placement through centre leader apple trees for different nozzle positions on an air blast sprayer

Yellow Albuz

Wide angle
Small droplets

D5-56
Narrow angle
Large droplets

NOZZLES
1 + 2

Cropliner
920 no SV
45,000 m3/hr
3.8 km/hr
Royal Gala
Leaf deposits
Full canopy

Data average of LHS+RHS

Source = Manktelow 04/1996
Deposit placement through centre leader apple trees for different nozzle positions on an air blast sprayer

Yellow Albuza
Wide angle
Small droplets

D5-56
Narrow angle
Large droplets

NOZZLES
3 + 4

Cropliner
920 no SV
45,000 m3/hr
3.8 km/hr
Royal Gala
Leaf deposits
Full canopy
Data average of LHS+RHS
Source = Manktelow
24/9/1996
Deposit placement through centre leader apple trees for different nozzle positions on an air blast sprayer

Yellow Albuz
Wide angle
Small droplets

D5-56
Narrow angle
Large droplets

NOZZLES
5 + 6

Cropliner
920 no SV
45,000 m3/hr
3.8 km/hr
Royal Gala
Leaf deposits
Full canopy
Data average of LHS+RHS
Source = Manktelow
01/1996
Deposit placement through centre leader apple trees for different nozzle positions on an air blast sprayer.

**Yellow Albuze**
- Wide angle
- Small droplets

**D5-56**
- Narrow angle
- Large droplets

NOZZLES 7 + 8

Cropliner
920 no SV

45,000 m³/hr

3.8 km/hr

Royal Gala
Leaf deposits
Full canopy

Data average of LHS+RHS

Source = Manktelow 06/1996
Deposit placement through centre leader apple trees for different nozzle positions on an air blast sprayer

Yellow Albuz
Wide angle
Small droplets

D5-56
Narrow angle
Large droplets

NOZZLES
9 + 10

Cropliner
920 no SV
45,000 m³/hr
3.8 km/hr
Royal Gala
Leaf deposits
Full canopy
Data average of LHS+RHS
Source = Manktelow 04/1996
The #2 Spraying Problem?
Is a failure to evenly deposit spray on the target

Air
Droplet sizes
Adjuvants
Volumes

You are spraying the row you are in
Too much air can reduce deposits, too little air reduces penetration
Spray droplets and nozzles:
Droplet size is an important factor in maximising deposition and coverage OR minimising drift

Smaller droplets improve
• Coverage
• Adhesion
• Spray use efficiency

But larger offer......
• Mass and momentum
• Longer evaporative life
• Lower risk of drift
Droplet Size

- ‘Size’ = diameter
- Measured in microns (μm)
- 1 mm = 1000 microns
- All sprayers produce a range of droplet sizes
- Typically most volume will be in 50 to 500 μm droplets
- best coverage and adhesion is seen with smaller droplet 70-150 μm
Comparison of Droplet Sizes

- 0.1-1.0 μm  smoke/fog
- 1-10 μm  aerosol
- 10-450 μm  orchard sprayers
- 450 μm  mist/drizzle
- 850 μm  lawn sprinkler

Fine (100-175 μm)
Medium (175-250 μm)
Coarse (250-375 μm)
Very coarse (375-450 μm)
Each halving of droplet diameter increases droplet numbers eight-fold!
Spread from one droplet of say 500 micron diameter
Spread from 8 droplets of 250 micron diameter
Spread from 64 droplets of 125 micron diameter
512 droplets of 62 micron diameter
The #3 Spraying Problem?
Balancing work rates against effectiveness

High spray volumes cover a multitude of sins
But do not guarantee coverage
And compromise work rates and droplet size

High speeds improve workrates
But can kill penetration and even coverage
Spraying work rates
How important are they to you?

• Rows per pass
• Travel speed
• Spray volume
• Tank size
• Mix and fill time
• Travel and turning times
• What else?
Spraying work rates calculator
Spreadsheet calculator on Future Orchards website

### Spraying time only (disregarding mixing time, turning times & edge row factors)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel speed</td>
<td>5 km/hr</td>
</tr>
<tr>
<td>Row spacing</td>
<td>4.5 m</td>
</tr>
<tr>
<td>Spray volume</td>
<td>1500 l/ha</td>
</tr>
<tr>
<td>Tank size</td>
<td>2000 l</td>
</tr>
<tr>
<td>Rows sprayed/pass</td>
<td>1</td>
</tr>
<tr>
<td>Labour cost</td>
<td>$25 $/hr</td>
</tr>
<tr>
<td>Tractor cost</td>
<td>$50 $/hr</td>
</tr>
<tr>
<td>Sprayer cost</td>
<td>$10 $/hr</td>
</tr>
</tbody>
</table>

**Distance travelled per ha** = 2.2 km

**Time to spray one hectare** = 27 minutes

**Time to spray one tank** = 36 minutes

**Area sprayed per tank** = 1.3 hectares

**Work rate** = 2.3 ha/hr

**Cost** = $38 per ha

### With mix and fill time included (disregarding turning times & edge row factors)

**Mix and fill time** = 20 minutes

**Work rate** = 1.4 ha/hr

**Cost** = $59 per ha

### With turning times factored in (disregarding edge row effects)

**Turning time per turn** = 10 seconds

**Average row length** = 150 metres

**Time spraying/ha** = 60%

**Time turning/ha** = 6%

**Time mixing/ha** = 34%

**Work rate** = 1.4 ha/hr

**Cost** = $63 per ha

### On a whole property basis

**Property area** = 25 ha

**Spray rounds per year** = 16

**Time to spray property** = 18.4 hours

**Cost to spray property** = $1,563 per round

**Total application cost** = $25,010 for season
Spraying work rates calculator
Spreadsheet calculator on Future Orchards website

Spraying work rates and application costs calculator

<table>
<thead>
<tr>
<th>Spraying time only (disregarding mixing time, turning times &amp; edge row factors)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel speed</td>
<td>5 km/hr</td>
</tr>
<tr>
<td>Row spacing</td>
<td>4.5 m</td>
</tr>
<tr>
<td>Spray volume</td>
<td>500 l/ha</td>
</tr>
<tr>
<td>Tank size</td>
<td>2000 l</td>
</tr>
<tr>
<td>Rows sprayed/pass</td>
<td>1</td>
</tr>
<tr>
<td>Labour cost</td>
<td>$25 $/hr</td>
</tr>
<tr>
<td>Tractor cost</td>
<td>$50 $/hr</td>
</tr>
<tr>
<td>Sprayer cost</td>
<td>$10 $/hr</td>
</tr>
<tr>
<td>Distance travelled per ha</td>
<td>2.2 km</td>
</tr>
<tr>
<td>Time to spray one hectare</td>
<td>27 minutes</td>
</tr>
<tr>
<td>Time to spray one tank</td>
<td>107 minutes</td>
</tr>
<tr>
<td>Area sprayed per tank</td>
<td>4.0 hectares</td>
</tr>
<tr>
<td>Work rate</td>
<td>2.3 ha/hr</td>
</tr>
<tr>
<td>Cost</td>
<td>$38 per ha</td>
</tr>
</tbody>
</table>

With mix and fill time included (disregarding turning times & edge row factors)

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mix and fill time</td>
<td>20 minutes</td>
</tr>
<tr>
<td>INClude travel time!</td>
<td></td>
</tr>
<tr>
<td>Work rate</td>
<td>1.9 ha/hr</td>
</tr>
<tr>
<td>Cost</td>
<td>$45 per ha</td>
</tr>
</tbody>
</table>

With turning times factored in (disregarding edge row effects)

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Turning time per turn</td>
<td>10 seconds</td>
</tr>
<tr>
<td>Average row length</td>
<td>150 metres</td>
</tr>
<tr>
<td>Time spraying/ha</td>
<td>78%</td>
</tr>
<tr>
<td>Time turning/ha</td>
<td>7%</td>
</tr>
<tr>
<td>Time mixing/ha</td>
<td>15%</td>
</tr>
<tr>
<td>Turns per hectare</td>
<td>15</td>
</tr>
<tr>
<td>Time spent turning per ha</td>
<td>2 minutes</td>
</tr>
<tr>
<td>Time to spray one hectare</td>
<td>29 minutes</td>
</tr>
<tr>
<td>Time to spray one tank</td>
<td>117 minutes</td>
</tr>
<tr>
<td>Work rate</td>
<td>1.8 ha/hr</td>
</tr>
<tr>
<td>Cost</td>
<td>$48 per ha</td>
</tr>
</tbody>
</table>

On a whole property basis

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Property area</td>
<td>25 ha</td>
</tr>
<tr>
<td>Spray rounds per year</td>
<td>16</td>
</tr>
<tr>
<td>Time to spray property</td>
<td>14.2 hours</td>
</tr>
<tr>
<td>Cost to spray property</td>
<td>$1,209 per round</td>
</tr>
<tr>
<td>Total application cost</td>
<td>$19,344 for season</td>
</tr>
</tbody>
</table>
## Spraying work rates calculator

### Viewing different scenarios

<table>
<thead>
<tr>
<th>Comparison</th>
<th>#1</th>
<th>#2</th>
<th>#3</th>
<th>#4</th>
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</thead>
<tbody>
<tr>
<td><strong>ASSUMPTIONS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Travel speed</td>
<td>5</td>
<td>5</td>
<td>7</td>
<td>km/hr</td>
</tr>
<tr>
<td>Spray volume</td>
<td>1500</td>
<td>500</td>
<td>500</td>
<td>l/ha</td>
</tr>
<tr>
<td>Tank size</td>
<td>2000</td>
<td>2000</td>
<td>2000</td>
<td>l</td>
</tr>
<tr>
<td>Mix and fill time</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>minutes</td>
</tr>
<tr>
<td>Turning time per turn</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>seconds</td>
</tr>
</tbody>
</table>

### WORK RATE

<table>
<thead>
<tr>
<th>WORK RATE</th>
<th>1.4</th>
<th>1.8</th>
<th>2.3</th>
<th>ha/hr</th>
</tr>
</thead>
</table>

*Includes fill, travel and turning times*

<table>
<thead>
<tr>
<th>Cost per ha</th>
<th>$63</th>
<th>$48</th>
<th>$38</th>
<th>per ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time to spray block</td>
<td>18</td>
<td>14</td>
<td>11</td>
<td>hours</td>
</tr>
<tr>
<td>Cost to spray block</td>
<td>$1,563</td>
<td>$1,209</td>
<td>$939</td>
<td>per spray</td>
</tr>
</tbody>
</table>
Sprayer tuning:
Decide on target rates and volumes
Then tune your sprayer to the canopies to be sprayed

Visual sprayer setup

- Park sprayer in row and turn off nozzles that will not hit target
- Calibration should set nozzle outputs to deliver most output to tree tops
- Tweak nozzle angles to prevent striping
- You are spraying the row you are in
- Look for upwind spray plume projection beyond target canopy
Before critical spray applications consider some kind of coverage visualisation

- Spraying is a black art
- You get little feedback as to coverage and performance from individual applications
- **Coverage assessment will help you to achieve maximum potential deposits**
- Coverage assessment using water sensitive papers is a useful rapid feedback tool
- Other options include surround (white clay) or UV tracers
What can water sensitive papers tell you? 
Droplet size and potential coverage

- Fine, 45L/Ha
  88 drops/cm
  8.5% covered

- Medium, 45L/Ha
  32 drops/cm
  8.5% covered

- Coarse, 45L/Ha
  35 drops/cm
  9.3% covered
But WSP don’t show adjuvant or plant surface effects

Each droplet contains the **same volume**

<table>
<thead>
<tr>
<th>No adjuvant</th>
<th>Du-Wett 50 ml/100 L</th>
<th>Du-Wett 100 ml/100 L</th>
</tr>
</thead>
<tbody>
<tr>
<td>WSP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>4 mm²</td>
</tr>
</tbody>
</table>

Leaf surface

2 26 50 mm²
We use sensitive papers to help tune and confirm sprayer performance.

We often score coverage.

- **Inadequate**
  - 700 l/ha

- **Adequate**
  - 700 l/ha

- **Excellent**
  - 2000 l/ha

- **Wet to runoff**

Aiming to achieve 80% with adequate or excellent coverage.
Coverage testing can help identify coverage gaps, droplet sizes and coverage intensity.

Fuji 5m tall, 5m rows, postharvest – 600 l/ha, 6.3 vs 4.7 km/hr in adverse cross wind.

Coverage achieved in tree tops.
Much improved deposit intensity.
The #3 Spraying problem?
Is variable chemical application rates

How do you interpret chemical labels:
- for different target canopies?
  - for different pest/disease pressures?
• Rate per hectare?
• Rate per 100 litres?
• Spray cover over time?
Typical tree crop chemical trials involve sprays applied by hand to runoff in small rep plots

- Typically the inner canopy is not wetted to the point of runoff and receives about half the dose of the outer canopy
- Apply a test chemical at different mixing concentrations and you will see a dose response
If I put a kilogram of chemical on per hectare what dose can I expect to achieve?

• Chemical per square centimetre will vary with……..
  • Canopy size
  • Stage of growth and/or canopy density
  • Sprayer targeting efficiency
  • Spray retention efficiency
Maximum potential deposits versus Range of expected deposits

Potential and expected chemical deposits in different target canopies

Target Leaf area index
(ha projected surface area per ha)
If I apply a constant rate per hectare through the season expected average deposits per square centimetre will.....

- Reduce as target surface area increases (chemical is being spread over a larger surface area)
- Get closer to the theoretical maximum as canopy retention potential increases (full leaf, even canopy, no gaps between trees)
- Show greatest potential variation in the early season (sprayer setup efficiency is really important here)
- Deposit variance increases with increasing canopy density (two-three fold variances are OK, five fold variance is not)
So....It is sensible to adjust chemical application rates to match the size of canopy being sprayed

- This can be done by estimating the runoff volumes required by different canopies
- Tree Row Volume (TRV) is still the best tool to estimate this in free standing tree crops
Canopy descriptors

Tree height
Row spacing
Row length
Canopy wall surface area
Canopy continuity
Tree volume
Tree-Row-Volume (TRV)

Leaf area index
Leaf area density
Light interception
TRV measurement systems

\[ a = \text{American Tree-Row-Volume (US-TRV)} \]

\[ b = \text{Half-Crown Tree-Row-Volume (HC-TRV)} \]

\[ c = \text{Height-Stratified Tree-Row-Volume (HS-TRV)} \]
Actual dilute spray volumes versus requirements predicted from HS-TRV

Coverage assumption of 10.7 m³ TRV per litre of dilute spray
TRV calculations

\[ \text{TRV (m}^3/\text{ha)} = \text{height (m)} \times \text{spread (m)} \times 10,000 \div \text{row width (m)} \]

Example: Height = 4.5 m, average spread = 2.5m, row width = 4.5m
\[
\begin{align*}
\text{TRV} & = 4.5 \times 2.5 \times 10,000 \div 4.5 \\
& = 25,000 \text{ m}^3/\text{ha}
\end{align*}
\]

Dilute spray volume required = TRV ÷ coverage factor
\[
\begin{align*}
& = 25,000 \div 14 \\
& = 1,800 \text{ l/ha}
\end{align*}
\]

Coverage factors
- Open canopies = 14 m\(^3\) TRV sprayed per litre
- Dense canopies = 11 m\(^3\) TRV sprayed per litre
- Drenching sprays = 7.5 m\(^3\) TRV sprayed per litre
Lookup tables for estimating spray volumes and chemical application rates

**Spraywise Dilute row length based application guide**

- Fungicides require 20-25 litres per 100 metres of row
- PGRs/miticides require 25-30 litres per 100 metres of row
  - To wet to the point of runoff
  - per metre of canopy height

---

<table>
<thead>
<tr>
<th>Grapes</th>
<th>20</th>
<th>25</th>
<th>30</th>
<th>35</th>
<th>40</th>
<th>45</th>
<th>50 ... 70</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><img src="green.png" alt="Fungicides" /></td>
<td><img src="green.png" alt="VSP" /></td>
<td><img src="green.png" alt="Sprawl" /></td>
<td><img src="green.png" alt="VSP" /></td>
<td><img src="green.png" alt="Sprawl" /></td>
<td><img src="green.png" alt="VSP" /></td>
<td><img src="green.png" alt="Sprawl" /></td>
</tr>
<tr>
<td></td>
<td><img src="green.png" alt="some PGRs" /></td>
<td><img src="green.png" alt="VSP" /></td>
<td><img src="green.png" alt="Sprawl" /></td>
<td><img src="green.png" alt="VSP" /></td>
<td><img src="green.png" alt="Sprawl" /></td>
<td><img src="green.png" alt="VSP" /></td>
<td><img src="green.png" alt="Sprawl" /></td>
</tr>
</tbody>
</table>

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**IMPORTANT:**

- Volumes are given for full canopy.
- Volumes may vary according to canopy type, e.g. VSP vs Sprawl, shape and density. Use the lower end of the spectrum for easier to cover targets, e.g. in grapes use 20–25 for VSP and 25–30 for Sprawl.

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Is essentially a simplified TRV system - but may be over simplified?
NZ apple sprayers
Tower variants are used
With assumed advantages in targeting and drift reduction

Old school 1990’s towers
Modern Tower Sprayers

Increasing use of multi-row towers in intensive plantings
But axial fan air blast sprayers dominate

Three models of 920-1000 mm fan air blast sprayers
The unit in the centre is too big for most apple plantings
The essence of getting it right

Learn to “look knowingly” at your sprayers

- Point nozzles where you want outputs to go
- Adjust output volume distributions to match target
- Symmetry is good
- Manage air outputs - How far does the spray plume push past trees on the upwind side?
- Confirm coverage
- Adjust output volumes and chemical rates to canopy sizes and needs
- Know whether you are dilute or concentrate spraying
**Right chemical, right time, right rate**

**Hit the target, cover the target**

- Successful spraying outcomes depend on achieving each of the five points above
- Sprayer calibration is the first step in hitting and covering the target
- Calibrated sprayers need to be tweaked to optimise coverage on specific targets
  - With tweaking based initially on visual adjustments to the spray plume as it interacts with the target canopy
  - With coverage confirmation for critical sprays based on water sensitive papers or other coverage visualisation aids