



ORCHARD AND VINEYARD SPRAYERS

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Summary

- Vertical crop spraying can pose unique issues with airborne Fine/ Very Fine droplets with kiwifruit (spraying upwards) being an extreme example and UAV spraying (downwards) another extreme where research is essential
- Australian DRT scheme initially did not include vertical crops (orchards, vineyards, forests), but much of the attention has been in those crops for data collection (and challenges with subsequent submission when studies weren't always done including registrants yet later they were key interest groups)
- One specific challenge for vertical crop risk assessment and DRT implementation is the dosing model and bridging between labels and applications based on area/ volume with leaf wall area



Orchard Sprayers

- Tree and vine crops can be challenging to spray efficiently due to their height, leaf area index and often sloping land
- When spraying vertically, unique challenges arise from spray drift and worker exposure-especially with very tall trees
- Dosing models for vertical crop spraying vary around the world and don't always link well with pesticide labels and regulations



Axial Fan Airblast



Deflected Airblast – e.g. Tornado



Combination Ducts



Multi Fan (e.g. SARDI Fans)



Tower Sprayers – e.g. Airtec Air Boom



Tunnel Sprayers



Vertical Crops

- Usually the sprayer is driven along rows within the orchard or vineyard either being towed by a tractor or as a self-propelled unit
- Some canopies such as kiwifruit are fully closed on the top and sides, so create a tunnel through which a very low sprayer may drive carefully, avoiding touching the fruit





UAVs

- Some applications use UAVs but canopy penetration can be challenging when spraying from above, as can swath displacement when there is a wind



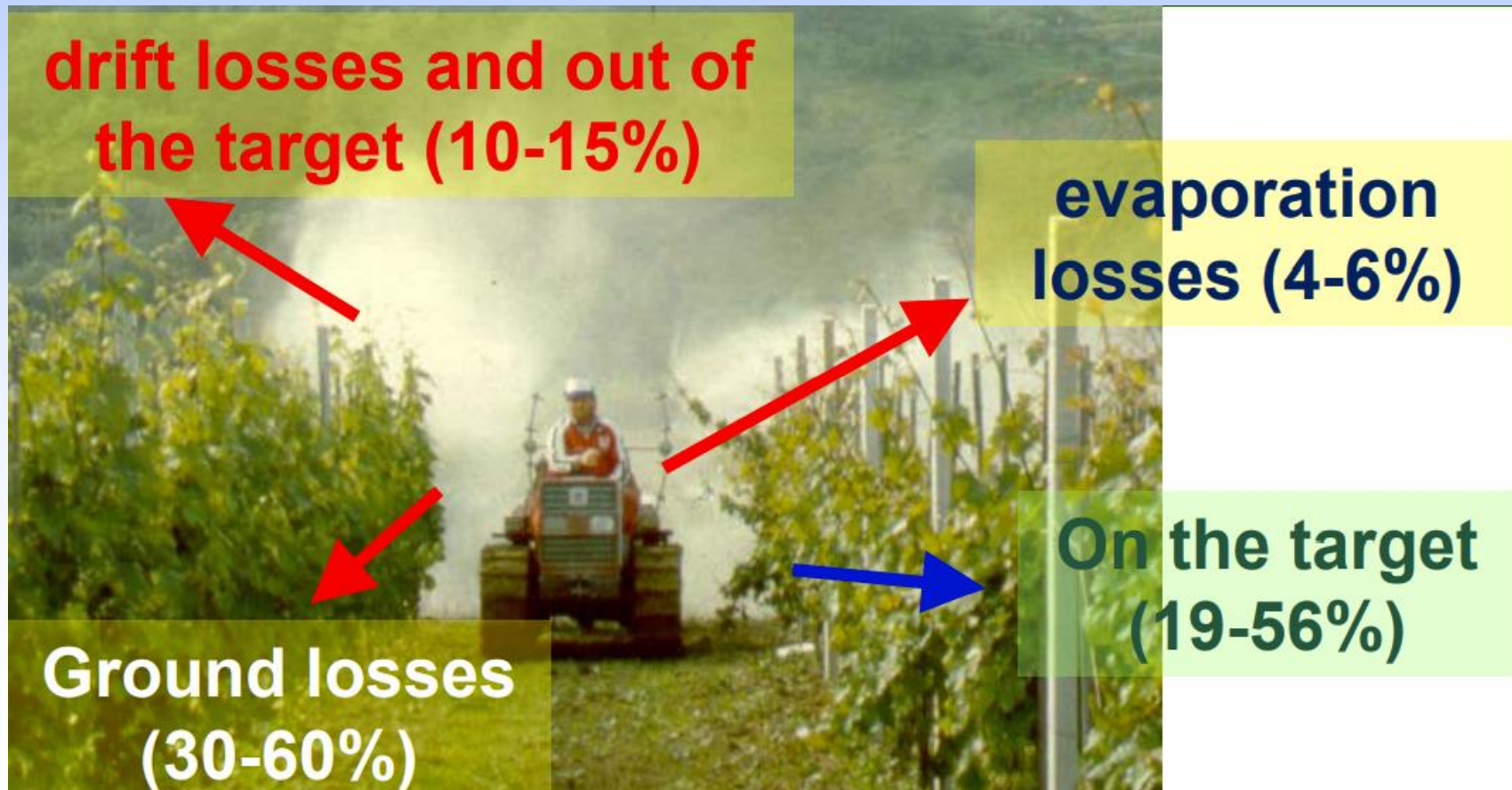


Backpack Sprayers



Mass Balance

- Balsari and Gil



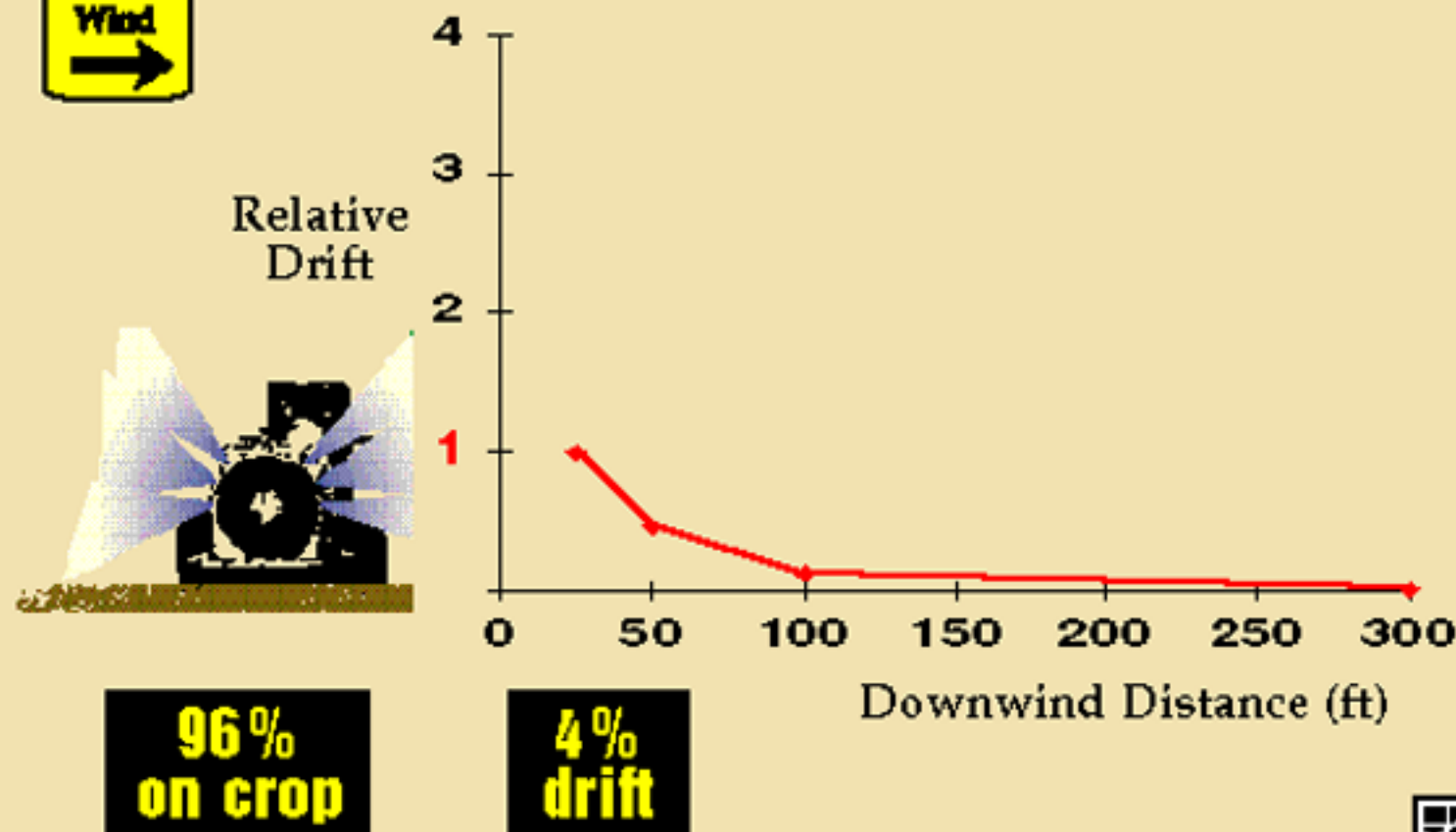
US and Australia

- Usually our assumptions on drift losses are lower than those of some others such as the prior Italian example, using SDTF data (the prior slide showed short vertical crops giving 10-15% losses, compared to <4% for AgDRIFT short vertical crop cases; however, drift was sometimes high for taller crops)



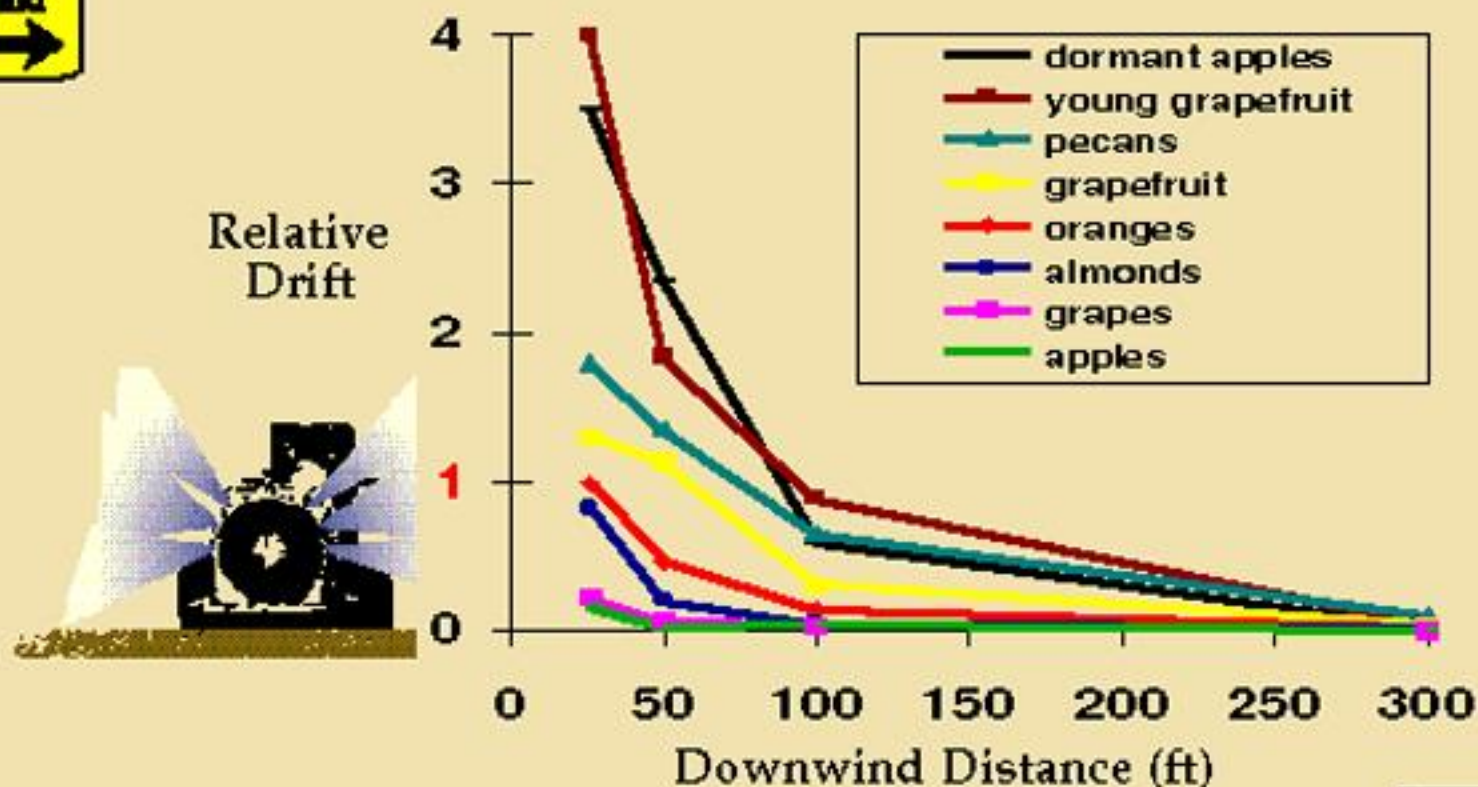
Drift from Application to Oranges

1 = 0.55 oz per acre



SPRAY DRIFT
TASK FORCE

How orchard type affects ground deposition

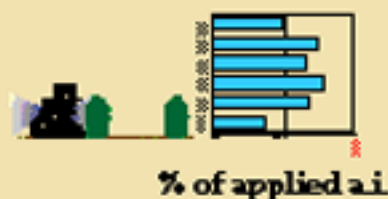


ERRATA DRIFT
TASK FORCE

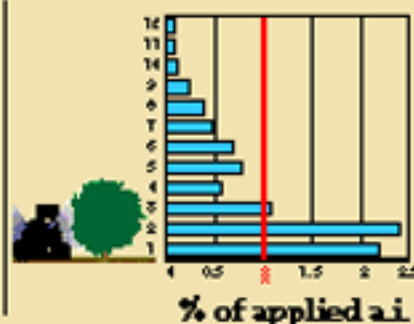
Vertical Deposition Profiles

1 Row (2 rows from grapes) Beyond Airblast Sprayer

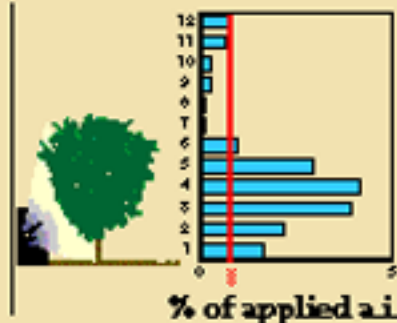
Grapes



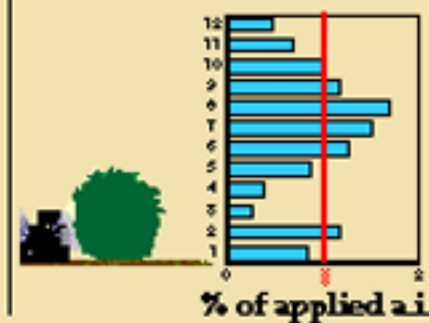
Apples



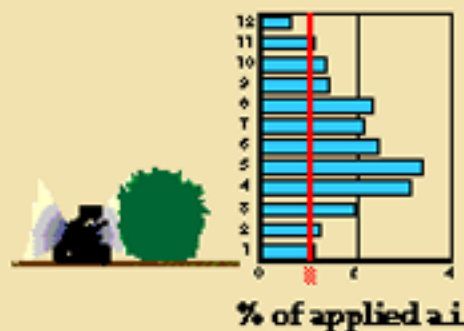
Almonds



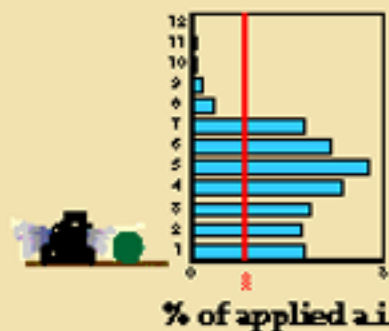
Oranges



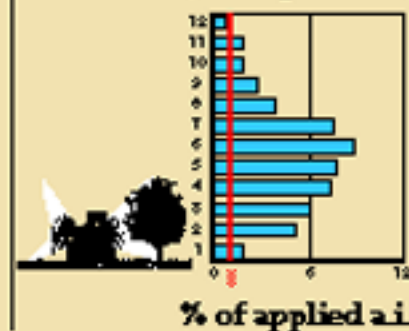
Grapefruit



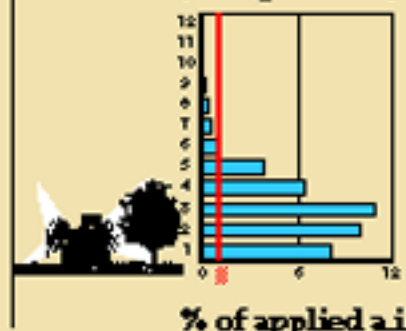
Young Grapefruit



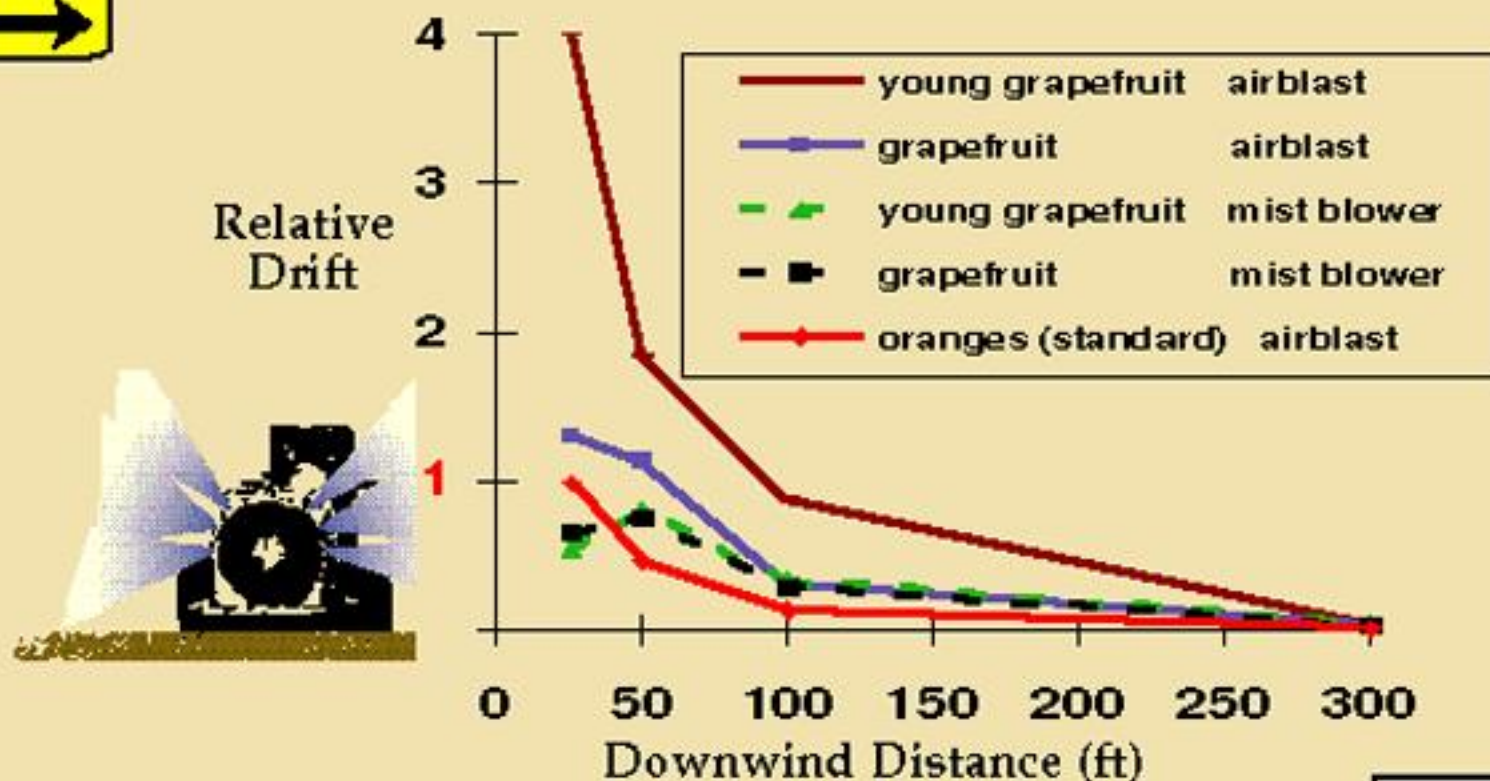
Apples Dormant
(12.2 mph winds)



Apples Dormant
(4.4 mph winds)



How tree size and sprayer affect ground deposition



SPRAY DRIFT
TASK FORCE

Numerous Different Growing Approaches for Crops

- Even within a single crop type, there can be many different ways of growing the canopy which makes it difficult to have a single approach to spraying, or even a single approach to dose expression. This is particularly the case for vine crops

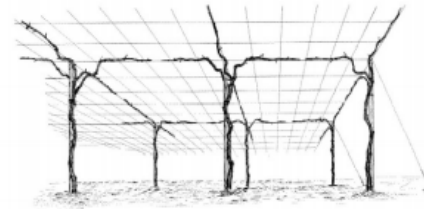


Slides from Balsari et al (Italy)

The vineyard training systems more spread in Italy are:

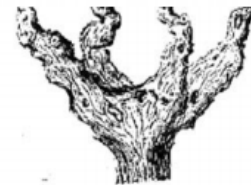
TENDONE

21%



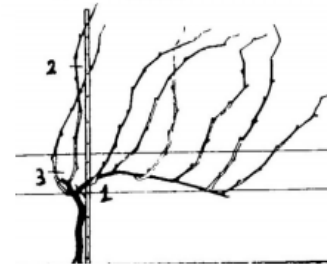
ALBERELLO

20%



GUYOT

15%

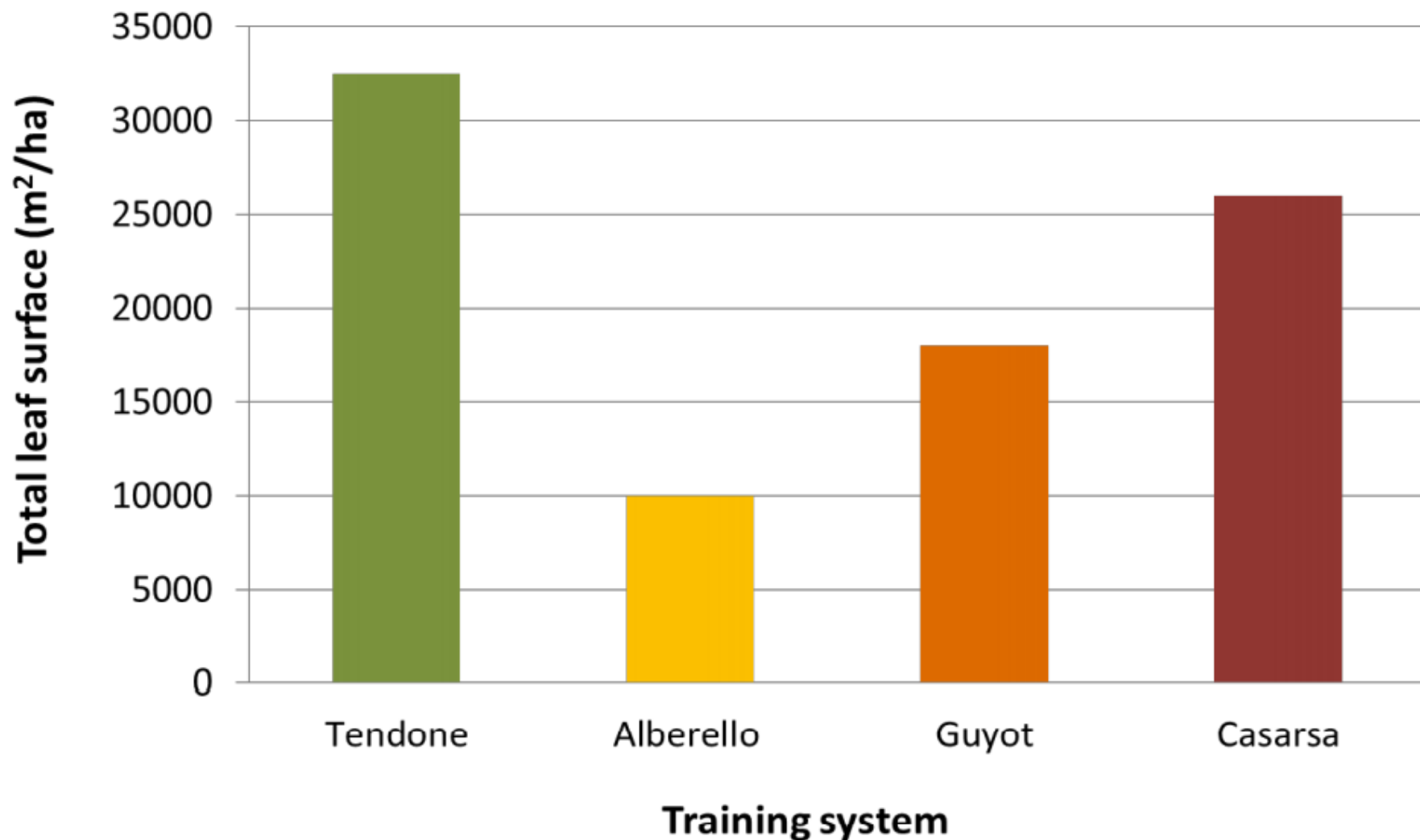


SYLVOZ/CASARSA

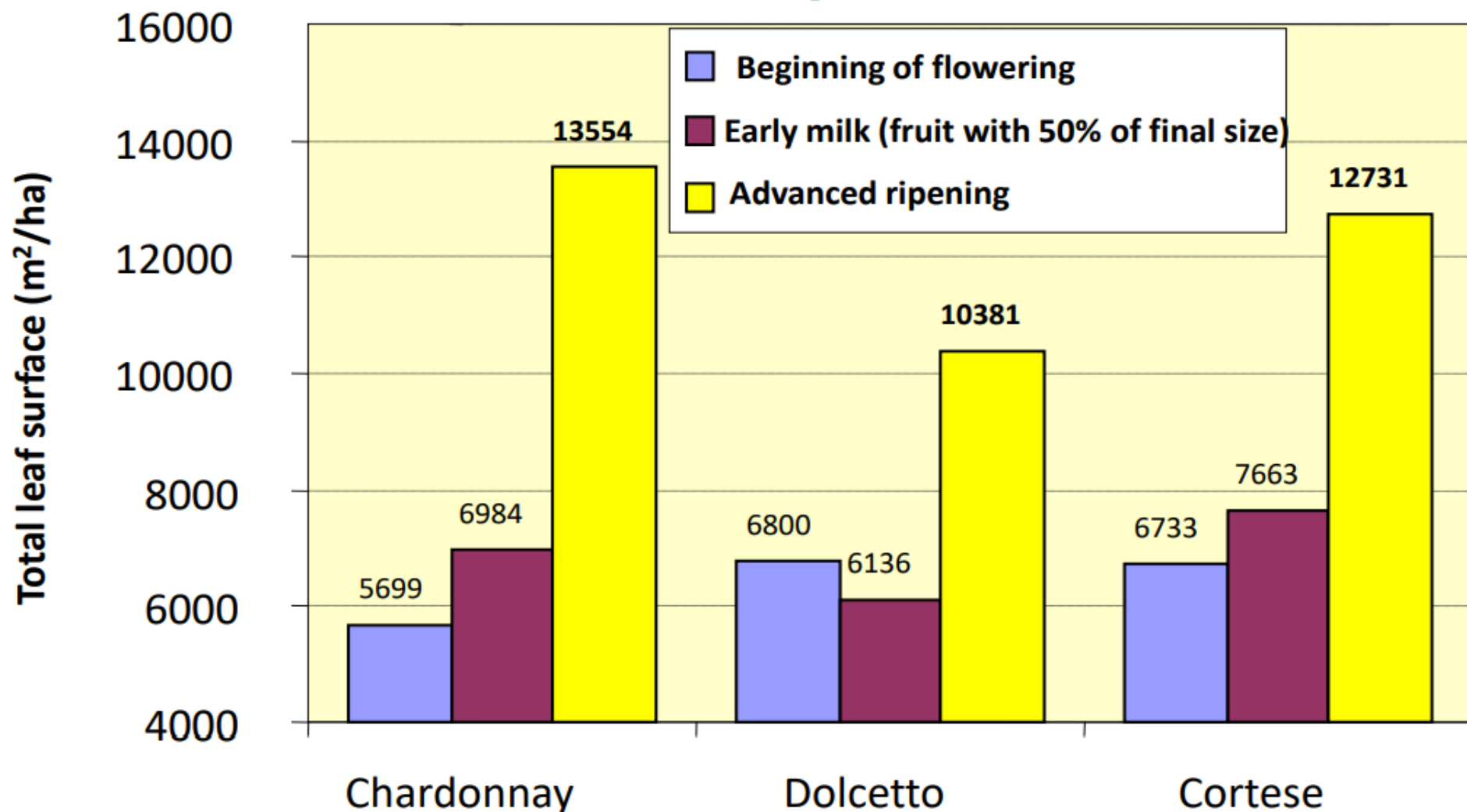
7%



Example of the target surface according to the training system (measured at the ripening of berries growth stage, BBCH = 81)



Total leaf surface according to the variety and the evaluation period

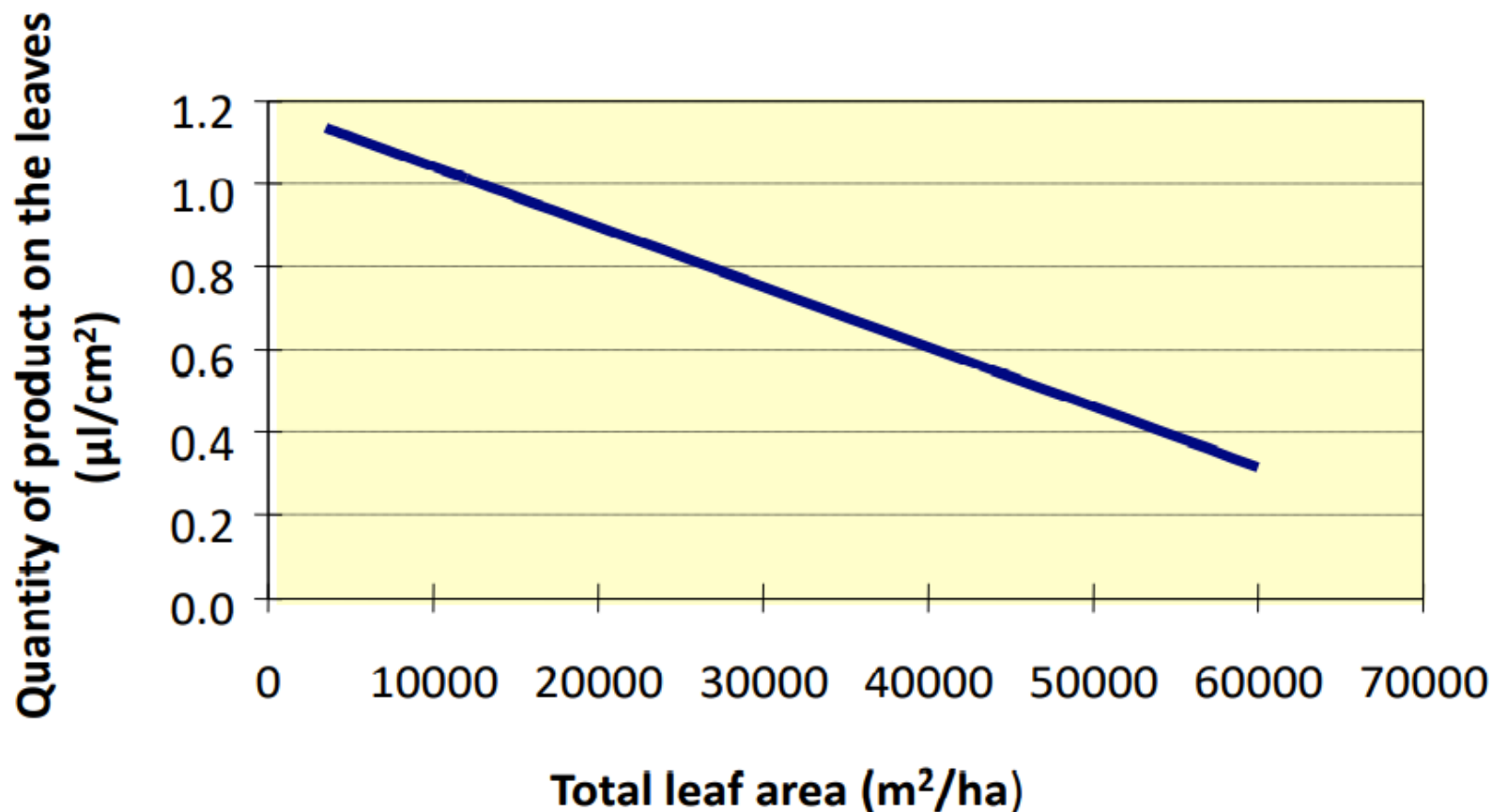


PIEMONTE - GUYOT
layout 2.8 X 1.0
3571 plants /ha

Results of tests made by DISAFA Univ.Torino



Amount of product on the leaves according to the leaf surface of the vineyard **distributing the same volume of water**
(Dose if the concentration is constant)



Results of the tests made by DISAFA Univ.Torino

Current dose rate expression for 3D crops in Europe

Reference units in the EU:

- ground area
- spray volume (concentration %)
- canopy height - CH
- leaf wall area - LWA
- tree row volume - TRV
- plant row

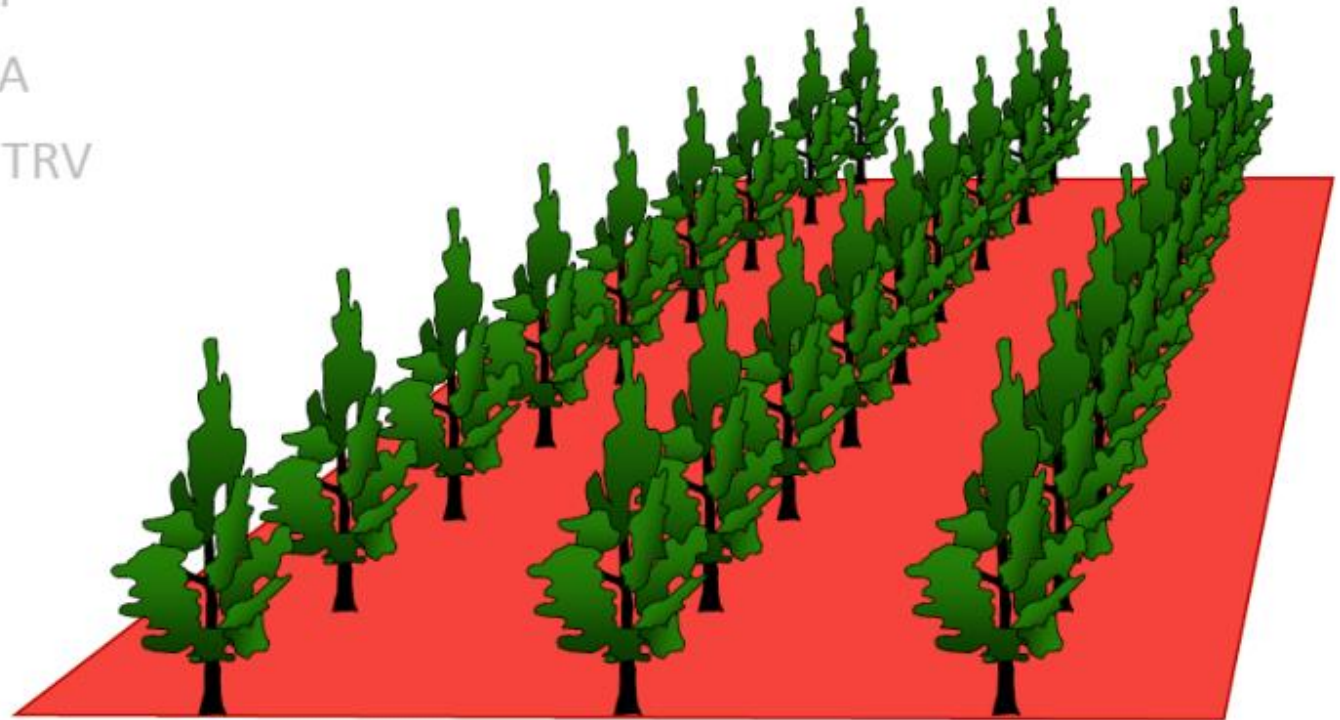


(Doruchowski 2017)

Reference units in the EU: SE, DK, FI, LT • CZ, HU, PL, SI, SK, UK • FR

- ground area
- spray volume (concentration)
- canopy height - CH
- leaf wall area - LWA
- tree row volume - TRV
- plant row

kg or L/ha ground



(Doruchowski 2017)

Reference units in the EU:

DK, FI, LT • NL • ES, GR, HR, IT, PT

- ground area
- **spray volume (concentration)**
- canopy height - CH
- leaf wall area - LWA
- tree row volume - TRV
- plant row

kg or L/100 L spray volume (%)
+ spray volume (max)
and/or + max dose/ha ground

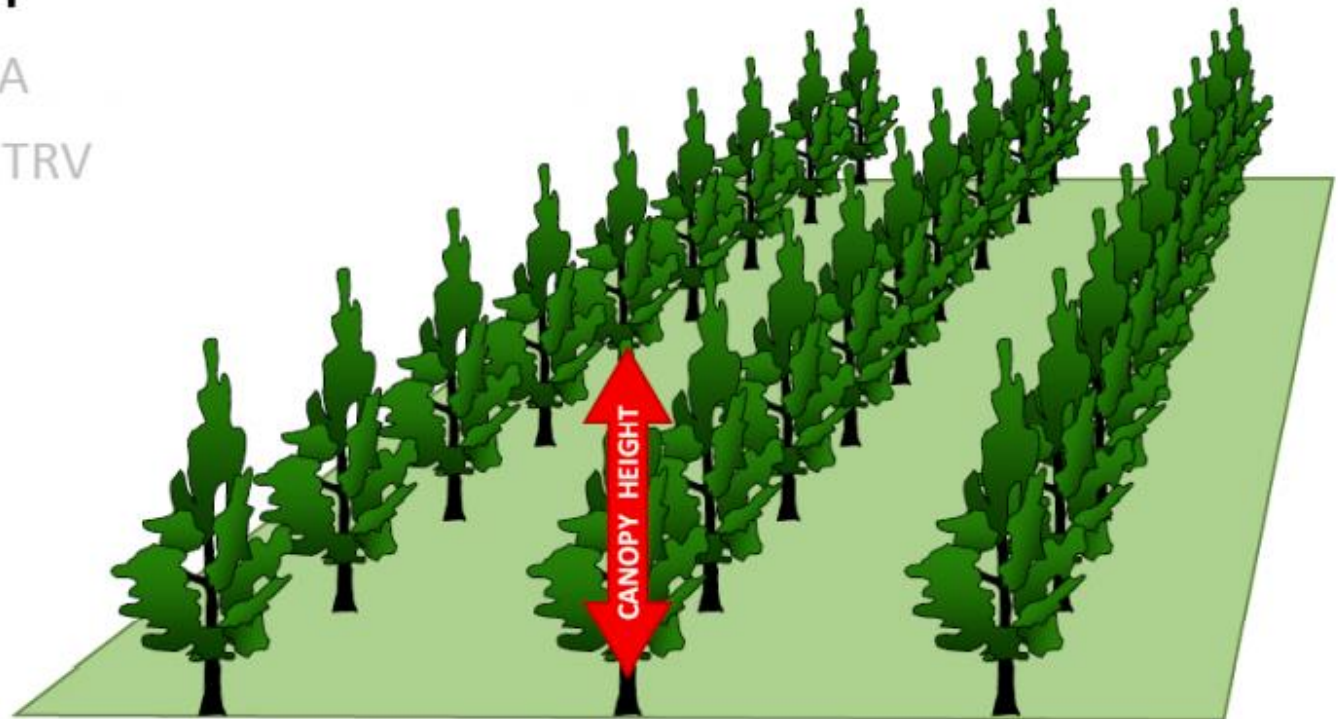


(Doruchowski 2017)

Reference units in the EU: SE, • DE, AT, (PL), (SI) • -

- ground area
- spray volume (concentration)
- **canopy height - CH**
- leaf wall area - LWA
- tree row volume - TRV
- plant row

kg or L/ha ground and m CH



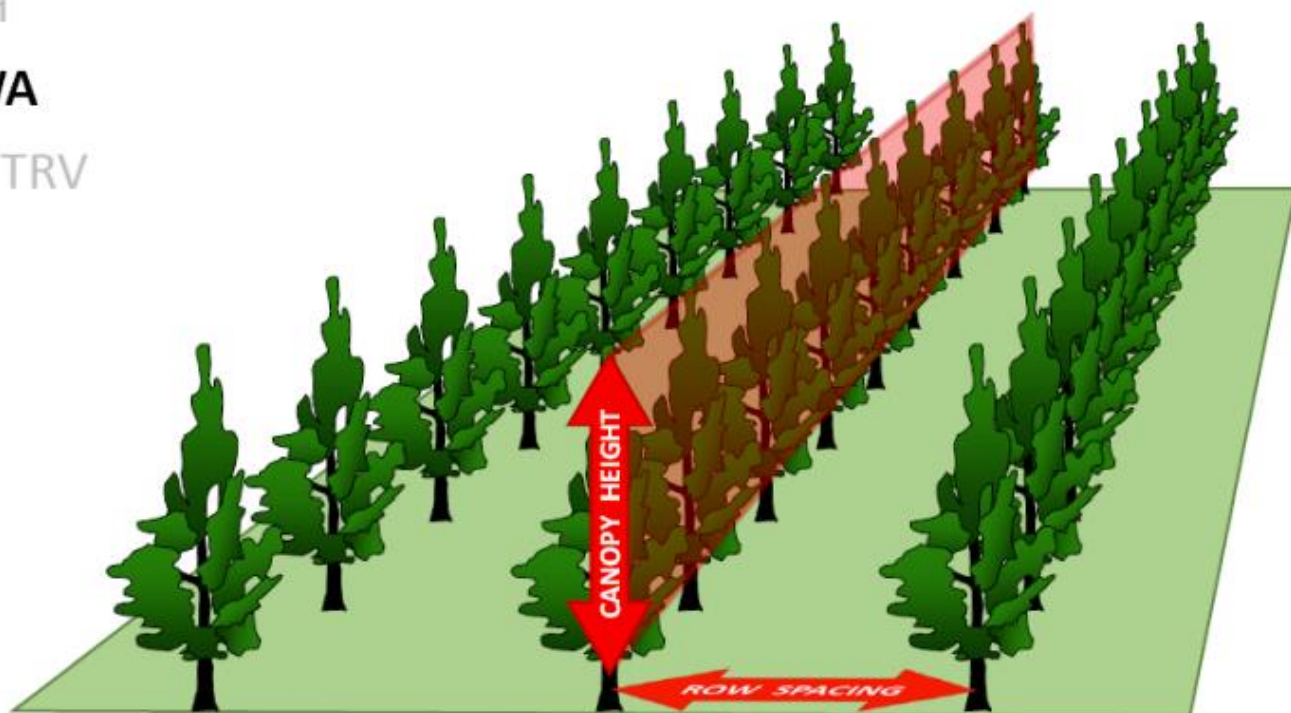
(Doruchowski 2017)

Reference units in the EU:

(LT) • BE, (PL), (SI), (AT) • -

- ground area
- spray volume (concentration)
- canopy height - CH
- **leaf wall area - LWA**
- tree row volume - TRV
- plant row

kg or L/10 000 m² LWA

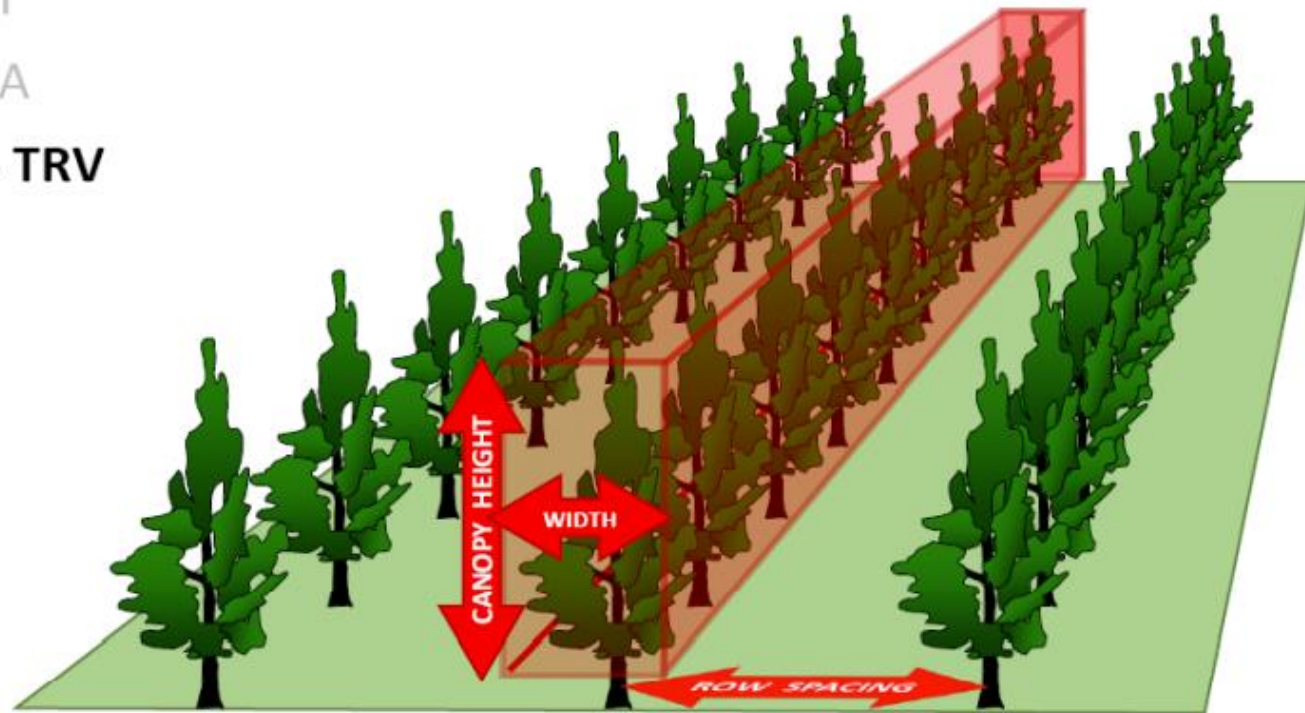


$$\text{LWA} = 2 * \frac{\text{canopy height [m]}}{\text{row spacing [m]}} * 10\,000 \text{ m}^2$$

Reference units in the EU: CH

- ground area
- spray volume (concentration)
- canopy height - CH
- leaf wall area - LWA
- **tree row volume - TRV**
- plant row

kg or L/10 000 m³ TRV



$$\text{TRV} = \frac{\text{canopy height [m]} * \text{canopy width [m]}}{\text{row spacing [m]}} * 10\,000 \text{ m}^2$$

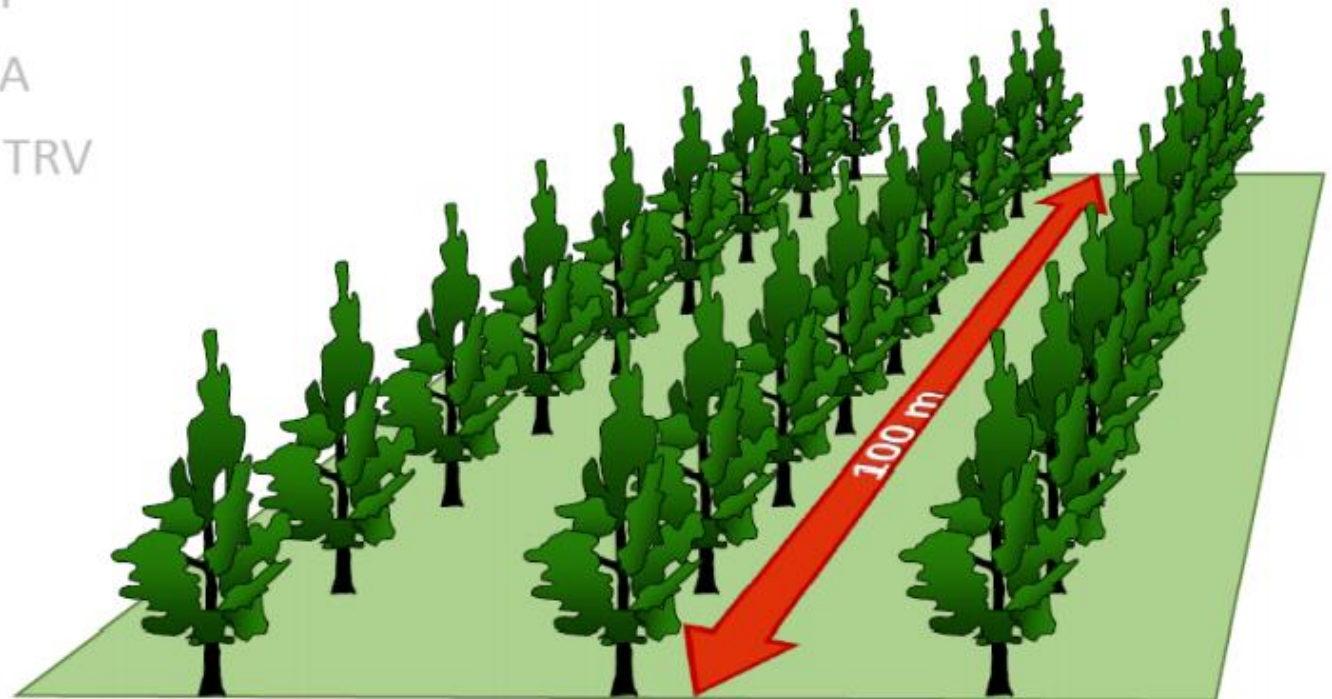
Reference units in the EU:

- ground area
- spray volume (concentration)
- canopy height - CH
- leaf wall area - LWA
- tree row volume - TRV
- **plant row**

NO

- • -

kg or L/100 m di filare



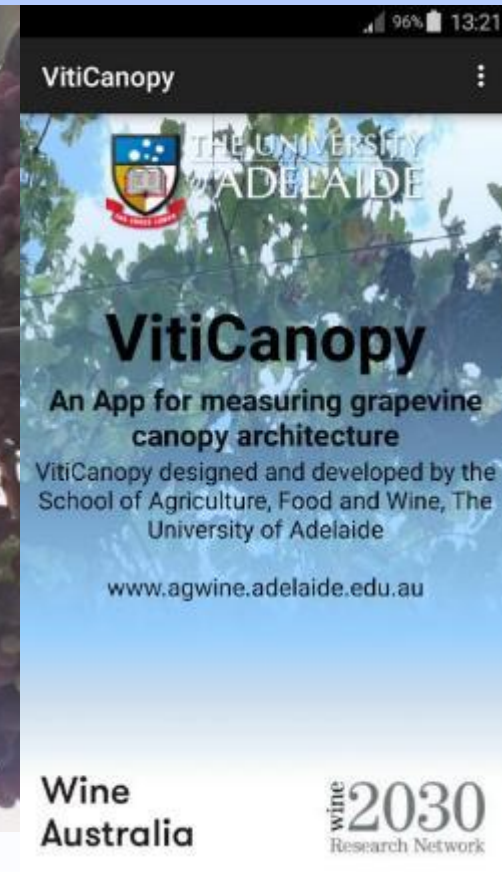
(Doruchowski 2017)

Canopy Leaf Wall Area

- The preferred dosing approach in Australia
- Not always consistent with labels and sprayer manuals, nor with some pesticide labels



Canopy Measurements





“Manual” (v Sensor Sprayer “Automated”) PACE

- Leaf Area Index (LAI) is leaf area per unit ground area
- Digital tools to assess canopy characteristics such as LAI that are needed to calculate optimum dose – Viticanopy, PARbars, other LAI sensors
- Ceptometry includes simple hand-held systems using linear arrays of photosynthetically active radiation (PAR) sensors

Complete PARbar



Leaf Area Meters



LAI In Canopies

- Ratio of canopy to sky gives approximation of LAI (e.g. hemispherical photography)

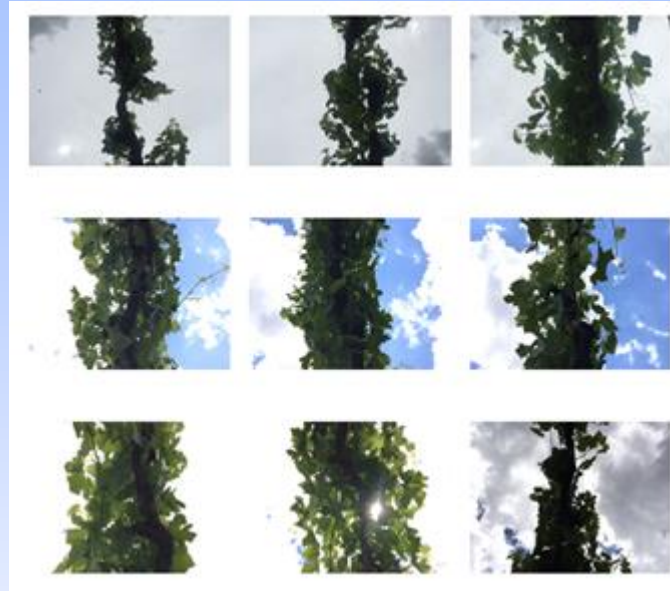
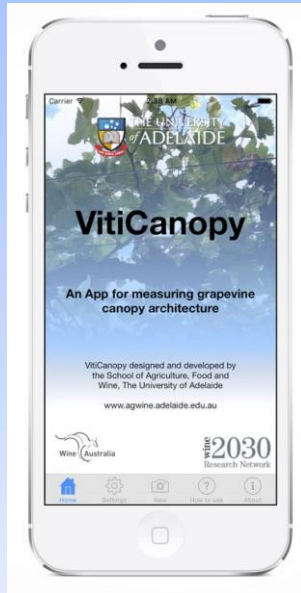


PACE

- Required coverage rate based on pest/ disease type and chemical (e.g. $\sim 1.3 \mu\text{L}$ per cm^2 for fungicides in Australia or 3.7 in some European countries)
- (We believe the range of seasonal maximum LAI values in Australian vineyards is $\sim 10,000$ to $25,000 \text{ m}^2/\text{ha}$ depending on row spacing and canopy size)
- Estimate of sprayer/ spraying efficiency (e.g. tapping into prior data from sprayer tests or a simple test by applicator assessing inner v outer canopy coverage using WSP, digital leaves, etc) – e.g. 10% efficiency will require higher application rate than 50% efficiency



Shiraz - approx. 20 samples each row



Using VitiCanopy:

- Row 2 – mean LAI 0.78, standard dev. 0.28
- Row 2 – 1.14, 0.7
- Row 3 – 0.83, 0.29



PACE Example

	Mean LAI	Required coverage uL/cm ²	Row Spacing m	Row Length m	Theoretical Spray Vol L/100m	Spray Vol L/ha	Sprayer Efficiency	Actual L/100m	Actual L/ha
Row 1	0.78	3.6	2.5	100	7.2	280	0.5	14.4	560
Row 2	1.14	3.6	2.5	100	10.2	410	0.5	20.4	820
Row 3	0.83	3.6	2.5	100	7.8	300	0.5	15.6	600

$$\frac{l}{100\text{ m}} = \frac{X\text{ }\mu\text{L}}{\text{cm}^2} * \frac{Y\text{ m}^2\text{ leaf}}{1\text{ m}^2\text{ land}} * \frac{10000\text{ cm}^2}{1\text{ m}^2} * \frac{1\text{ ml}}{1000\text{ }\mu\text{L}} * \frac{1\text{ l}}{1000\text{ ml}} * \frac{Z\text{ m}}{1} * \frac{100\text{ m}}{1}$$

Deposition
factor

LAI

Row
Distance

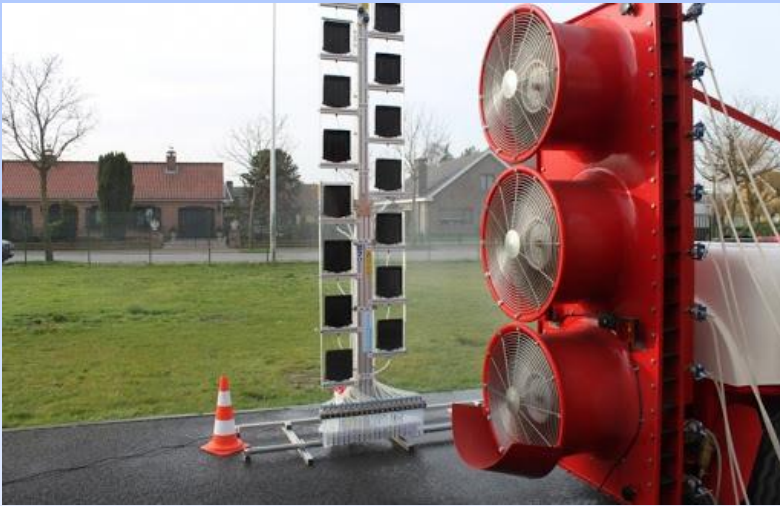


Calibration

- In addition to determining the correct application rate based on the appropriate dosing model(s), sprayers need calibration for spray distribution as well as air velocity profile
- Calibration needs to be applicable to the actual field use



Vertical Patternator (e.g. AAMS Salvarani)





Air velocity

- Where possible, adjust the air velocity to match the canopy and not be excessively high that spray carries through several rows
- Can measure air velocity profile using anemometers on a vertical tower



Custom Drift Curves

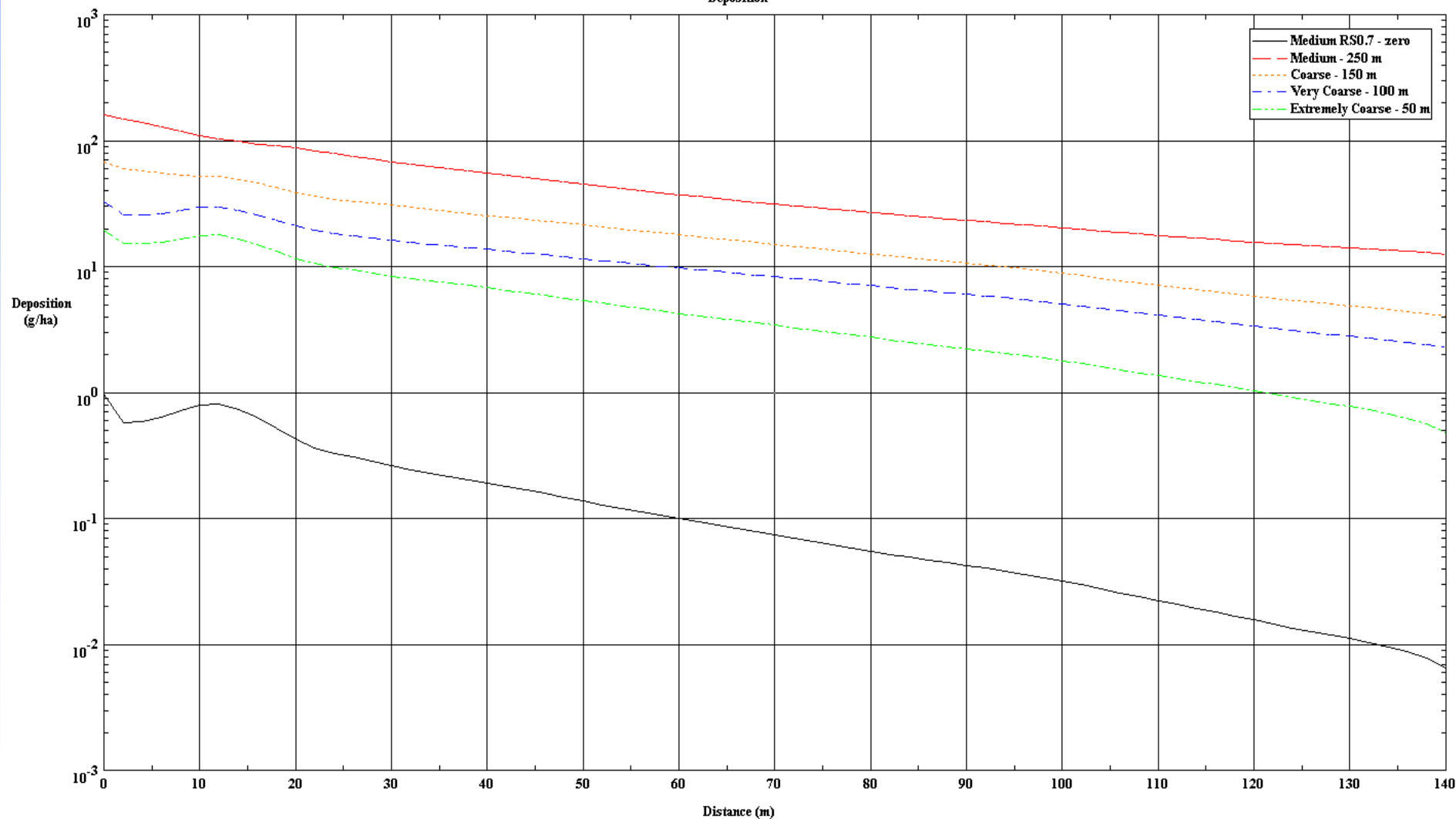
- AgDRIFT includes baseline regulatory drift deposition data for use in US, based on SDTF data
- APVMA in Australia mainly considered European data and divided canopies mainly according to height ($<$ or $>$ 2m)
- DRT scheme allows submission of data for lower drift scenarios such as better sprayers



Droplet Size as a DRT-Modeled Ground

Medium Spray with DRT for Dv0.1/ Fines

Deposition

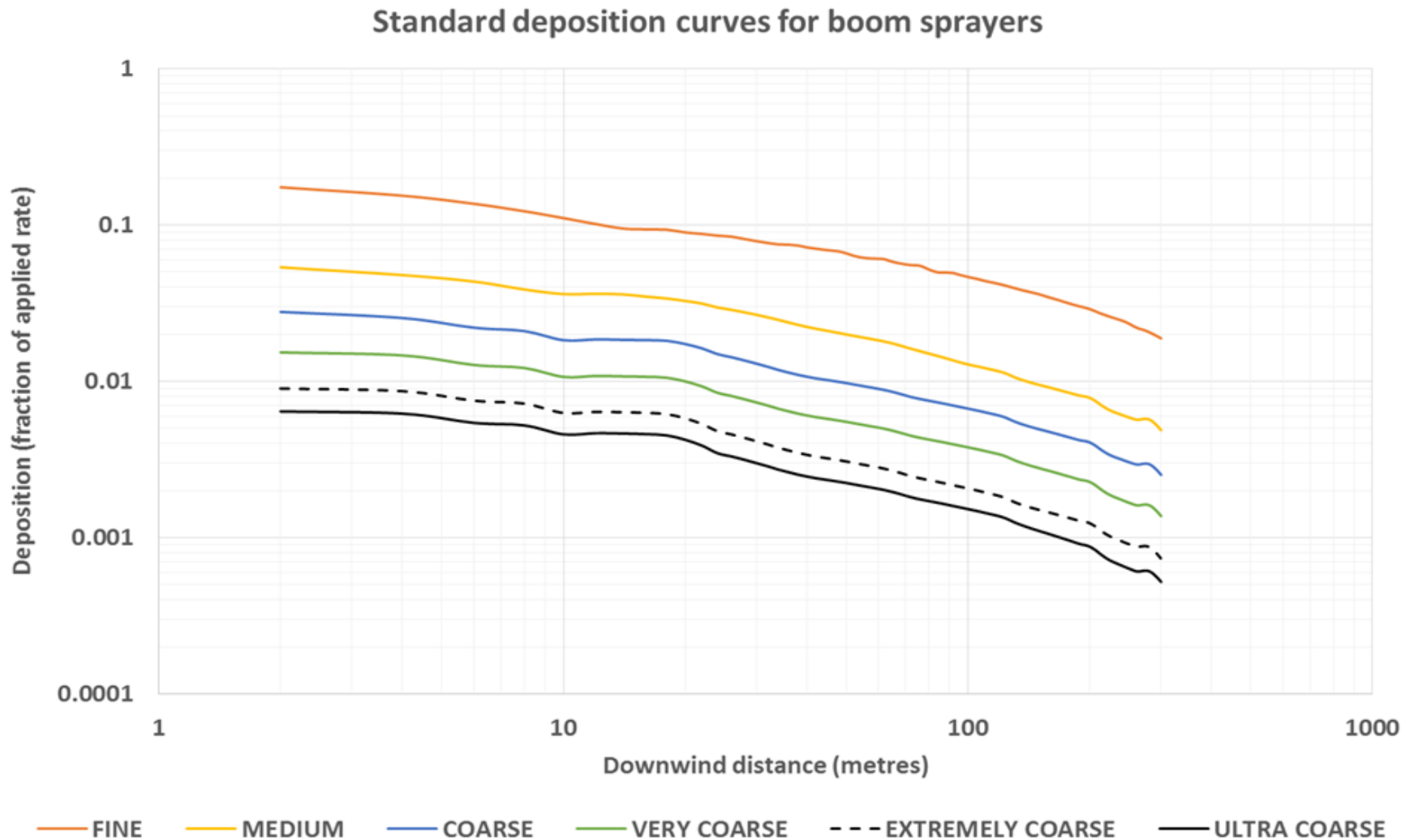


APVMA Drift Assessment Approach

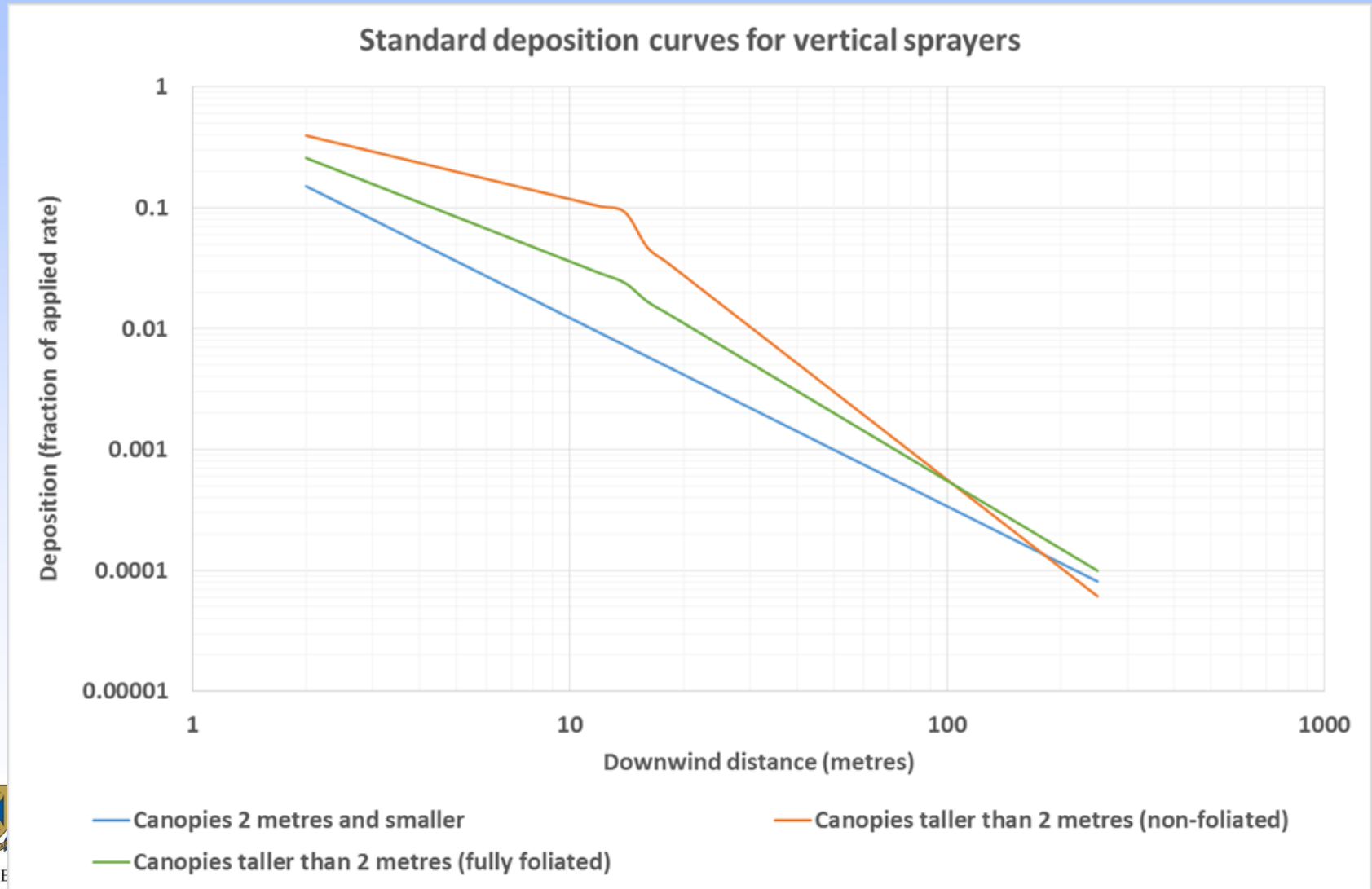
- Spray Drift Risk Assessment Tool (SDRAT)
- Spray Drift Management Tool (SDMT)
- Covers all application platforms and aims to offer no-spray buffer zone flexibility
- Based on AGDISP model use, but with appropriate inputs and methodology



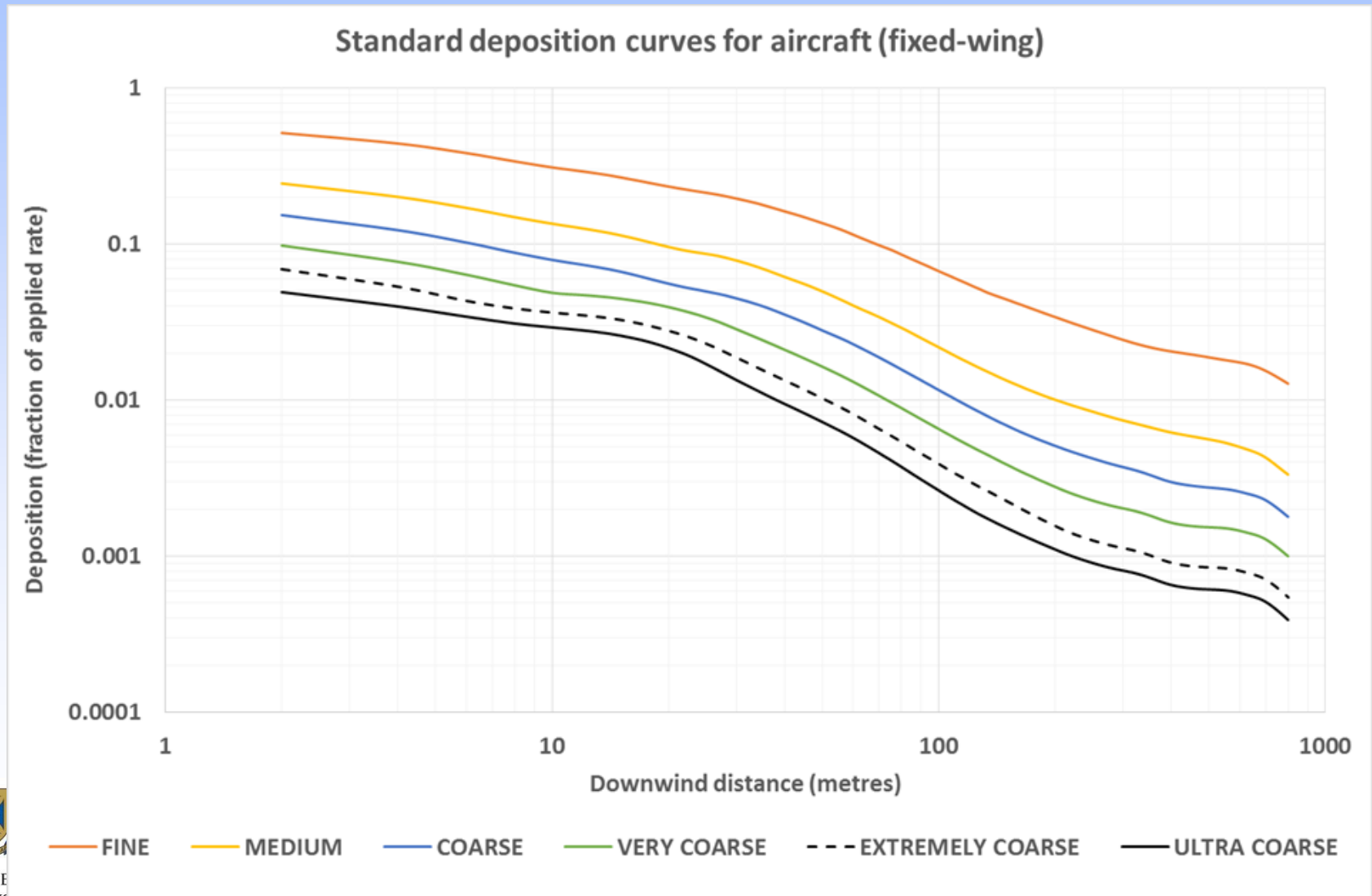
Standard Ground Deposition Curves



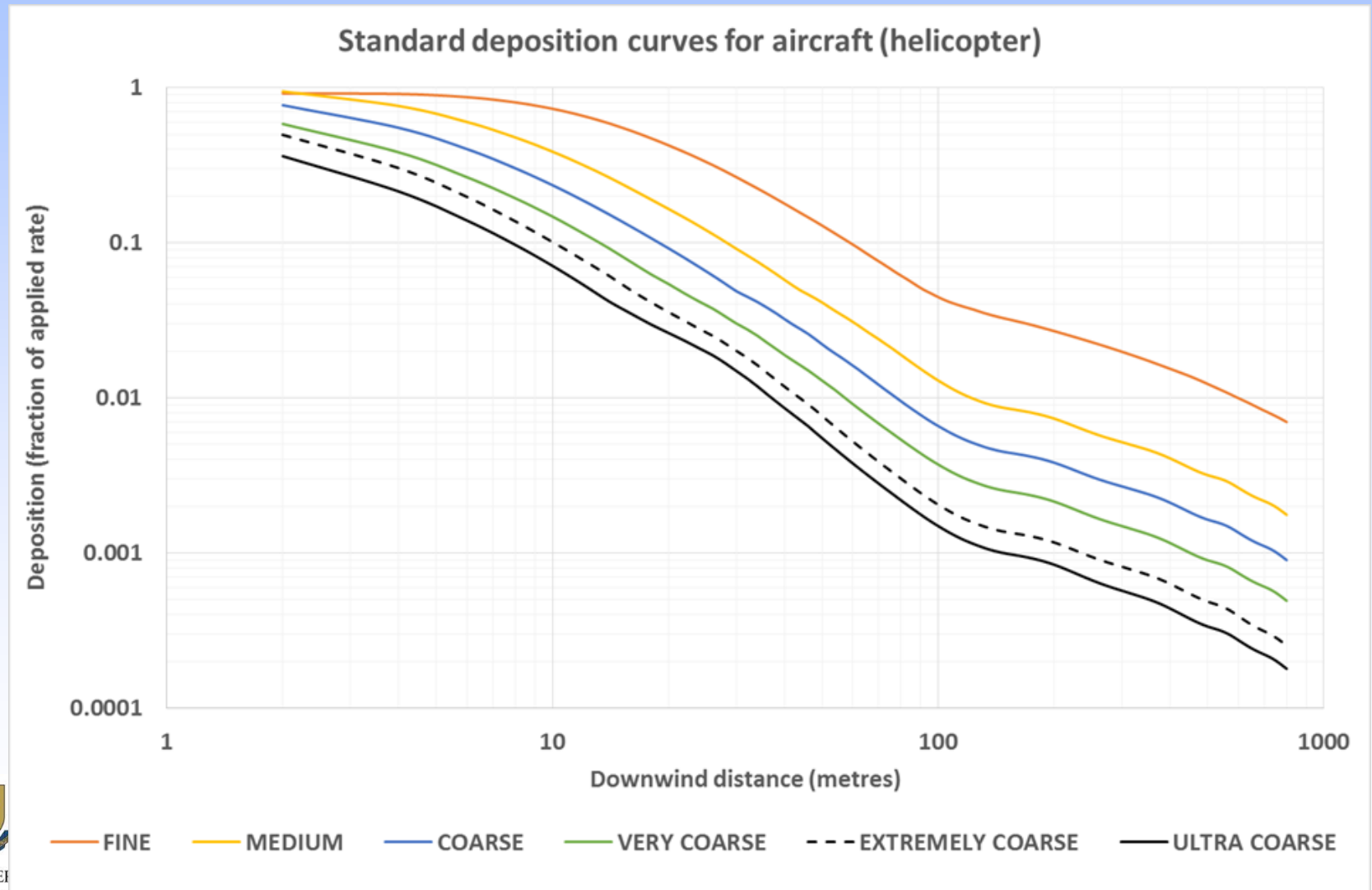
Vertical Sprayers



Fixed Wing Aircraft



Rotary Wing Aircraft



Comparative Buffer Zones by LOC and Application Platform for Typical Current Spraying

LOC	Ground	Aerial FW	Aerial RW	Vine- Tree
0.1	0	6	11	3-10
0.01	50	100	80	10-30
0.001	~500	~1000	800	50-80



I assumed Coarse sprays for aerial and ground here

Spray Drift Management Tool

Custom deposition curves will typically be generated from information that relates to drift reducing practices, technologies or innovations, including:

- Specific nozzle performance
- Improved equipment designs
- Equipment modifications
- Adjuvants (additives and components of formulations)
- Improved equipment operating practices



Field Trial Data

- 90th percentile will be the key
- Values below the limit of detection cannot be considered in the risk assessment
- Reference sprayer required unless statistical validity can be proven (e.g. large number of reps). Reference sprayer should be similar to the current reference defaults (note we have already proven this for our vineyard research sprayer)
- ISO 22866 (also reference to other standards – ASABE, JKI, EPA DRT)



Wind Tunnel Studies

- Drift potential data: ISO 22856 and background materials in ASTM and EPA DRT standards

ISO 22856: Equipment for crop protection -- Methods for the laboratory measurement of spray drift -- Wind tunnels

- Droplet size data: ASABE reference droplet size data to be supplied (current ground and future aerial)
- Droplet size converter is run to convert droplet size data from each lab to a single format for input to APVMA assessments



Adjuvant Testing

Spray drift data should be generated with either:

- The specific nozzle or nozzle/s and pressure ranges intended for use (which would then form specific label instructions or SDMT conditions that limit use only to what was tested), or
- The set of nozzles listed in Table 1 for the droplet size relevant to the application (which would then allow label instructions or SDMT conditions to apply to any nozzle/pressure which can achieve that droplet size classification)



Nozzle Type	Exit orifice Type	Nozzle	System Pressure (bar)					
			F	M	C	VC	XC	UC
Air induction	Single	Hypro ULD120-04				6.0	4.5	2.5
		Hardi ISO Minidrft 025		6.0	4.0	2.0		
		TeeJet AIC11025				6.5	4.5	2.5
		TeeJet AIXR11002		6.0	5.0	2.5	1.5	
	Twin	TeeJet AI3070-02			4.0	2.0	1.5	
		Hardi ISO Minidrft Duo 025		6.0	4.0	2.0		
Air induction - Anvil	Single	TeeJet TTI110015					7.0	3.5
	Twin	TeeJet AITTJ60-11003			7.0	4.0	2.5	1.5
Anvil	Single	TeeJet TT11001	6.0	2.5				
		TeeJet TT11004			4.5	1.5		
	Twin	TeeJet TTJ60-110025		6.0	4.5	1.5		
Flat fan	Single	Hardi ISO F-110 015	5.0	1.5				
		TeeJet TP11001	3.5					
		TeeJet XR8003	4.0	1.5				
	Twin	TeeJet TJ60-6503	4.0	2.0				
Hollow cone	Single	TeeJet TX-18	5.0					
Pre-orifice flat fan	Single	Hardi ISO LD-110 025		5.0	2.0			
	Twin	TeeJet DGTJ60-11002	4.0	2.5				

Aerial and Vertical Sprayers

Due to the relatively small range of nozzles available, for aircraft and vertical sprayer equipment spray drift data should be generated only with the specific nozzle or nozzle/s and pressure ranges intended for use



Tank Mixes

If a tank mix is a specific instruction in the 'Directions for Use' table of the label then wind tunnel studies should be reflective of this tank mix, i.e. if the label directions for use require another product to be included in a tank mix then both products should be included in the test solution.

If a tank mix is not a specific label instruction but is allowed under applicable [state or territory legislation](#), there is no need to include tank mix partners in wind tunnel testing. This is reflected in the current [APVMA labelling agricultural labelling code](#) in section '16. Compatibility statements' and is a matter for industry stewardship programs to address. However, in accordance with [Reporting new information](#) requirements, if a tank mix is known to increase spray drift risk, applicants or registrants are required to notify the APVMA and include incompatibility statements on product labels.



Label Statements - Adjuvants

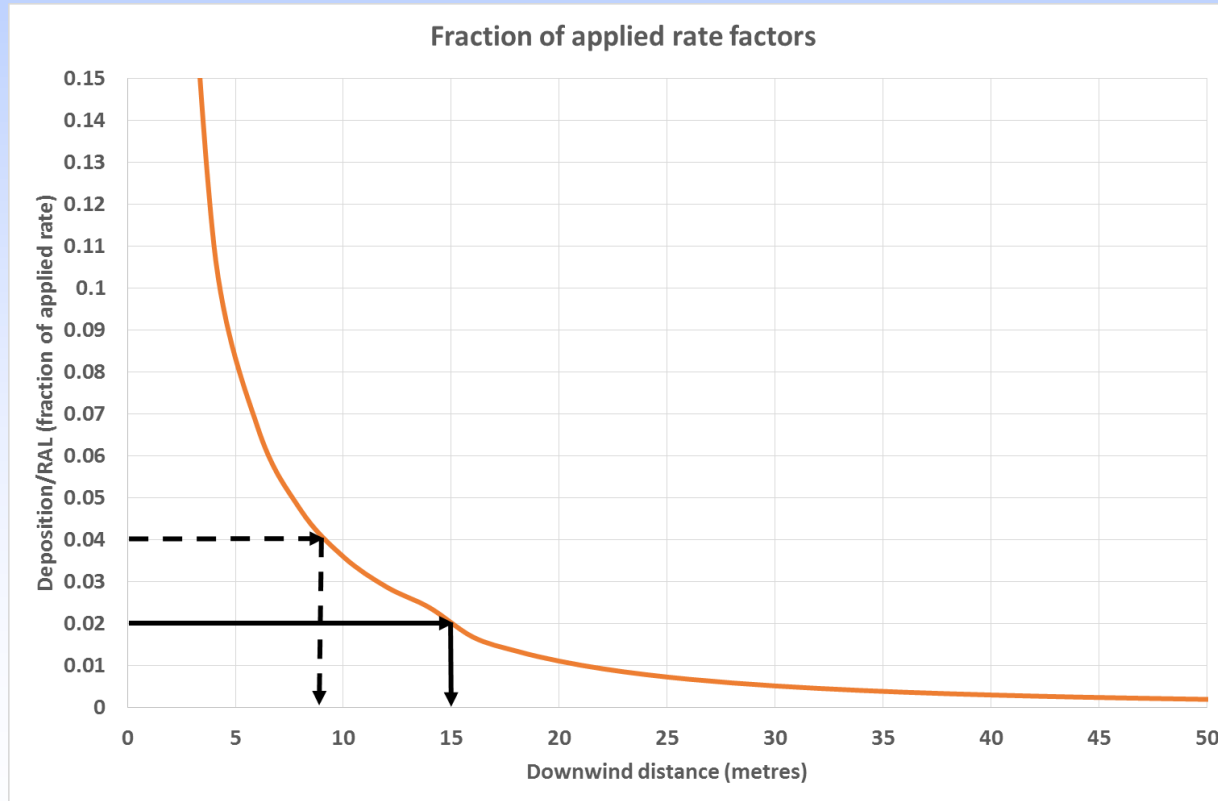
When an application proposes the addition of a drift reduction adjuvant, examples of potential additional instructions are:

- 'only to be applied when [Adjuvant Product Name and Number] is used in a tank mix at label rates'
- 'minimum distances between the application site and downwind sensitive areas that appear in the 'Mandatory buffer zones' section of the table below titled 'Buffer zones for boom sprayers with or without using adjuvant' (where the first row of the table lists buffer zones established by a risk assessment using standard deposition curves and the second lists buffer zones established by a risk assessment using custom deposition curves)



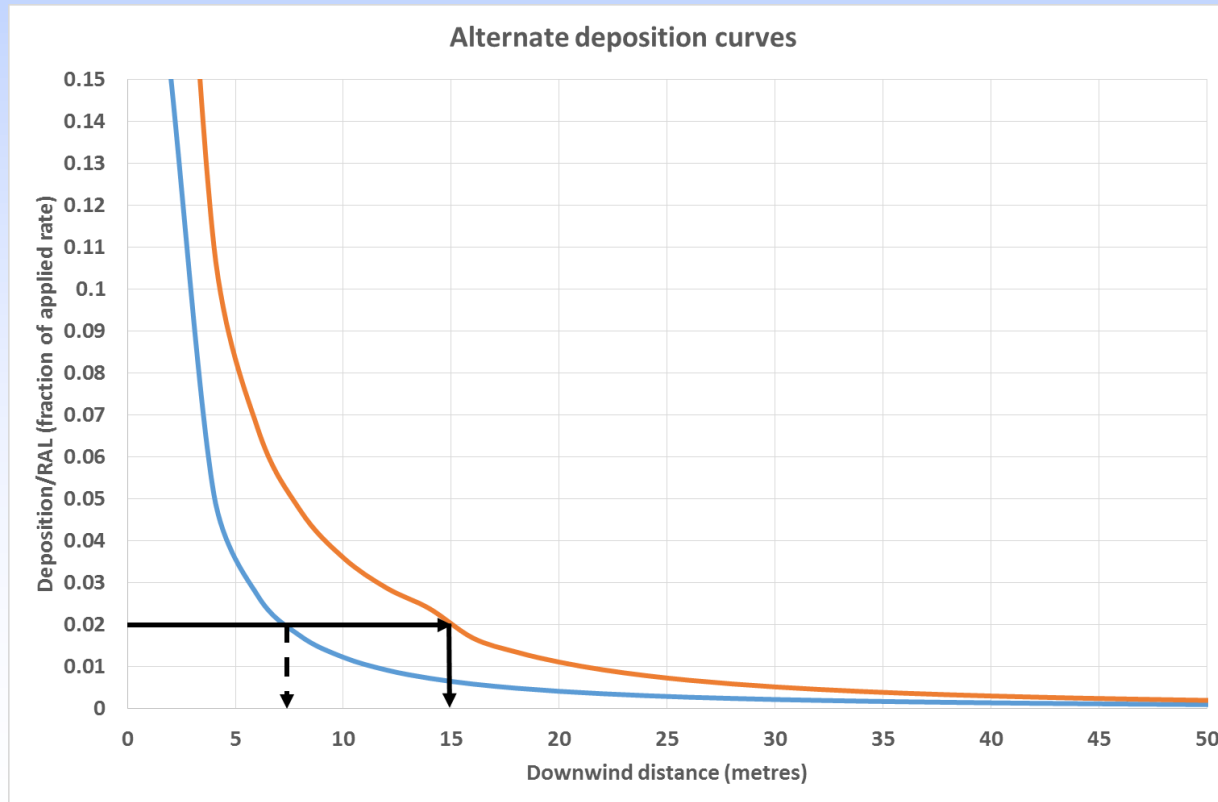
Buffer Zone Modification via Fraction of Application Rate

(e.g. different use rate; different pond depth; spot spraying)

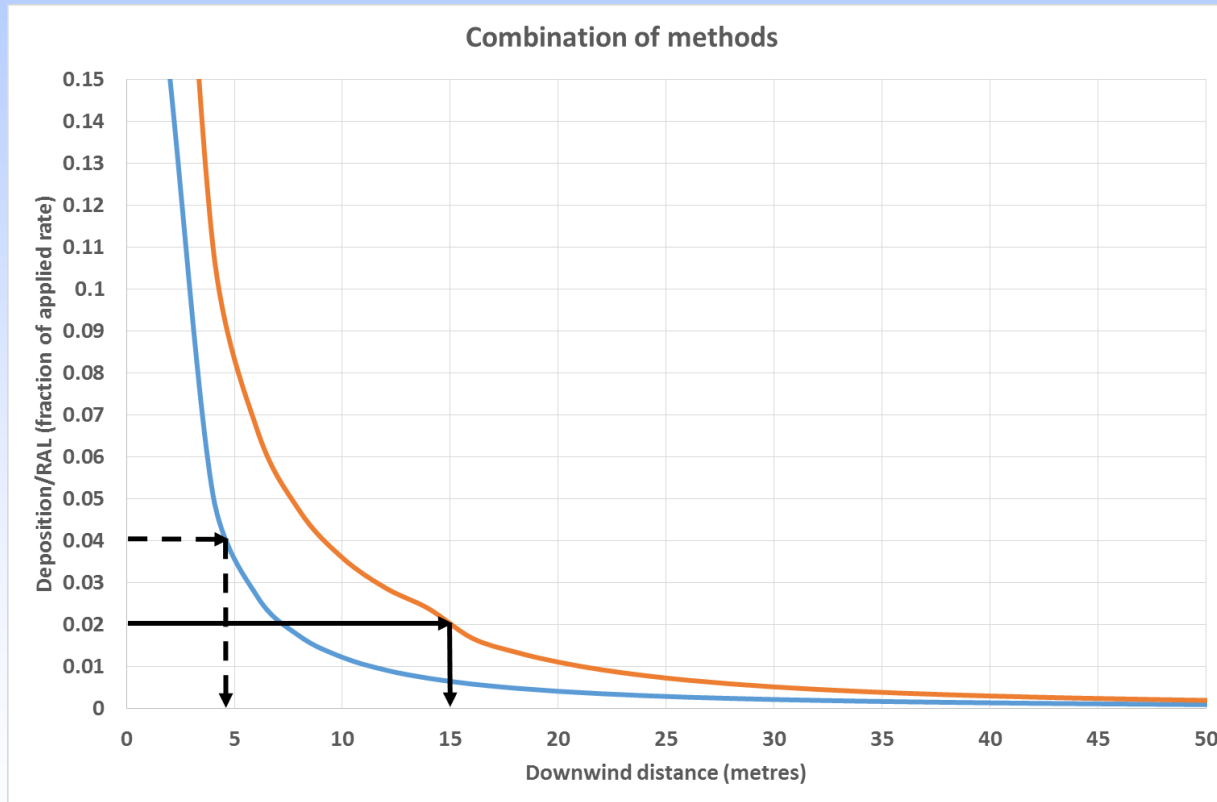


Buffer Zone Modification via Deposition Curves

(e.g. different equipment or adjuvants)



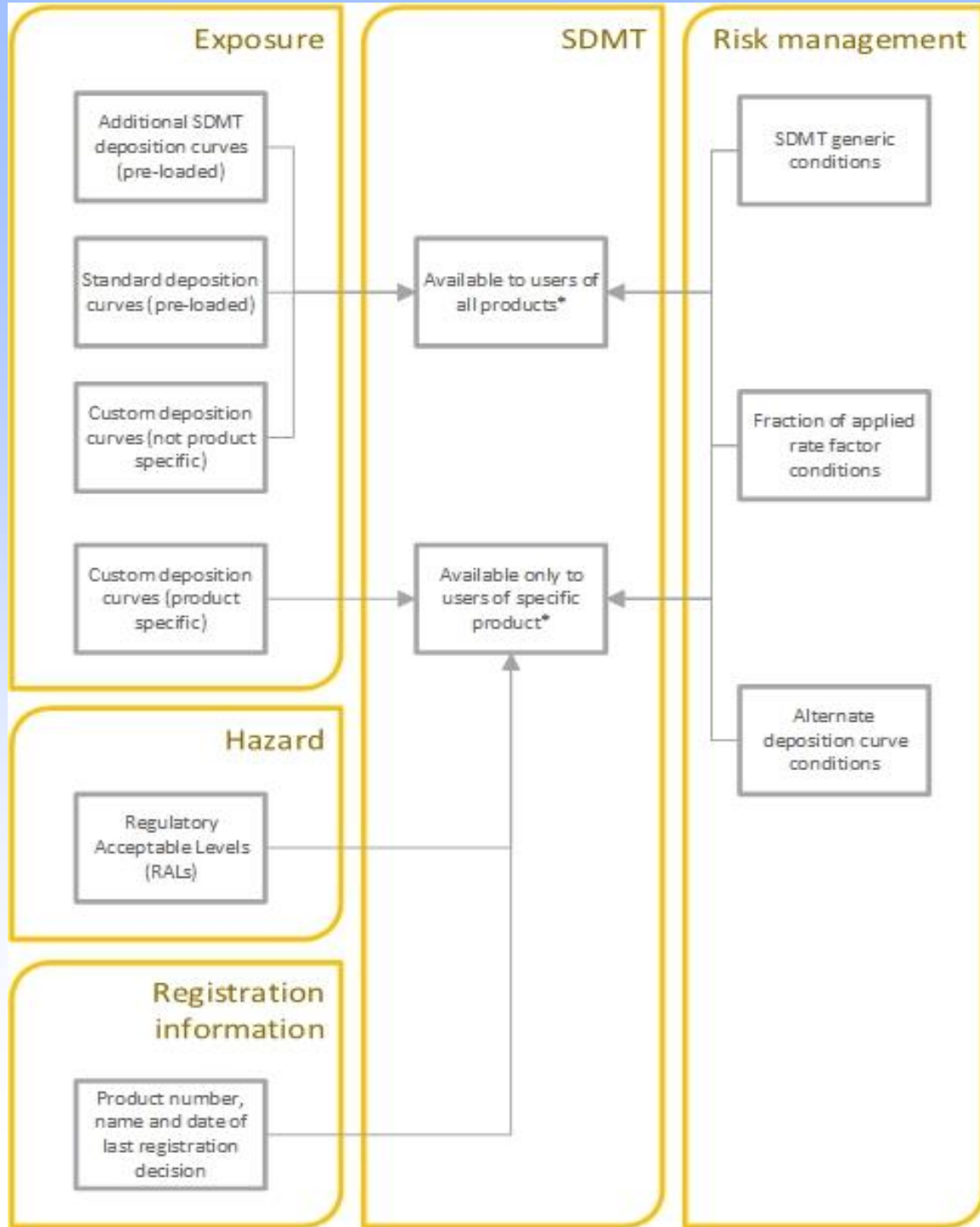
Combination of Methods



More on Data for New Deposition Curves

- Adjuvant or nozzle company (for example) would submit data to APVMA for technical assessment
- The company can then seek consent of a registrant to support the technology in their registration, or consent to APVMA to make their data available to any registrants



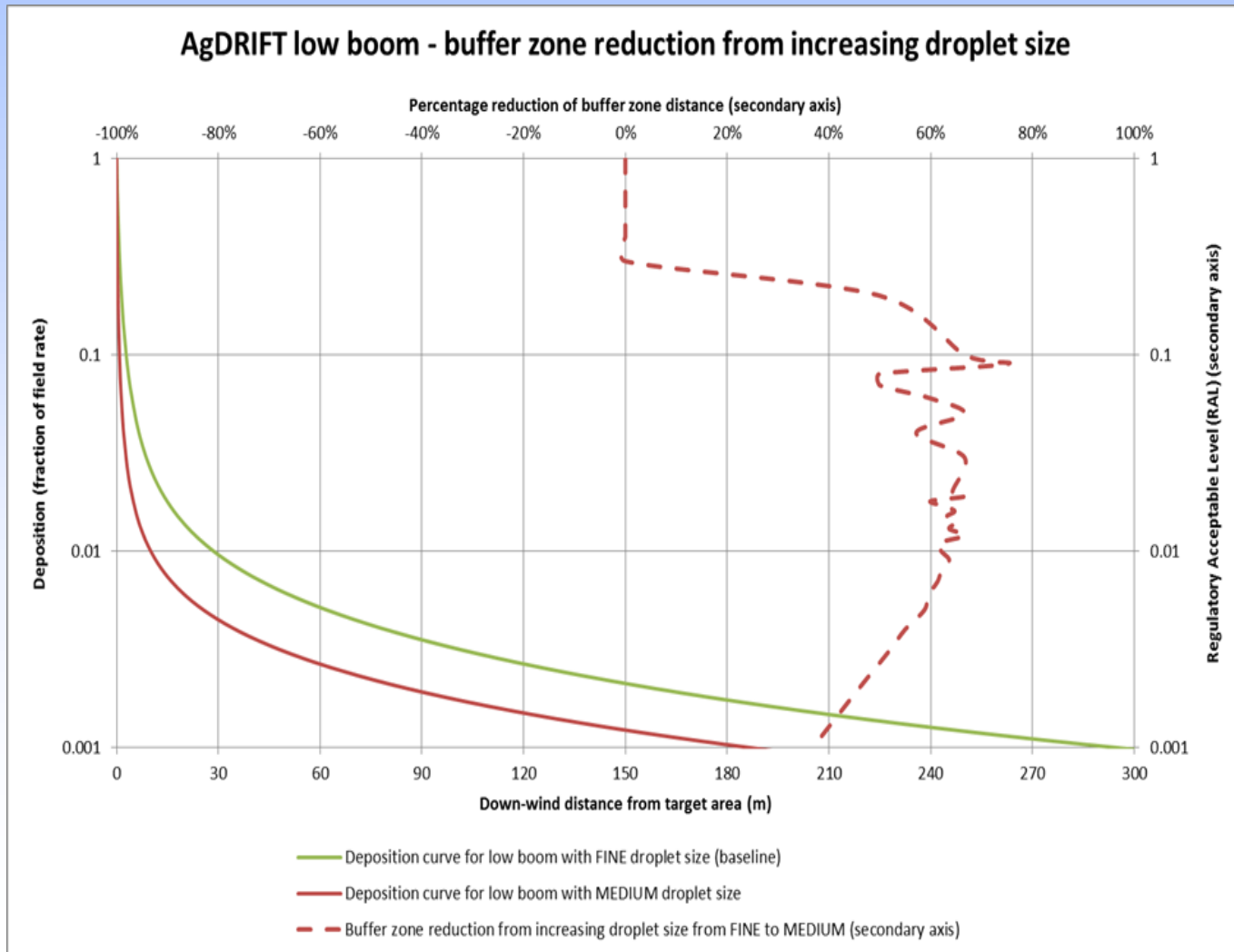


Caveat

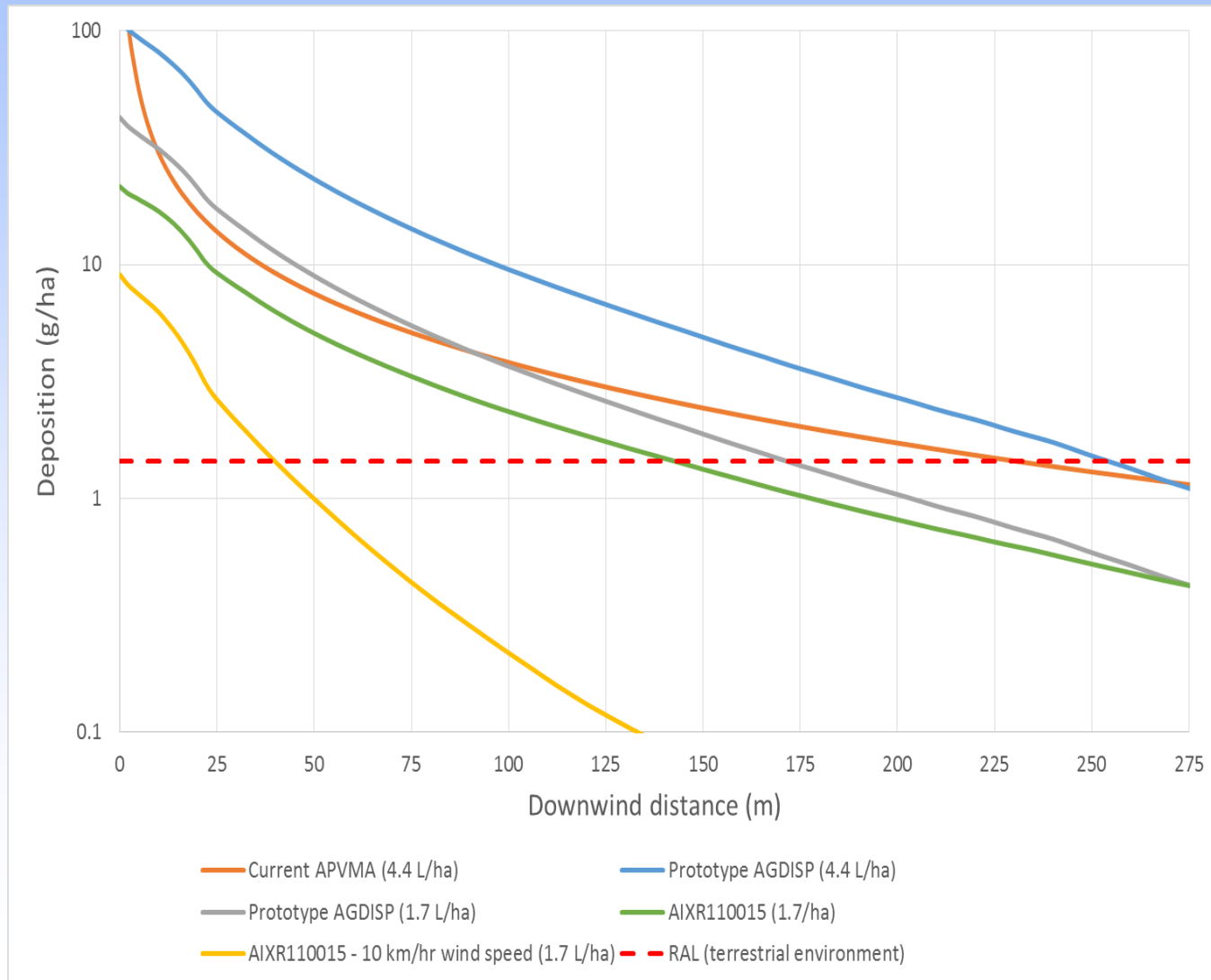
- It is the responsibility of the chemical user to ensure any practices, technologies or innovations specified in SDMT conditions will be efficacious for the product and use situation.



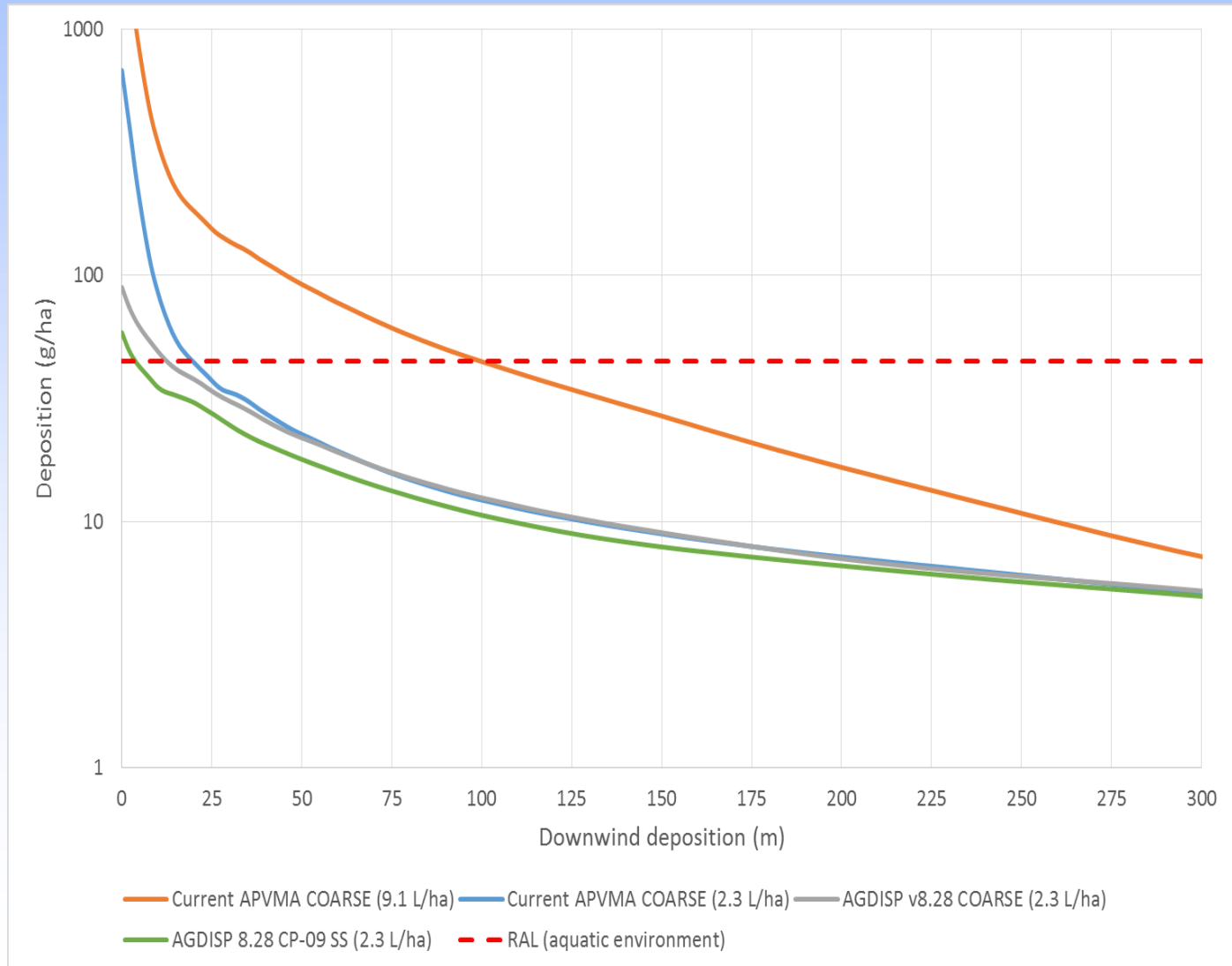
DRTs - One Size Does Not Fit All



Ground Drift Analysis Example



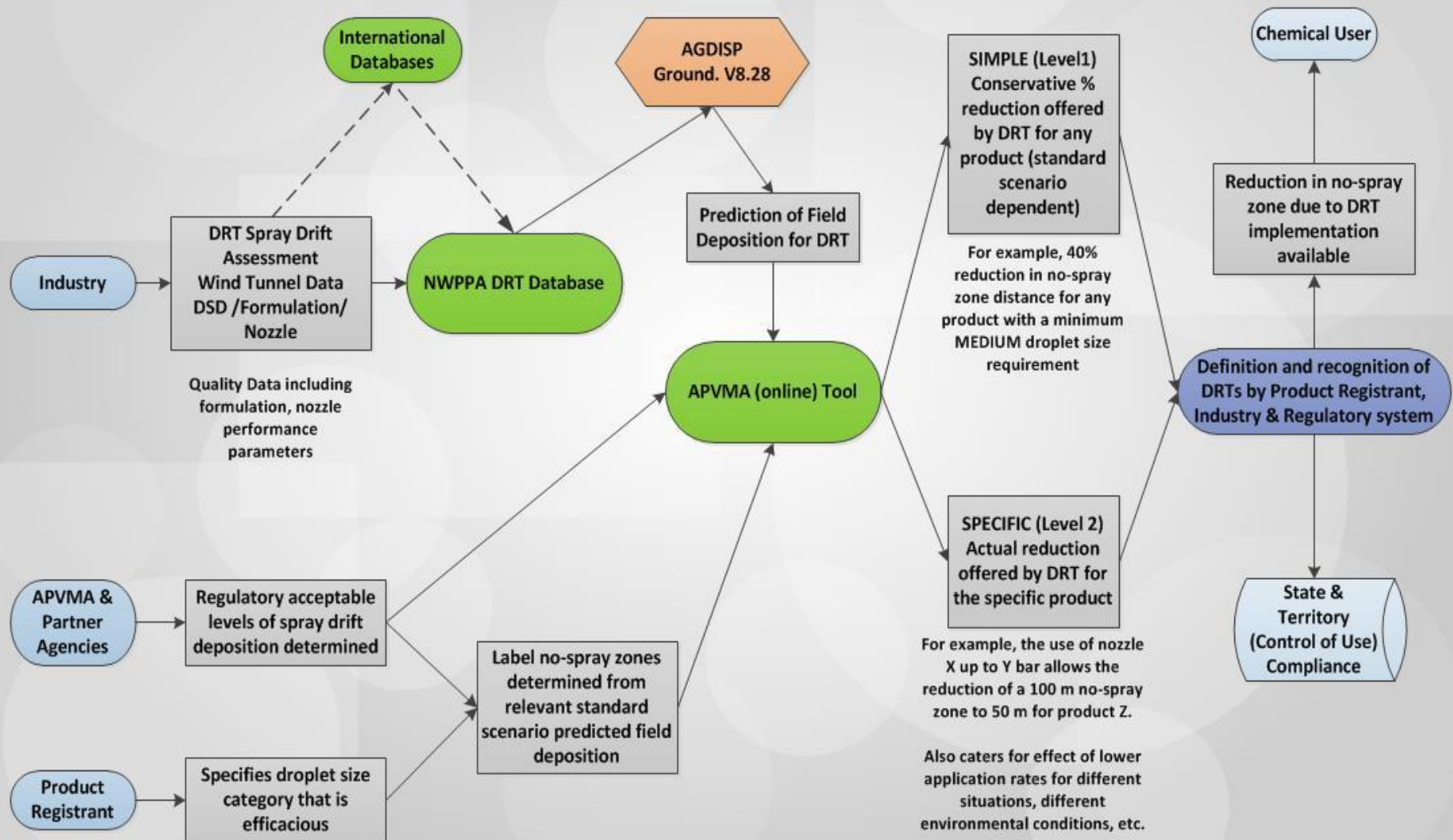
Aerial Drift Analysis Example



Overview of potential DRT Regulator Scheme being proposed by the NWPPA TWG (Boom Sprayer Ground)

To facilitate recognition of DRTs and opportunity to lower buffer distance.

Reduction of no-spray zone calculated using AGDISP Ground v8.28 and based on reduction in predicted deposition compared to product assessment



Actual Applications

- Some registrant and grower groups have submitted data to APVMA under the new scheme or are in the process of doing so (we are working with one company and the forestry sector to submit some of our field study wine industry and wind tunnel forestry research for lower drift nozzles and sprayers for example, to seek reductions in no-spray buffer zones and special permits)



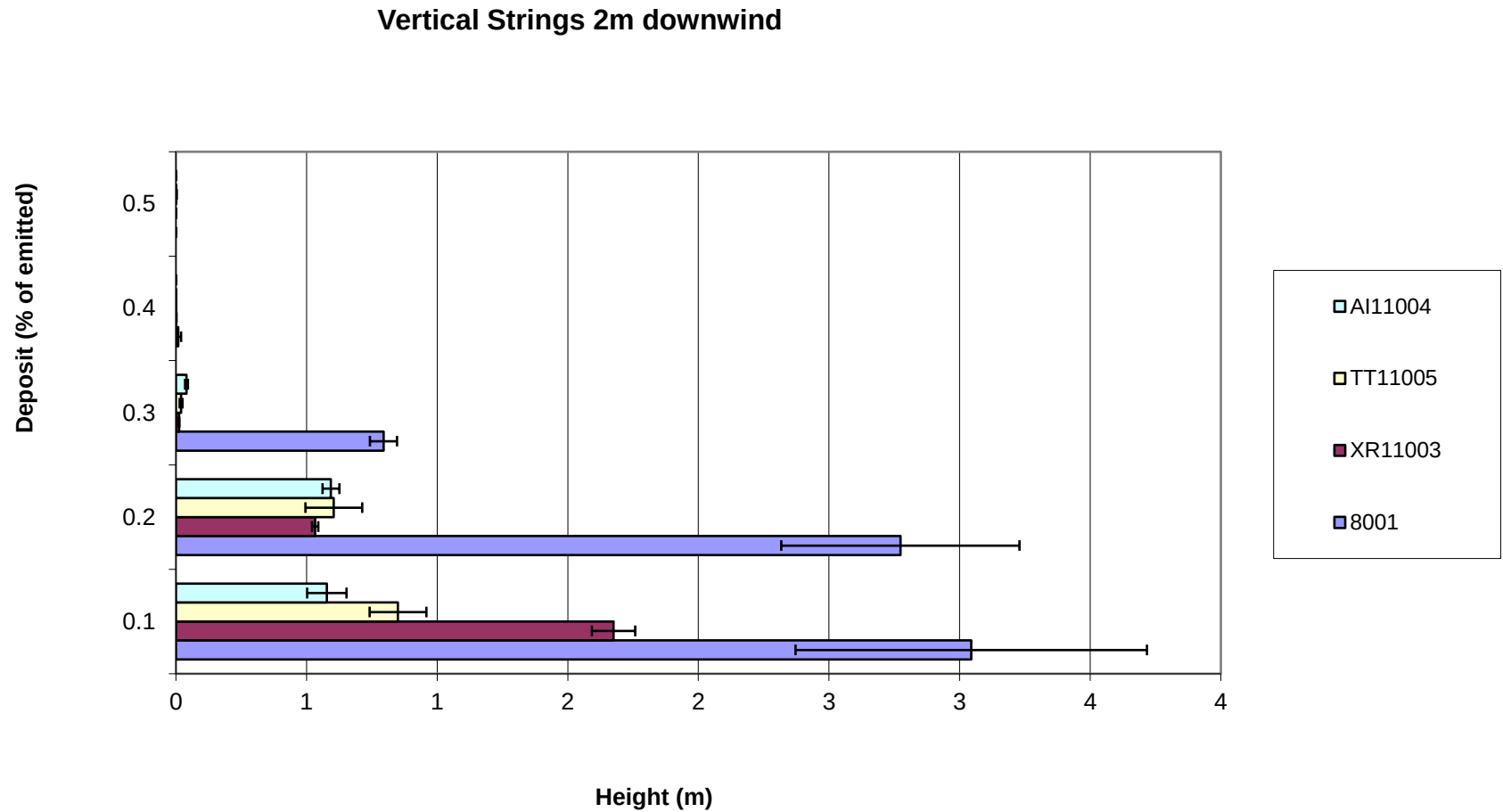
DRTs

- Many DRTs can be easily tested in wind tunnels (e.g. nozzles, adjuvants, PWM, etc)
- A few DRTs may require field testing (e.g. entire sprayers)

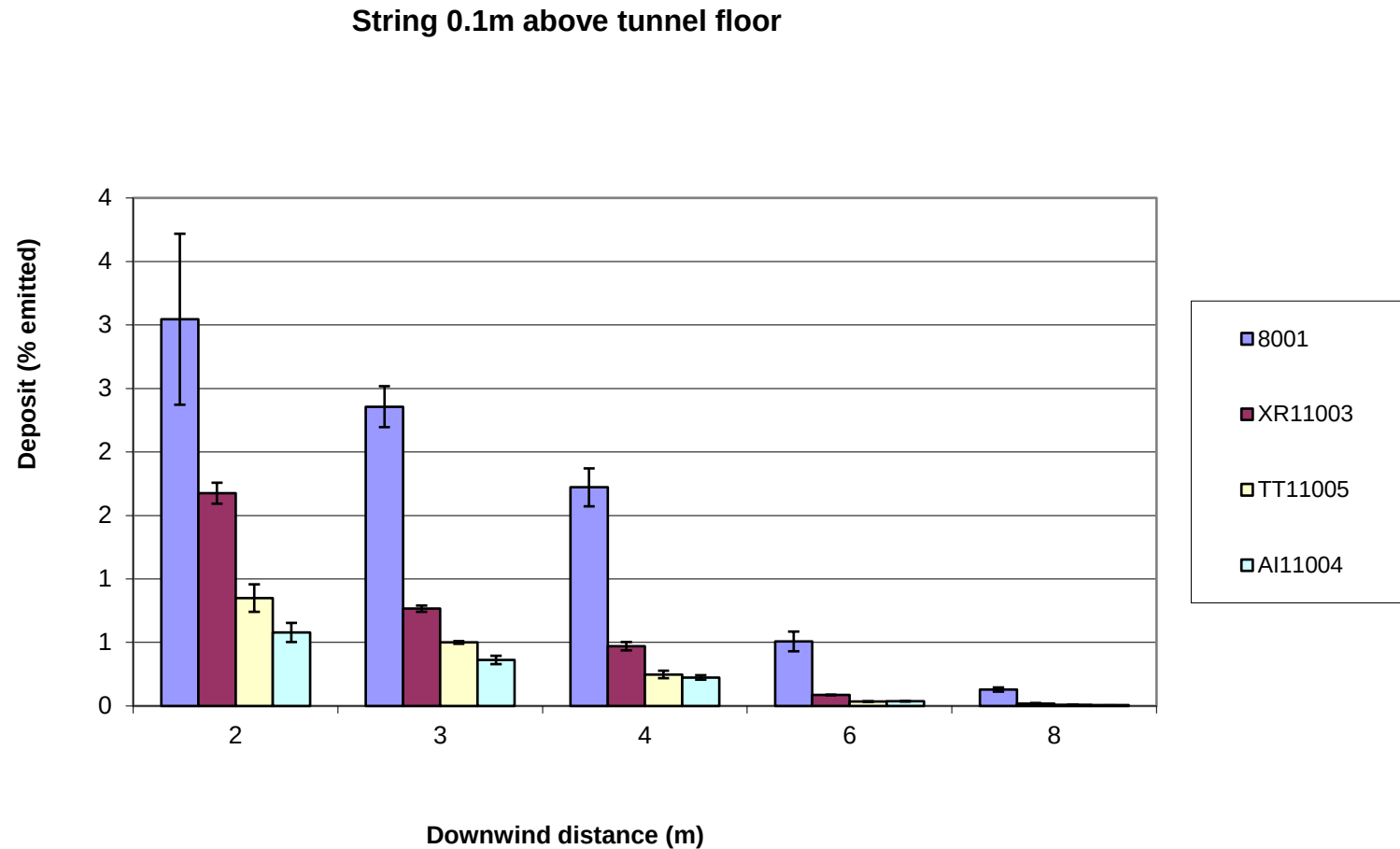




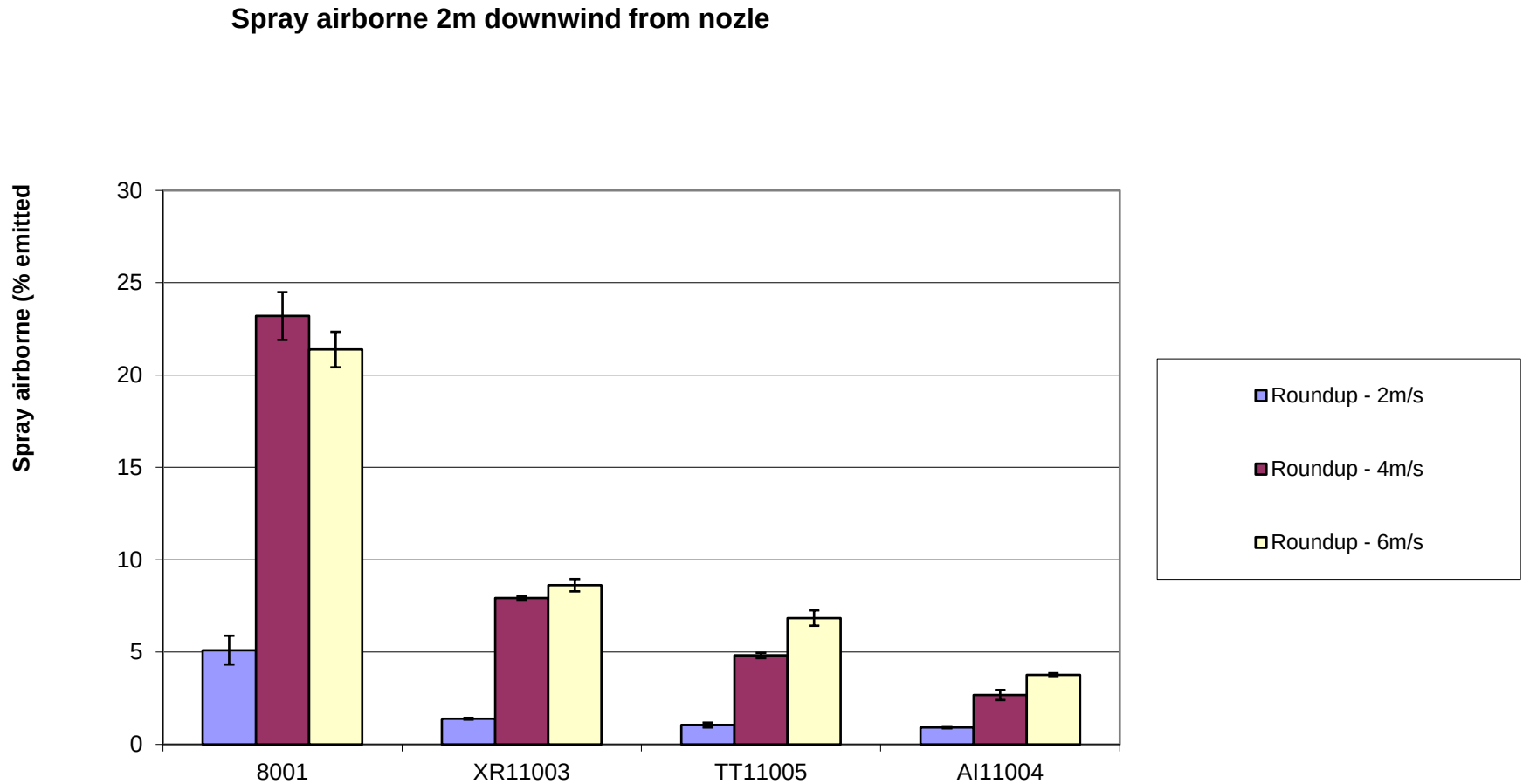
Airborne Drift at 2m



Deposition Downwind of Nozzle

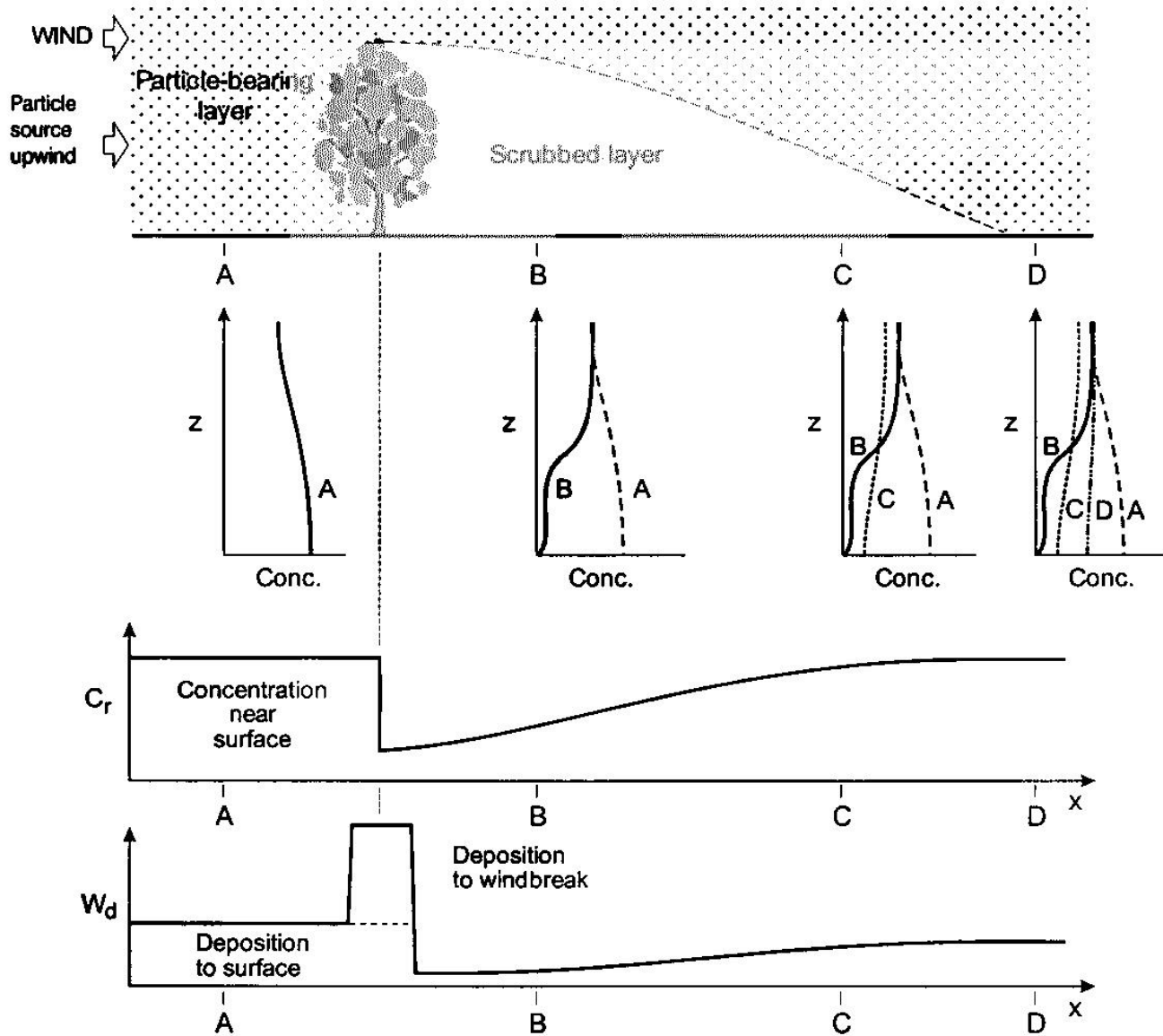


Effect of Wind Speed on Drift



Hedges and The Rural/Urban Interface





Conclusions

- GRDC and others have collected droplet size data for DRT use in ground spraying. Limited aerial data have been collected for DRT use but UAV work is ramping up. Vertical crop data in wind tunnel and field studies have been collected and some (e.g. forestry) are being directly used for risk assessment while others (e.g. vineyard) are being adapted for such use
- Most of the data and model developments in Australia are handled through the National Working Party on Pesticide Application and its Technical Working Group, yet separate groups do the research and then it can be challenging to submit data which weren't collected with registration uses in mind
- APVMA DRT policies and tools are being tweaked but it is likely that the testing principles (wind tunnel and field studies) will not change much
- Baseline curves are deposition for different application scenarios, and can be supplemented by new data from companies
- DRT testing could be kept as confidential for specific scenarios or linked with many/all registrant products
- Some forestry groups have collected data already to submit to APVMA for their own regulatory change requests

