Crop-Adapted Spraying

A proposal to adopt a more consistent method of spraying in apple orchards

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Ontario

The Hypothesis

- **Many pesticides used in apple orchards include instructions that are subjective or vague and therefore are often misinterpreted during spray applications.**

- **Despite clear warnings, many growers adopt their own ad hoc methods of rate adjustment which are inconsistent and often inaccurate.**

The Hypothesis

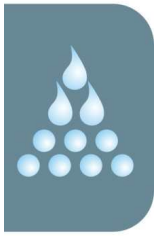
...continued

- **From Canada's perspective, existing methods of label rate adjustment (e.g. Tree Row Volume) have been considered too complicated, too simplistic, or not applicable and are not generally promoted.**

- **The collective result is the over- or under-application of pesticides in many orchards, which leads to wasted resources and/or compromised results.**

Establishing Common Terms

the pesticide label



- The pesticide label is intended to express the safest and most effective way to handle and apply an agrichemical product.
- Fundamental to this intent is the application rate. For orchard spraying this is the carrier volume times the agrichemical product's dose rate and it is often based on the size of the area to be sprayed.

A		B		A x B
Carrier Volume	x	Dose Rate	=	Application Rate
1,000 L/ha		50 g / 100 L		500 g/ha

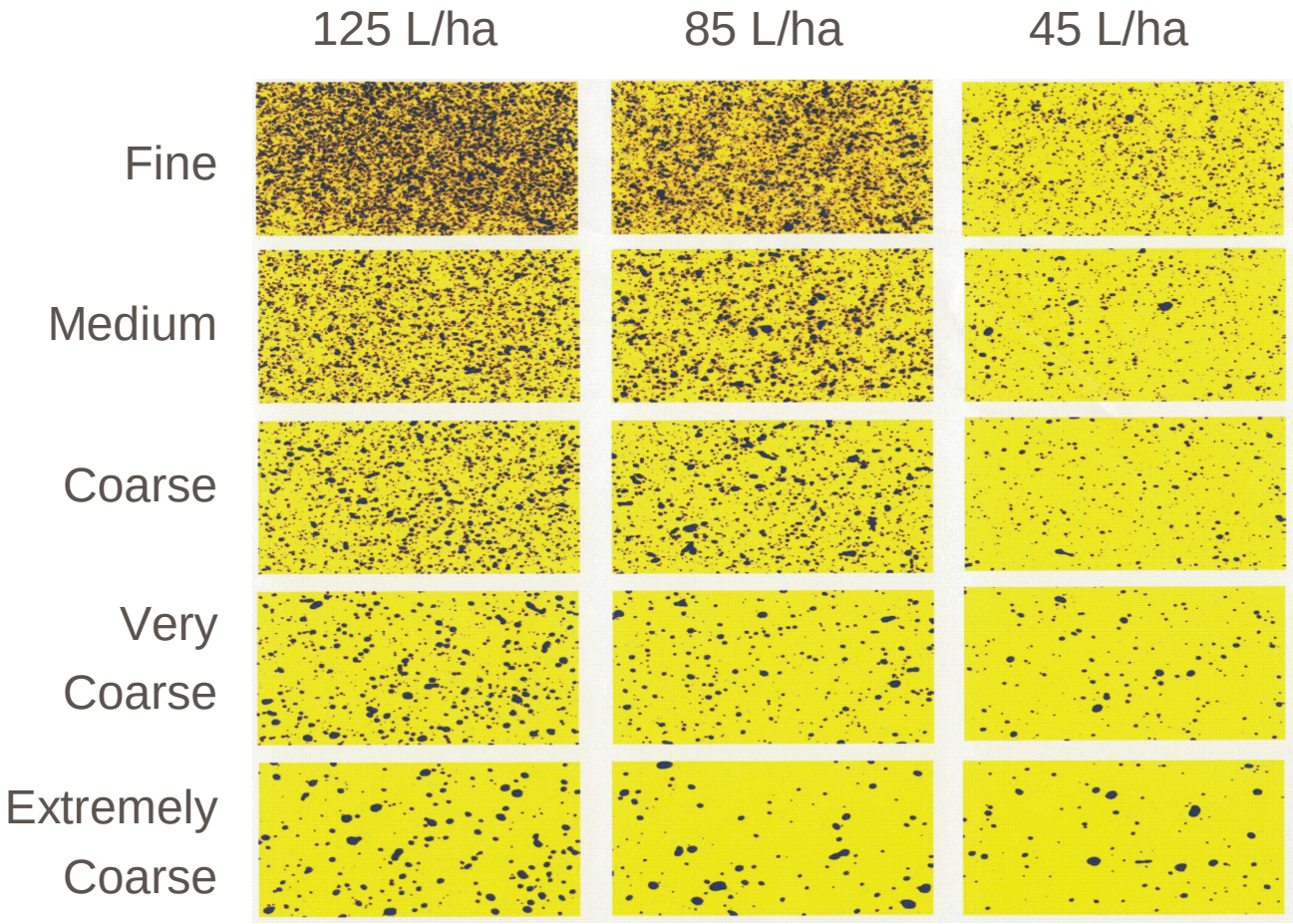
The Carrier

What is it?

- The carrier in orchard spraying is usually water.
- The carrier **conveys** the product to the target and **distributes** it in the desired pattern at the desired concentration.

- The desired pattern is generally a **high droplet density** (discrete droplets per unit area) which is often conducive to an effective application.

The Carrier

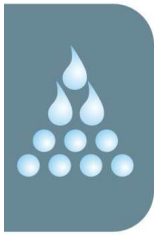


Courtesy of T. Wolf (AAFC)

Specific volume is seldom indicated on the label expect in generalities, such as minimum and maximum or based on subjective criteria.

Dose Rate

How is it determined?

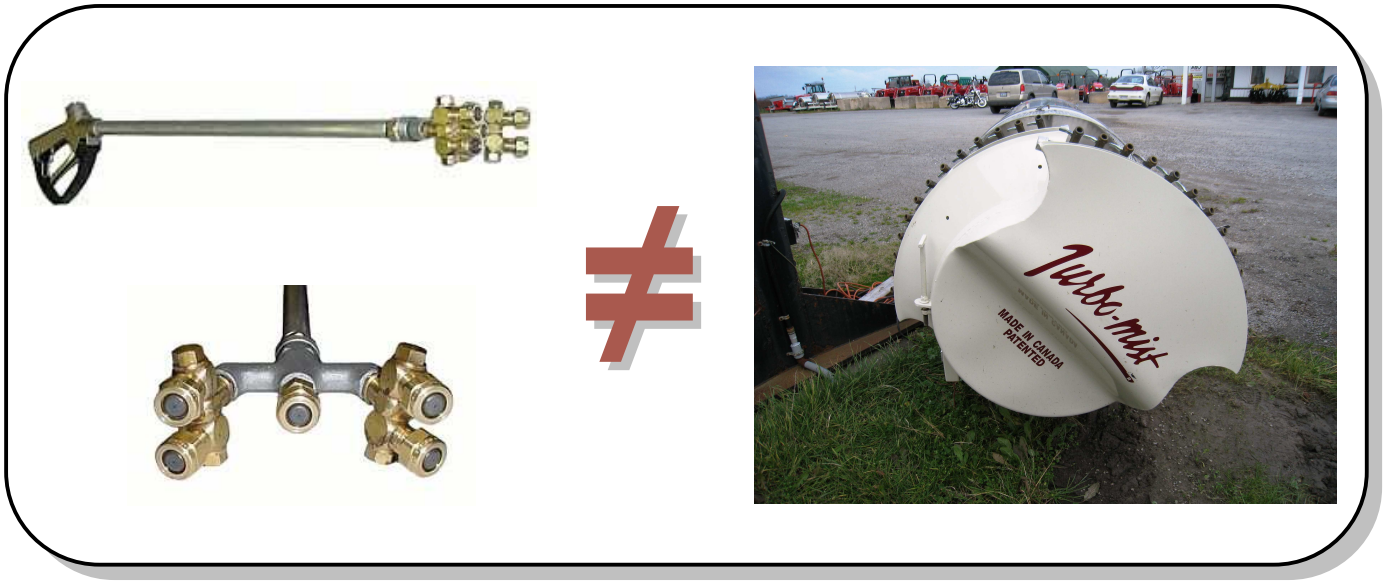


- For an application to achieve the desired result, a threshold amount of active ingredient must be deposited per unit target area.
- Generally, the lowest efficacious dose is determined for dilute spray mixtures applied "to the point of run-off or drip" using a spray gun on a limited number of trees.
- There is a high degree of variability and subjectivity between the application trials that establish the rate (or confirm the registrant's claims) and a grower's orchard application.

Application Trials

A few disconnects between trials and real-life applications

1. It is questionable whether a spray gun accurately reproduces the grower's methodology.

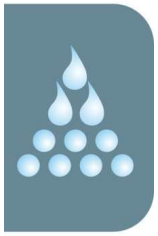


2. Operator perceptions of coverage, run-off, application volume and sprayer setup vary widely between canopies and equipment.

Application Trials

A few disconnects between trials and real-life applications

3. **"To-the-point-of-runoff or drip"**
   - Highly subjective
   - Represents a dilute application – not representative
   - Outer canopy drenched before inner canopy



4. **Registrant's margin of error**
   - Sometimes introduced by registrants, it is subjective and inconsistent

5. **Canada's Lowest efficacious dose**
   - Reduces any margin for error for grower
   - Only represents the conditions that achieved the objective at lowest dose

6. **Application Rates often delivered as per-area**
   - Areas are not volumes, and the volumes are variable

Inter-Orchard Variability

same planted area – different canopy volumes

- **In a 2001 survey, three English apple orchards measured at the same time of season ranged from 8,500 to 19,000 cubic metres per hectare.**
- **This is due to growth stage, root stock, tree shape, planting density and pruning practices (see next slide).**
- **So, should rates be expressed strictly by planting area?**

All photographs taken on the same day in Simcoe, Ontario

Intra-Orchard Variability

same crop – different canopy volumes

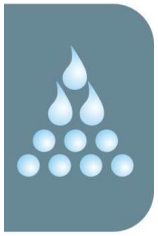
- In a 1997 survey, apple canopies in New Zealand ranged from **10,000 to 40,000 cubic metres per hectare** and **increased by 30% between bud-break and harvest**.
- Studies in the U.K. have shown that spraying at a fixed rate across orchards at different growth stages results in a **six-fold variation** in deposit.
- So, is one rate or single sprayer set-up applicable throughout the season?

Are Label Rates Relevant?

- **When methodology, subjectivity and orchard variability are considered collectively, given that neither deposit rate variability nor test tree parameters appear on the label, and given that orchard application trials have no common or standardized reference condition, they far less relevant than they should be.**

- **It fact, in 2008 it was demonstrated in the U.K. that fixed application rates provide suitable orchard coverage less than 50% of the time.**

Spelling out the Impact



- **Choosing to interpret the label rates, many growers modify the carrier volume and/or dose rate using their own methods which may or may not provide adequate coverage.**

- **Over-spraying leads to unnecessary environmental contamination and financial loss. In typical high volume airblast applications studies show that as much as 80% of the product can be lost to drift and ground deposition.**

- **Under-spraying reduces coverage and control and may encourage resistance. If coverage is insufficient, the operator may be required to re-apply, having a greater net-impact on the environment.**

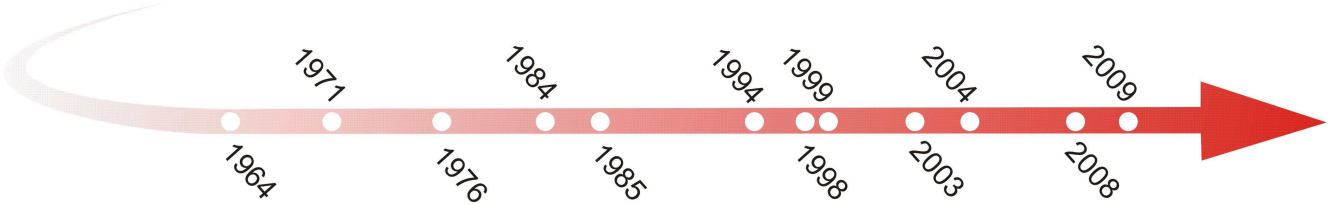
Possible Actions

- Maintain the Status Quo – The “do nothing” approach.
- Change the way products are tested and registered in Canada to include transparency (e.g. multiple testing scenarios, standardized targets & application equipment and coverage/efficacy variability on the label). – The “pie-in-the-sky” approach.
- Encourage existing rate adjustment methods, despite issues with complication or inaccuracy. – The “better-than-nothing” approach.
- Demonstrate and promote a new method.

The Proposal

- **A simple system is required from which growers (who are already modifying rates) can adjust their practices.**
- **The concept of adapting spraying practices to a leaf area within a volume of canopy with a well-calibrated and oriented sprayer is Crop-Adapted Spraying (CAS).**
- **CAS is not a new concept:**

A *Brief* History of Crop-Adapted Spraying

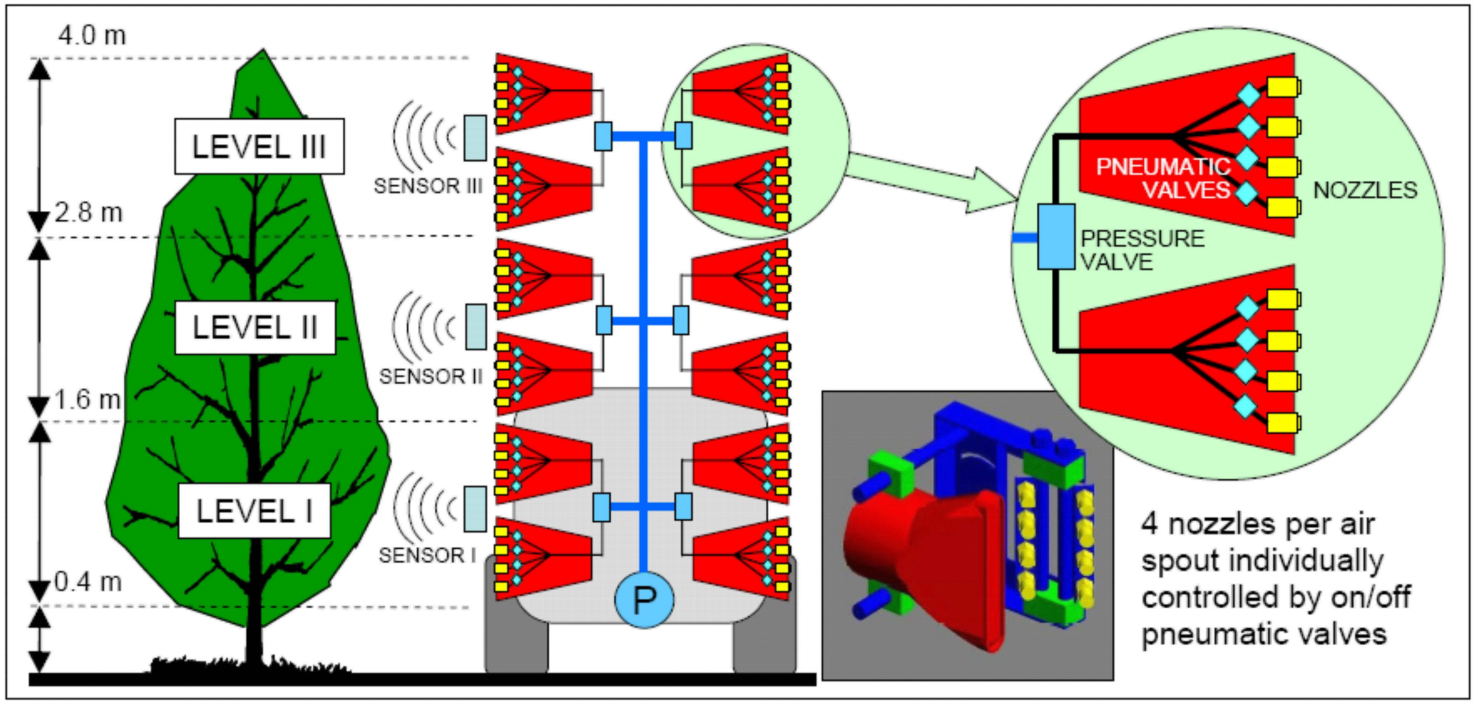


1964- Fruit-Wall Area. For dilute spraying, does not account for sprayer type. Limited to fruit-wall hedging.
1971- Tree-Row Volume - For dilute spraying, translates ground-area to foliar volume. Refers to "Standard" canopy (6.1m tall, 7.0m wide, 10.7m row spacing (US-TRV). Successful pest and disease control using a base dilute volume of 3,740 L/ha (500 US gallons/acre).
1976- OMAFRA Publication 373 (1976 revision of 1971). Standard trees are 5.5 metres (18 feet) high, row spacing from 3.7-8.5 metres (12-28 feet). Recommended carrier volumes 3,370 – 4,494 litres per hectare (300 - 400 imperial gallons per acre) (360 – 480 US gallons per acre).
1984- Tree-Row Volume recognizing density. Does not account for sprayer.
1985- OMAFRA "Sprayer Technology & Application Techniques for Horticultural Crops (Paul Goodwin et al. c.1985) Attempts to bridge older recommendations, Tree Row Volume was proposed. Standard tree was 4.9m high, 7.9m wide, 11m between rows. Selected 1,000 litres to spray 1 hectare of std. trees. No mention of area-density, dilute/concentrated spraying, weather or method.
1994- The 100m tree row (Norway). Based on a 1m wide, 1 m high, 100m long section of canopy. Assumes 20-50 litres for complete coverage depending on density. Dilute spray volume (L/100m) = 20 to 50 L / UCR x canopy height (m) x canopy width (m).
1998- Unit Canopy Row (Australia). Similar to 11m tree row. Does not account for area-density
1999- Boucher proposes Spray Volume Factors (SVF) to modify TRV. This is the number of litres of spray retained by 1000 cubic metres of TRV sprayed to run-off and it varies depending on age and density.
2003- Tree-Area Density (UK). Assumes limited variation in tree density. Limited info on this method.
2004- Pesticide Application Adjustment (PACE+, UK). Uses pictographic key with formulae to calculate dose adjustments for early season (pre-blossom before 1st flowering), after first flowering and mid-season (full leaf). A modification of this scheme (PACE+) allows pesticides with higher sensitivity or reduced safety margins (e.g. scab fungicides) multiplies dose adjustments by a factor of two in early season. No link to growth-stage and doesn't do well when tree height variation is 25% or more.
2008- Publication 310 (IPM Apples -OMAFRA)- Considers size-controlled planting to be 3m wide, 3.4m wide, 5.5 m between rows. No recommendation of standard volume (Page 229-230) except no less than 300 L/hectare when protecting fruit.
2009- Spray Calculator- Borrows from TRV, PACE+, Ontario's historic practices and Area-Density.

CAS-Purposed Sprayers

A prototypical reality in Poland, Italy and The Netherlands

- **Real-time rate changes based on crop density.**

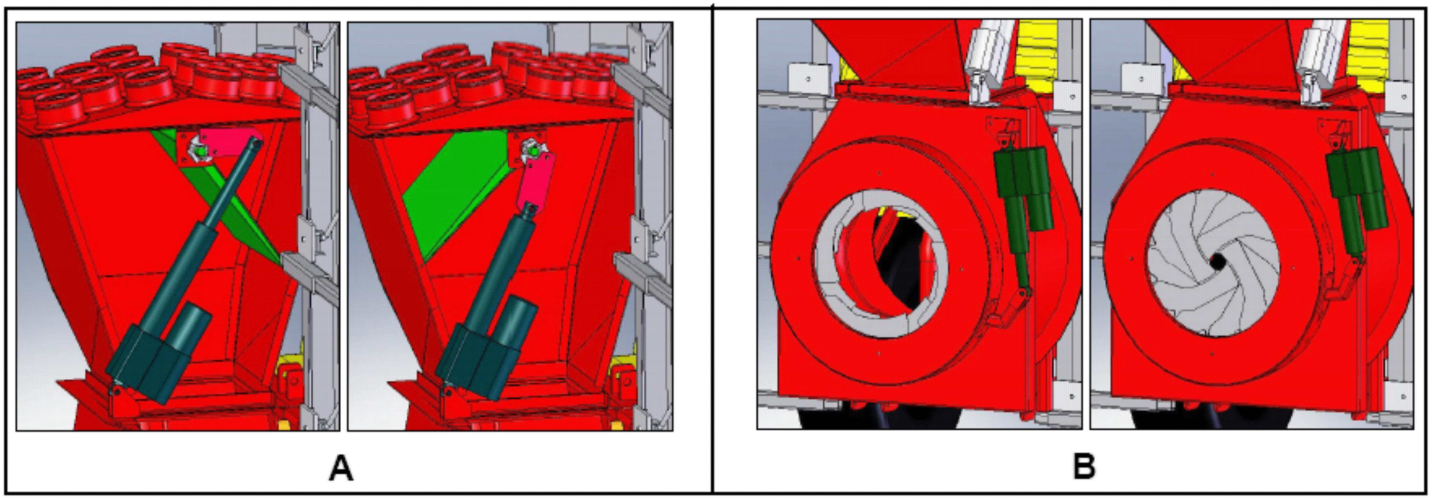


from Doruchowski, Balsari and Van de Zande, Acta Hort 824, ISHS 2009

CAS-Purposed Sprayers

A prototypical reality in Poland, Italy and The Netherlands

- **Real-time air flow changes based on crop density.**



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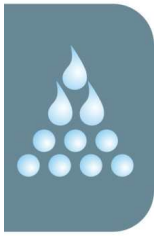
Crop-Adapted Spraying

The Method

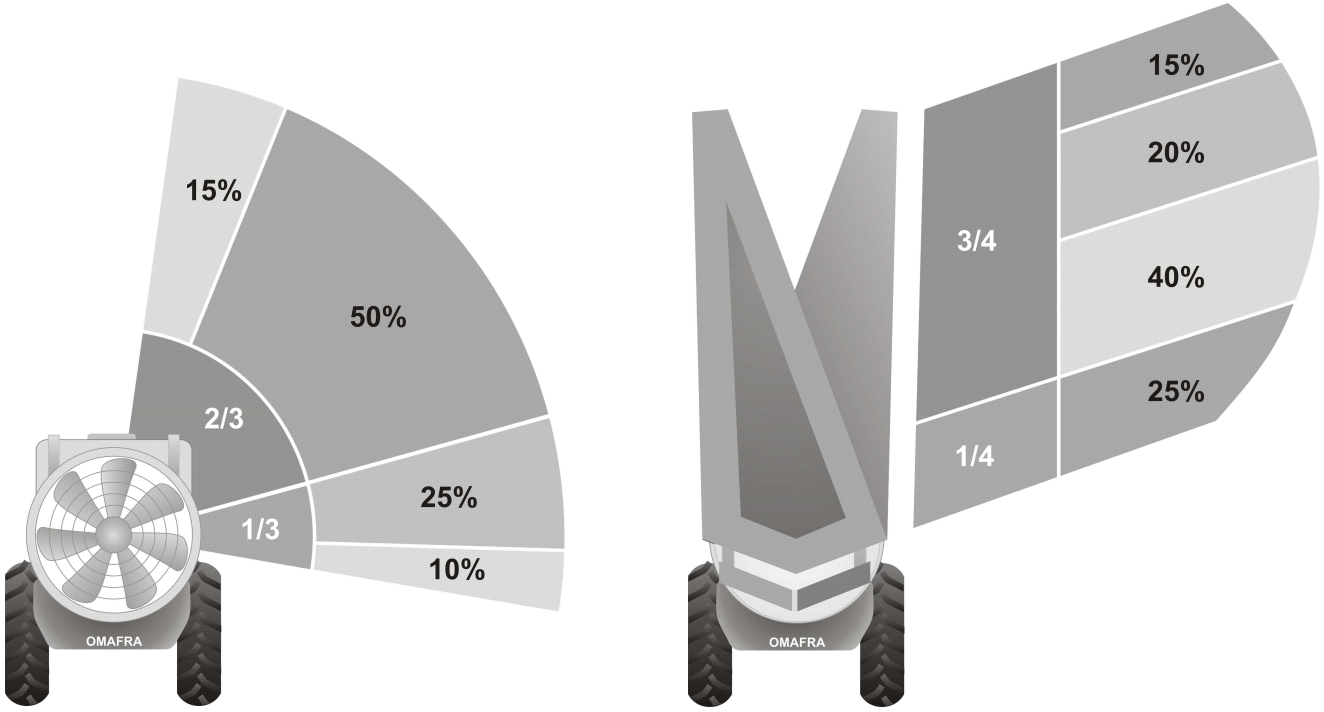


- **The method has eight steps based on practices already in place in other countries and adapted to suit Ontario's apple production culture.**

Step 1

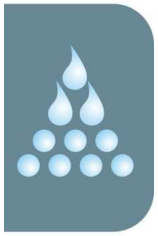
Establish Ideal Sprayer Settings

1. **Calibrate sprayer and select nozzles that distribute spray based on the figures below (classic spindle).**



Step 1

Establish Ideal Sprayer Settings



2. **Orient nozzles so top of spray plume just covers the top of the highest tree in the block. Orientation should be adjusted at the beginning of the season and around the 1.0” fruit stage (just past mid-season).**

3. **Adjust air output to only just move the leaves at the centre of the canopy. Air settings should be adjusted at the beginning of the season and around the 1.0” fruit stage and are affected by ambient wind.**

4. **Choose a sensible working speed (e.g. 4-6 kph).**

Step 2

Follow Integrated Pest Management Protocol

1. **Follow Integrated Pest Management (IPM) Protocols to assess the need to spray, to determine timing and to select pesticide(s).**

2. **IPM should also be employed to assess the success of the CAS method for given products or orchard blocks.**

Step 3

Determine if CAS is appropriate

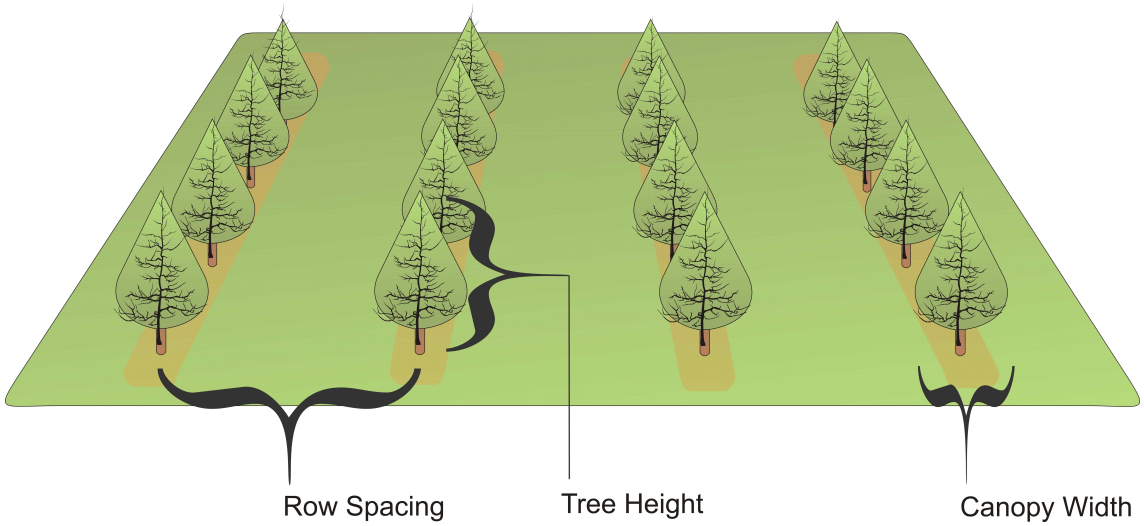
1. **DO NOT use crop-adapted spraying if the label prohibits concentrated, reduced or low-volume spraying or offers less than “control” (e.g. “suppression” or “reduction in damage”). High pest pressure may also warrant a return to full rates.**

Step 4

Calculate Classic Tree Row Volume

1.

A		B		C		D		AxBx(C/D)
Canopy Width (m)	x	Tree Height (m)	x	Hectare Area (m2)	/	Row Spacing (m)	=	Tree Row Volume (m3/ha)
3.5		3.0		10,000		5.0		21,000.0



In the case of inter-cropped varieties or mixed-size plantings, err on the side of caution and use the largest trees to calculate Tree-Row Volume.

Step 5

Multiply TRV by the coverage constant

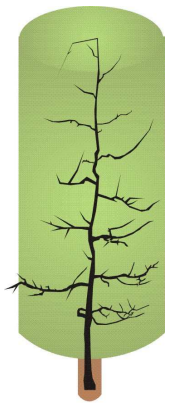
1. **Multiply the TRV from Step 4. by 0.08 litres, which is the calculated volume of dilute spray that will suitably cover 1.0 m^3 of post-blossom (i.e. full-foliage) canopy to the point of run-off.**

2. **This figure was derived from a literature review of 25 instances where volume was established through experiment, or based on historical evidence, from six countries spanning 1964 to the present.**

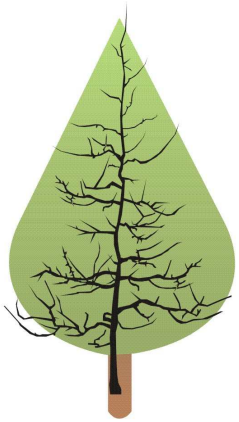
Step 6

Tree Shape Discount Factor

1. **Compare the average tree in the block to be sprayed with the following illustrations and multiply the carrier volume from Step 5 by the appropriate discount factor (these discounts are based on simple geometry).**



Column
0.5x



Rounded Cone
0.6x

Sphere
0.75x

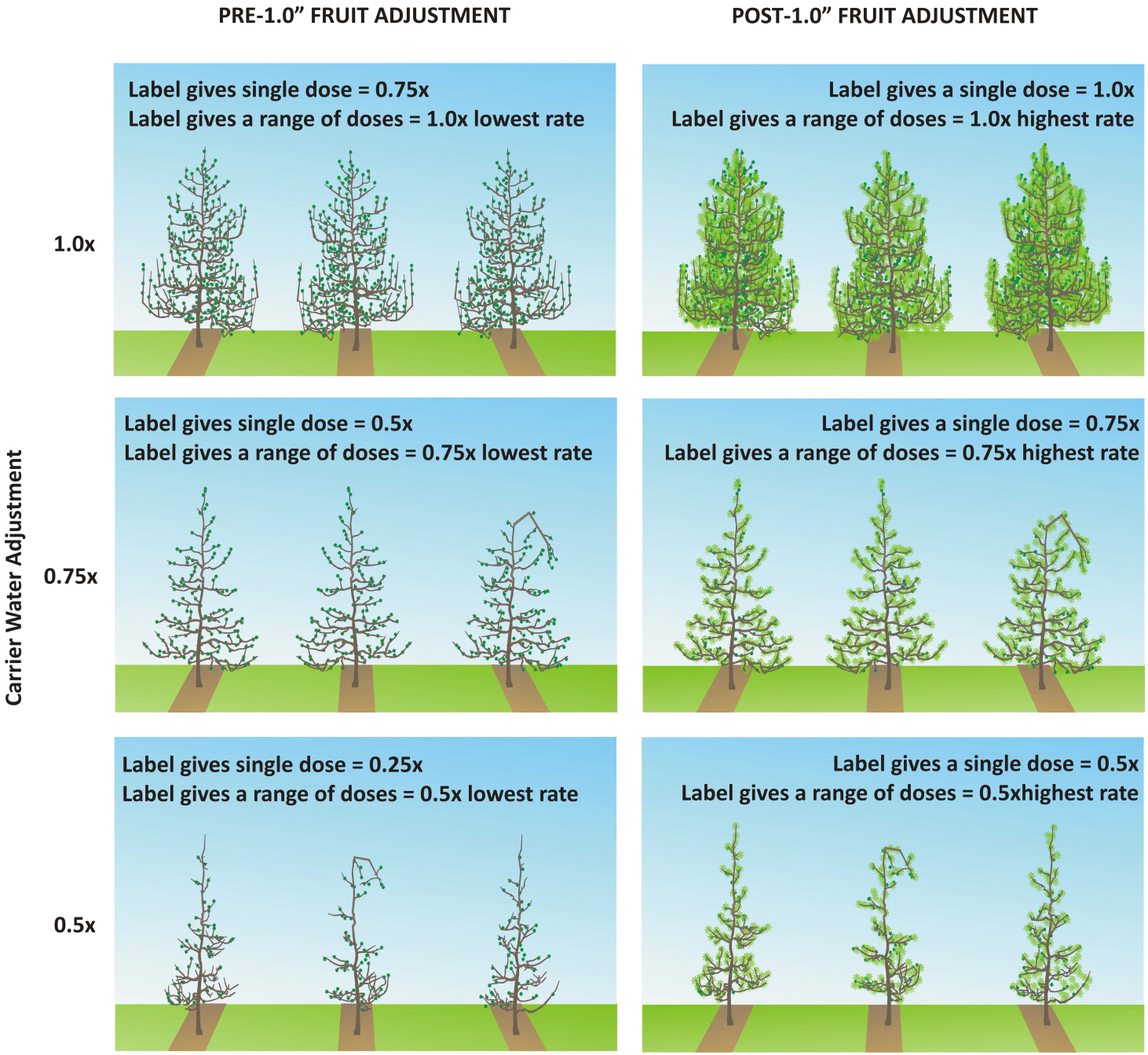
Cube
1.0x

Step 7

Canopy Density Discount Factor

1. **Carrier volume can be further adjusted to reflect foliar development and branching density.**

   Compare the density of the block to be sprayed with the following illustrations (adapted from the UK PACE+ scheme) and multiply the carrier volume from Step 6 by the appropriate discount factor (1.0x, 0.75x or 0.5x). This new dilute volume should bring the application to the point of run-off.



Step 7 (cont.)

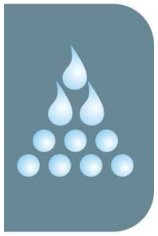
Canopy Density Discount Factor

2. **While there is no definitive minimum carrier volume for directed (e.g. airblast) applications in apple orchards, there is a threshold where there are not enough droplets to suitably cover the target.**

3. **Based on a literature review of international practices and a survey of local (Ontario) practices, using a carrier volume lower that 500 l/ha (53.5 US g/ac) may not suitably cover an orchard, particularly after the 1.0” fruit stage. It is not generally advisable to spray less than this volume.**

Step 8

Adjust Application Rate



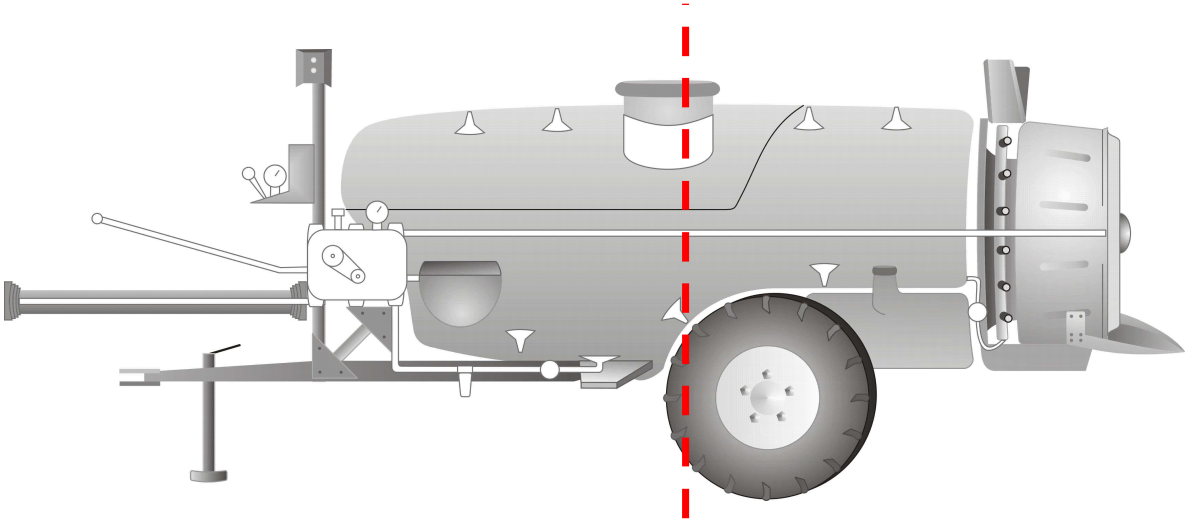
1. **Until this point, the CAS model has only modified carrier volume. The operator can now choose to reduce the amount of product per crop area, if appropriate.**

It is important not to think of this as reducing the amount of product that is deposited on the target… it's more like banded spraying; if there's no target, why spray it?

Step 8 (Cont.)

Adjust Application Rate

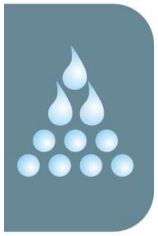
- **Suppose the label recommends 200 grams of product in 2,000 litres of water per hectare.**
- **Suppose further, that you can demonstrate you have only enough foliage to warrant 1,000 litres of water.**
- **Given that a saturated leaf will not exceed tank concentration, why apply more when applying a dilute spray?**



200 grams in 2,000 litres has the same concentration of active ingredient as 100 grams in 1,000 litres.

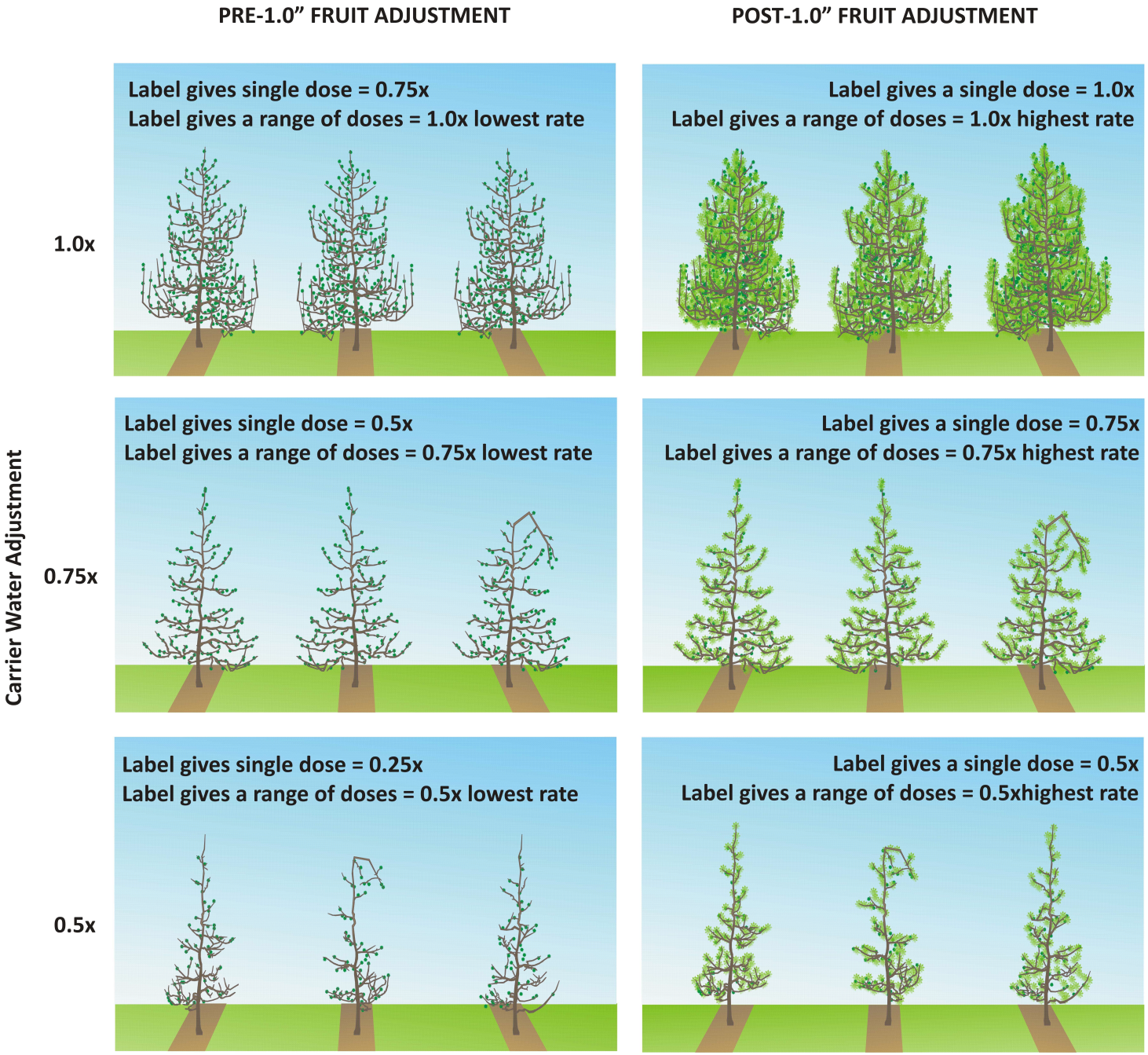
Step 8 (Cont.)

Adjust Application Rate

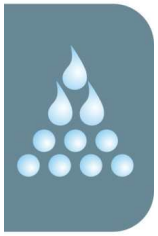


2. To adjust the application rate, determine if the label gives a range of rates. If so, the lowest rate is generally the pre-1.0” fruit rate while the highest rate is generally the post-1.0” fruit rate. Return to Step 7 and multiply the label rate by the appropriate discount factor. If only one rate is provided on the label, or the rate is pest-specific, assume it is the post-1.0” fruit rate.

3. **DO NOT increase the label rate.** Doing so could increase the re-entry interval, increase residue levels or induce phytotoxicity.



...and there we have it.



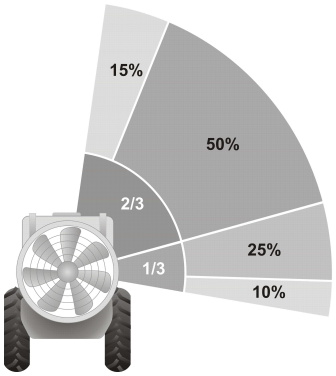
- This method is **not** intended to save the grower water or pesticide, although it's likely to. The process is intended to reduce deposit variability between orchard applications, reduce wastage and improve coverage.

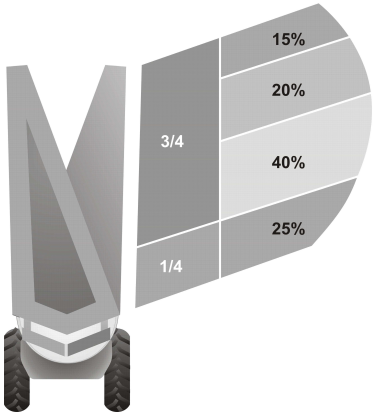
- **There will always be exceptions** when attempting to apply a universal practice, but even if CAS is only applicable to half of orchard applications, considerable benefits could be realized.

- The model has yet to be formally demonstrated in Canadian orchards, but **far more stringent** variations are in practice in Europe and are being promoted in the states by groups like the USDA and Ohio State Extension.

Crop-Adapted Spraying Calculator

for apple orchards





CROP-ADAPTED SPRAY APPLICATION RECORD

Applicator's Name (or) Cert. #	H. Berges	Time of Application	6h00
Application Date	Jul 3	Duration of Application (hr)	1.86

PRODUCT

Product Applied	Bug Killer	Re-Entry Date	
Label Dose Rate (g/1,000L)	100.0	Adjuvant Applied (if any)	
Suggested Dose Rate (g/1,000L)	100.0	Buffer Zone Width	
Product added per full tank (g/tank)	144.0	Earliest Harvest Date	
Product added to partially-full tank (g/tank)	115.2		
Volume of Carrier water in last, partially-full tank (L)	1600		

CROP

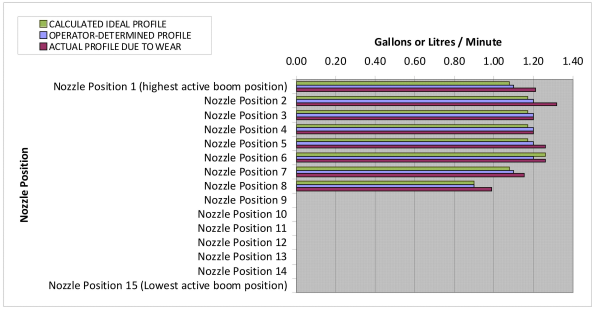
Orchard Name or Block #	Home Block 3	Highest Tree Height (m)	3
Crop	Honeycrisp	Average Canopy Width (m)	2
Stage of Growth:	2nd year green tip	Average Row Spacing (m)	3

WEATHER

Average Wind Speed		Temperature	
Predominant Wind Direction		Relative Humidity	

SPRAYER

Sprayer Make/Model	Hardi	Gear / PTO RPM	3H / 1,000
Forward Speed (km/hr)	5	Operating Pressure (kpa)	120.0
Total Output - Single Boom (L/min.)	9.1	Nozzle Type	



STEP SIX - ENTER PRODUCT INFORMATION

(41)	Name of Product Applied	Bug Killer
(42)	Label Dose Units	g/1,000L
(43)	Label Dose Rate (g/1,000L)	100.0
(44)	Cost per gram ($/g)	$2.50
	Suggested Dose Rate (g/1,000L)	100.0
	Suggested Dose Rate by area (g/ha)	72.0
	Product added per full tank (g/tank)	144.0
	Product added to partially-full tank (g/tank)	115.2
	Volume of Carrier water in last, partially-full tank (L)	1,600.0
	Ideal Product Cost ($/ha)	$180.00
	Actual Cost due to Nozzle Wear ($/ha)	$184.22
	Financial Loss from Worn Nozzles ($/ha)	$4.22
	Total Ideal Spray Cost ($/block)	$360.00
	Total Actual Spray Cost due to Nozzle Wear ($/block)	$368.44
	Total Cost of Worn Nozzles ($/block)	$8.44

Job only requires a partially full tank.
Use this amount of product for job.
Use this amount of water for job.

? When completed, return to any step to review or alter entries (see tabs at bottom of page)

Thank-You

The “Sparrow Sprayer” System