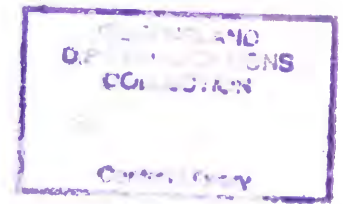
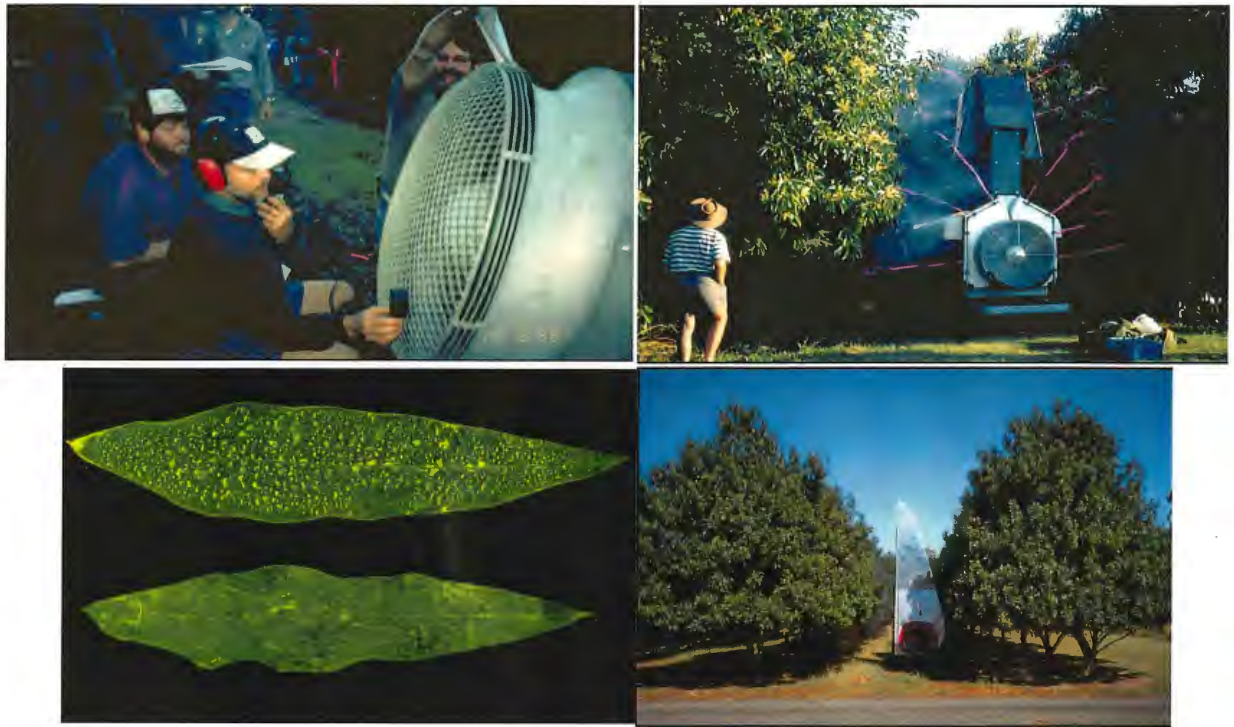


# MACADAMIA AND AVOCADO SPRAY TECHNOLOGY WORKSHOPS

Project HG97011



Final Report



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# Macadamia and Avocado Spray Technology Workshops

**Project HG97011**

**FINAL REPORT**

**This report includes an overview of some key issues affecting the long term sustainability of orchard spraying practices for the avocado, macadamia and other orchard industries.**

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## 1. SUMMARY

### *Industry Summary*

The workshop series on spray application technology for macadamia and avocado crop protection conducted in this project received overwhelming support from growers, agri-business staff and consultants. This demonstrated there was considerable enthusiasm by growers to receive information relating to technological advances or other techniques that may improve the efficiency and efficacy of their pesticide application systems. The workshops served to create awareness on general techniques that can be applied to make spraying tree crops more efficient. All users of agrochemicals in the farming sector are under close scrutiny by both the public and media. The avocado and macadamia industries are no different. Many avocado and macadamia production districts are in close proximity to highly valued urban developments. The long term viability and profitability of these farming enterprises may be decided by whether or not these farmers can continue to spray. It is therefore imperative that development and extension work in spray application be continued to enable these growers as well as the whole industry to become as efficient as possible.

Without detailed research in the specific tree canopies of these crops for spray coverage using a range of volumes and equipment types, firm recommendations on optimum sprayer configurations for growers are not possible.

### *Technical Summary*

An extension project was conducted delivering nine workshops to macadamia and avocado growers in seven production regions throughout Australia. These workshops covered topics on air and water volume calibration, the principles of droplet generation and presented a range of results from application trials in apples, lychees, macadamia and citrus. At each workshop growers were given the opportunity to apply the theory presented in the technical sessions by calibrating sprayers. Using equipment made available by growers and supplied by equipment resellers, fluorescent dye was applied to trees and the spray deposits examined under black lights after dark. This gave growers the opportunity to visually compare the spray deposits

throughout the tree canopy as well as non-target areas. Approximately 400 participants attended the workshops with 75 from the agribusiness sector and industry consultants (Table 1).

**Table 1. Workshop program summary:**

WORKSHOP NUMBER	DATE	LOCATION	NO OF PATICIPANTS	
			Agribusiness Consultants	Growers
1	8 <sup>th</sup> December 1997	<b>Bundaberg* Qld</b>	16	
1	9 <sup>th</sup> December 1997	<b>Bundaberg Qld</b>		20
2	18 <sup>th</sup> August 1998	<b>Dunoon<sup>+</sup> NSW</b>	9	50
3	19 <sup>th</sup> August 1998	<b>Alstonville<sup>+</sup> NSW</b>	5	86
4	25 <sup>th</sup> August 1998	<b>Kin Kin** QLD</b>	17	21
5	4 <sup>th</sup> September 1998	<b>Grantham* QLD</b>	10	13
6	9 <sup>th</sup> September 1998	<b>Glasshouse Mnts** Qld</b>	-	41
7	15 <sup>th</sup> September 1998	<b>Alstonville NSW</b>	-	13
8	6 <sup>th</sup> October 1998	<b>Tolga* Qld</b>	11	68
9	10 <sup>th</sup> November 1998	<b>Pemberton* WA</b>	7	12

\* A calibration kit was left at these locations \*\* kit located in Nambour<sup>+</sup> 2 kits located in Lismore

Orchard sprayer calibration kits were provided in seven of the regions where workshops were held. These kits contained resources to undertake a complete air volume and water volume calibration as well as basic sprayer coverage assessment. Approximately 500 copies of the workshop manuals titled "Efficient Pesticide Use in Tree Crops" were distributed to workshop participants.

The following key issues requiring further research were highlighted by the industry during these workshops:

- Matching application volumes and chemical doses to tree size. This requires addressing label shortcomings and requires significant input from experienced researchers, chemical manufactures and the National Registration Authority.
- Developing strategies for canopy management that complement existing application equipment and encourage more efficient pesticide application.
- Providing specific information on the performance of specific types of sprayers, including air-shear technology and other innovations such as under tree conveyors and multi-headed spray systems.
- Developing best practice strategies that can help reduce spray drift and minimise environmental contamination.

### ***PUBLICATION SCHEDULE***

As the project did not have a research component no technical material was created for publication. The workshops were featured in articles appearing in the “Queensland Country Life”, “Good Fruit and Vegetables” and the “Queensland Fruit and Vegetable News”.

#### **Proposed Publications relating to spray application in tree crops:**

“Matching the pesticide dose to tree size: A proposed method for pomefruit”

“Improving spray deposit estimates on leaves by eliminating chlorophyll quenching on fluoresce readings”

“Alternate row spraying: the possibilities for spraying apples”

“Pesticide residues in apples from dilute and concentrate spraying”

## **2. OVERIVIEW OF INDUSTRY ISSUES**

### ***Introduction***

The appropriate use of suitable application equipment is an important component for successful implementation of integrated pest management (IPM) strategies in macadamia and

avocado crops. In Australia there are many newly planted macadamia orchards and a large proportion of established orchards reaching maturity (> 10 years) (Battaglia and Harden 1997). The macadamias and avocados canopies are very dense and this makes pest management difficult due to poor spray penetration and uneven pesticide dosing. It is crucial that the application of pesticides to these crops is optimised so growers can improve their returns through improved pest control and importantly minimise off-target losses. Equipment such as low profile airblast sprayers are the dominant type of sprayer used by the macadamia industry and in some circumstances these can be modified to improve spray deposition levels in the tree canopy. Growers must however recognise the limitations of their equipment. Research undertaken for the pomefruit industry demonstrated improvements in the spray deposit levels by 20-30% as well as improvements in the uniformity of spray deposit could be achieved by modifying low profile airblast sprayers (Dullahide 1997).

The macadamia and avocado industries use similar types of equipment to apply pesticides to their orchards. Although the pest profiles differ for these industries they share some similar problems in relation to the use of pesticide application equipment and other issues relating to canopy size and tree canopy management.

Issues highlighted by growers across production regions where workshops were conducted included:

- canopy management,
- concentrated versus dilute spraying,
- does the sprayer do the job?
- equipment work rate and efficiency of application,
- off target movement of pesticides,
- matching spray volume and dose to canopy size.

An overview of these issues and their impact on the long term sustainability of macadamia and avocado growers are included in this report. Some of the information included under these headings has been extrapolated from research in other crops.

### **Canopy Management**

Tree size and crowding in mature trees is a significant issue with both industries. Conventional tree spacings for avocados may range from 6-12m between rows and 6-15m between trees and in macadamias 7-10m between rows and 4-5m between trees. As trees within an orchard mature they not only grow taller but the canopy fills the gap between rows and between the trees to the point of forming a continuous wall of foliage. The depth of canopy that results due to the wide row spacings is large in comparison to other crops such as stonefruit and pomefruit. The crowding that occurs can cause yield losses due to poor light infiltration, hinder tractor and sprayer access, impede spray penetration and affect spray coverage uniformity. Figure 1 shows a tractor and sprayer positioned between two rows in a mature macadamia orchard where crowding is evident. The practice of hedging where the sides of trees are trimmed was not undertaken in this block and the access depicted in this picture makes spraying difficult and also restricts the type of equipment that can be used.

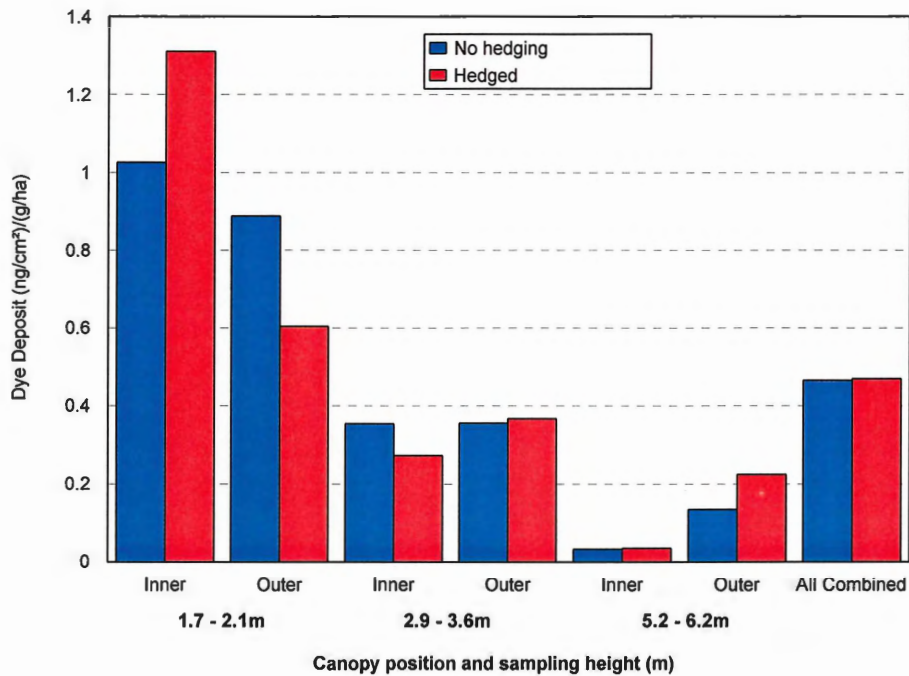


**Figure 1. A low profile airblast sprayer shown in a macadamia orchard with no hedging or tree shaping. The ribbons show the most likely path of droplets from the various nozzle positions. Much of the spray will be intercepted by foliage in the lower part of the tree.**



Although both industries undertake some form of canopy manipulation there are no universal methods agreed upon by growers. Macadamia growers either hedge the sides of trees and remove lower branches, known as skirting, to a height of 1.2 – 2m or do nothing. Hedging and skirting improves the access of equipment between row and gives access for under tree air conveyors as shown in Figure 4a and b. Hedging and skirting of lower limbs is also practiced in avocados. An extreme form of canopy management in avocados is called staghorning, where trees are cut to a height of about 1.0 to 1.5m above the ground with the stubs of four or five larger branches left behind. Some macadamia growers are removing and replanting large trees with a good success rate. In the long term this practice will encourage the remaining trees to grow larger as the canopy grows to fill the space made available.

With low profile sprayers, tree height is the most significant factor affecting the spray distribution in the tree canopy. Trees taller than 4m cannot be evenly sprayed with a conventional low profile airblast sprayer. The spray distribution may also be further affected by canopy shape. Leaves or branches brushing past spray nozzles can result in significant areas of the tree remaining unsprayed. Figure 2 shows the dye deposit on macadamia foliage at 3 heights and at two canopy positions, these being inner and outer. In the top part of the tree the average deposit was 70 to 90% lower than the bottom and middle positions. In this trial the same sprayer was used in an orchard that was hedged and wasn't hedged. The deposit average across all positions was the same in both canopies. Even though there was 21% and 40% more spray recovered in the lower inner position and top outer positions in the hedged trees these differences were not significant. This was a preliminary trial investigating numerous variables and the lack of significance was probably due to insufficient replicates being used.



**Figure 2. Deposit distribution using a standard low profile airblast sprayer in a mature macadamia orchard (canopy hedged versus no hedging).**

### ***Concentrate spraying versus dilute spraying***

A recent survey showed most macadamia growers are using pesticide concentrations of 1X, 2X, 3X or as high as 8X (Battaglia and Harden 1997). The pesticide concentration used is usually a reflection of the water volume applied per hectare, ie the higher the concentration the lower the water volume applied per hectare. Application of low water volumes from 200-300 L/ha or less than 1 L/tree is attractive in large orchard plantations as there is an increase in the time efficiency. Fewer refills are required to complete a spraying operation and depending on where the filling station is, this can result in substantial time saving.

When product labels provide rates of active ingredient per hectare then generally the water volume applied does not restrict the concentration of product that may be prepared unless specified on the label. Labels that provide a dilution rate only (ie. rate of active per 100L of water) can not legally be applied using low volume equipment in a concentrated form. The concept behind the dilution rate is that water volumes are increased as trees grow and

consequently the pesticide dose applied is also increased. By manipulating water volumes the dilution rate provides a means to adjust chemical rates per hectare or per tree. This does not help the users of low volume equipment! With most low volume controlled droplet application (CDA) and air-shear sprayers, the water volumes can not be significantly increased as they are designed to operate effectively at low flow rates. The concentrate spraying issue is also a concern in other industries such as pomefruit where growers are also using conventional airblast sprayers at considerably lower volumes (500 -1000L/ha). Lower application volumes are favoured for efficiency reasons as well as reducing spray losses through run-off.

Further discussion on chemical rates appears in the section "matching spray volumes and pesticide dose to tree canopy size". The issue of concentrate spraying especially for products that do not specify rates, requires urgent attention as it affects all tree crop industries. It is currently being addressed by an Avcare working party that will be forwarding a submission to the National Registration Authority with proposed solutions to the problem.

### ***Does the sprayer do the job?***

It is no wonder growers have difficulty in deciding on the type of sprayer to purchase as there are so many different types available on the market as well as numerous grower inventions or modifications. Examples of the types of sprayers and modifications currently in use by orchard industries are shown in Figures 3-10. These range from conventional low profile airblast (single fan, Figure 3a-d), low profile sprayers with a single and double sided air conveyors plus under tree air conveyors (Figure 4a-b), low profile sprayers with twin fans (Figure 5), single and double sided towers with one or more axial fans (Figure 6a-c), custom built sprayers (Figure 7), air-shear tower sprayers (Figure 8), multi-head spray towers (Figure 9a-c), a combination of airblast and single heads (Figure 10).



(a)



(b)

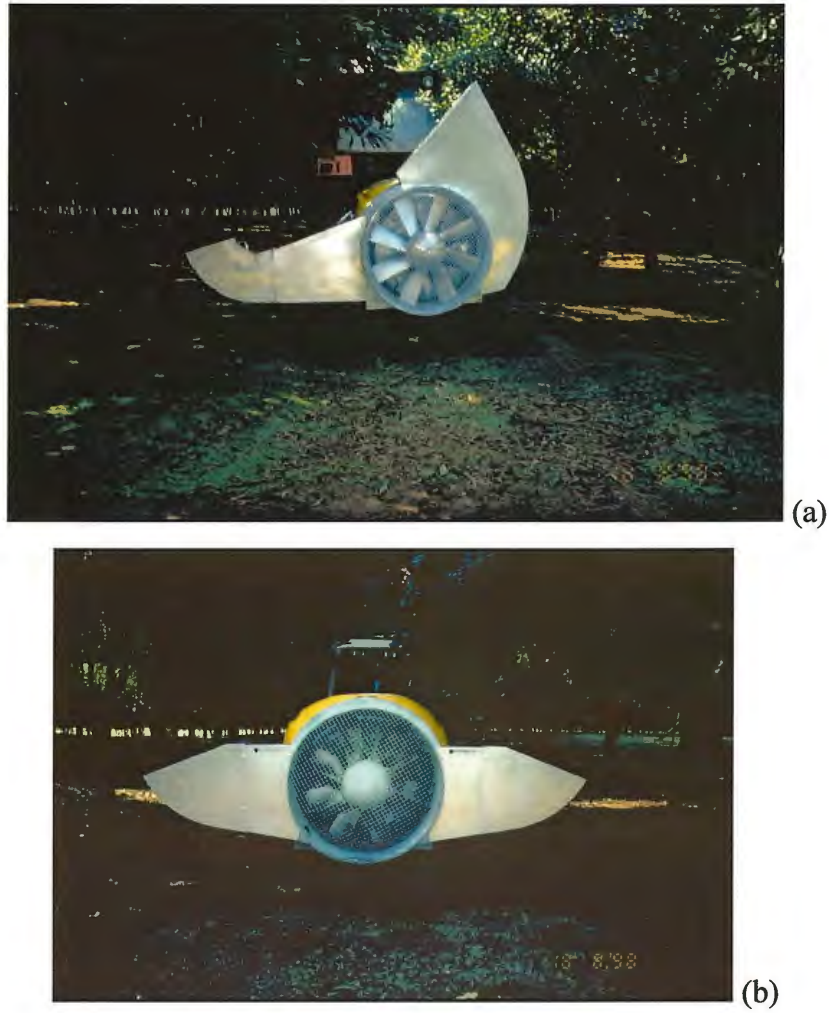


(c)

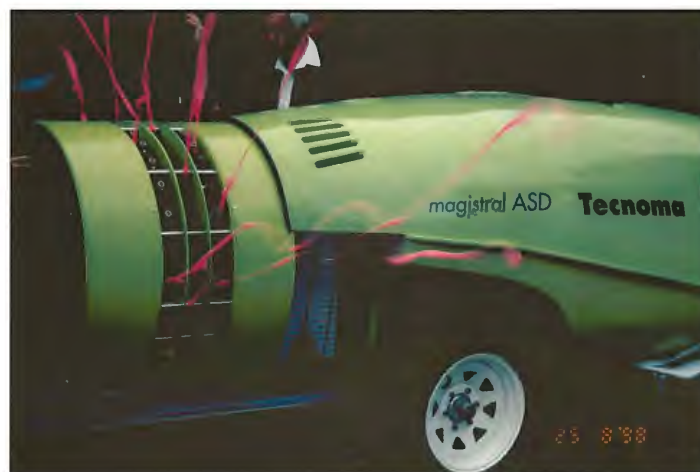


(d)

**Figure 3. Some examples of different low profile airblast sprayers used by many orchard industries. Air baffles have been fitted in sprayers a,b and d to manipulate the air flow direction from the top of the sprayer manifold.**



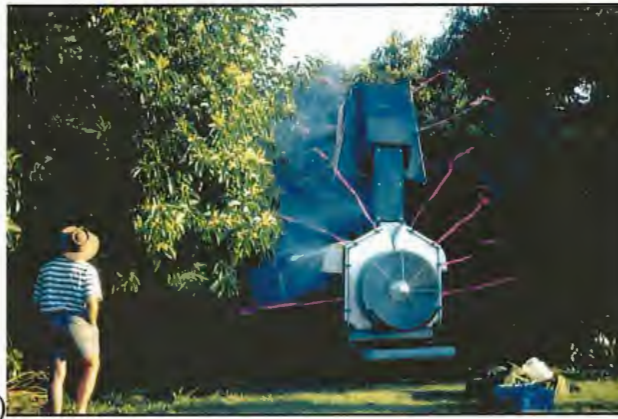
**Figure 4. A modified low profile airblast sprayer fitted with (a) single sided air conveyor and (b) and two sided air conveyor.**



**Figure 5. A low profile airblast sprayer with two fans.**



(a)



(b)



(c)

**Figure 6. Examples of airblast tower sprayers (a) Cropland's Tri-fan, a two sided tower with 3 fans, (b) Jan-ell's Jen-Tech-Raider 2000, a two sided with two separate fans and (c) the Hardi eco-tower, a single sided tower.**



**Figure 7. A custom built, low profile airblast sprayer, comprising of two axial fans. The unit is not powered by the tractor but a separate diesel motor that operates the two fans and pump unit.**



**Figure 8. A Silvan air-shear sprayer set up to spray apples with a short tower . There are four outlets on this tower, two per side.**



(a)



(b)



(c)

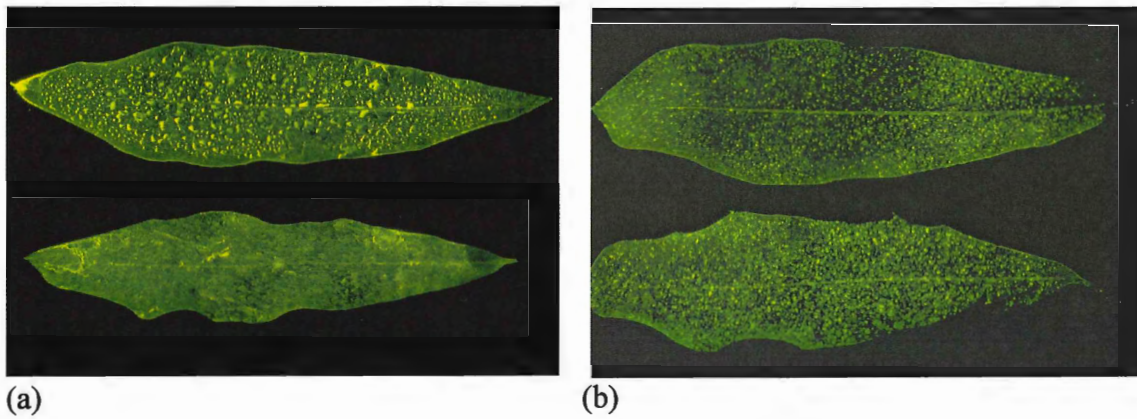
**Figure 9. Examples of multi-head spray systems mounted on single sided or two sided towers (a) A two sided tower with Spanspray heads (b) A single sided tower with Hydra-fan heads (c) A single sided tower with Micromaster heads**





**Figure 10. A combination of two sided airblast with two Hydra fan heads mounted on extended arms.**

Growers must not only consider the sprayers' ability to achieve good coverage. *Access in their orchard, the power requirements to run the sprayer, the efficiency of the sprayer, the cost and the after sales service are all important criteria when choosing equipment.* Obtaining good coverage is a serious concern amongst growers and this becomes more of an issue in mature orchards. Fluorescent dyes and to a lesser extent water sensitive paper are good visual tools that can be used to assess coverage levels on various parts of the canopy, fruit, nuts, leaves and flowers as well as off target deposit or run-off to the ground. Figure 11a-b shows the fluorescent spray deposit on macadamia leaves sampled from 2m and 5.5m from ground level. With most low profile airblast sprayers it is often unavoidable to overdose certain parts of the canopy to get to other internal parts. Usually the coverage and doses delivered to the lowest parts of the canopy are excessive as shown by the lower leaves in Figure 11a. This results in over dosing and substantial losses to the ground. The droplets are more distinct in Figure 11b with very little merging of droplets. The graph in Figure 2 showing the dye deposit in six positions in a macadamia canopy is very typical of the deposit profiles from low profile sprayers when used in large trees.



**Figure 11. Macadamia leaves sampled from two heights (a) 2m and (b) 5.5m showing fluorescent dye deposits. The leaves in Figure a show excessive deposit whilst Figure b shows adequate deposit with very distinct droplet stains.**

### ***Equipment efficiency and timeliness of application***

To achieve effective pest management, the timely application of pesticides is just as important as the equipment used to do the job. There is little value in using the best available equipment and applying sprays two to three days late when the pest activity or disease infection has already occurred. Large orchard plantations need the capacity to treat entire orchards within predetermined periods so that minimal damage or losses are incurred. This window of opportunity to spray may only be one or two days with some pests. This requires an investment in sufficient capital (spray equipment) and the labour force to do the job when it is required. Quiet often growers compromise spray operations by travelling too fast in the orchard. The available air volume from a sprayer and the ability to displace the tree canopy volume with droplet-laden air are important for even spray coverage. A macadamia tree 5.5m tall, with an average canopy width of 6m and a row spacing of 9m has a canopy volume of approximately  $25,333\text{m}^3/\text{ha}$  (excludes the skirt to 1.7m). Theoretically a sprayer producing  $50,000\text{m}^3/\text{hr}$  would need to travel at  $3\text{km}/\text{hr}$  to displace the canopy volume with air from the sprayer. In doing this calculation an air volume enhancement factor of 2 was used, that is the air volume created by the sprayer was doubled to allow for the increase as surrounding air is sucked in through a venturi action as the air from the sprayer moves towards the tree. Most airblast sprayers with axial-flow fans generate between  $30,000\text{m}^3/\text{hr}$  to  $60,000\text{m}^3/\text{hr}$ , depending on their configuration. In comparison the sprayer shown in Figure 7 with 2 axial-

flow fans produces approximately 150,000 m<sup>3</sup>/hr and the multi-head system in Figure 9a approximately 10,000 m<sup>3</sup>/hr per head (100,000 m<sup>3</sup>/hr for both sides). The canopy volume air displacement theory does not apply to sprayers that use an air-shear principle to create droplets. These sprayers produce low volume, high velocity air. The underlying factors that influence the performance of air-shear technology on target orientated coverage need to be determined by undertaking further research.

### ***Environmental Issues***

Endosulfan, an insecticide registered for use in numerous tree crops has received a barrage of negative publicity relating to spray drift incidents, residues in beef cattle and its impacts on riverine systems. Although the events receiving publicity have been largely associated with the spraying of broad acre crops, the off-target movement of endosulfan and other pesticides is also a concern for all users in the tree crop industries. The Queensland Fruit and Vegetable Growers (QFVG) supported by funding from HRDC have developed the Farmcare Code of Practice for sustainable fruit and vegetable production in Queensland (QFVG 1998). One of the sections in the code of practice relates to air pollution management. Tree crop industries need to develop and evaluate strategies in relation to minimising off-target losses of pesticides that will assist growers in meeting the expectations of the code of practice.

Off-target losses not only result from airborne drift but also losses due to canopy run-off that may result in soil contamination. Spray drift onto adjacent urban areas or rural properties is clearly a concern for many growers. Twenty-five percent of growers who responded to an industry survey in macadamias indicated urban encroachment was a significant issue for their enterprise (Battaglia and Harden 1997).

Large, mature trees that are allowed to form hedges can provide effective barriers and minimise spray drift. This is demonstrated by the fact that spray penetration through these dense canopies is difficult. The following strategies can be promoted to assist with minimising the levels of off-target movement, however these will require rigorous testing to determine the most effective methods for reducing both *airborne* and *ground* spray losses.

- Selecting not to spray sections of the orchard when the prevailing wind is the direction of a sensitive area.

- If land is not a limiting factor, planting a vegetative buffer consisting of mixed foliage types between the property and sensitive area. This is a long-term strategy as it takes time to establish but should be considered when planning new orchards.
- Selecting spray volumes per tree or hectare that do not result in significant canopy run-off losses.
- Using existing rows of trees as an unsprayed buffer (eg. 1 or 2 rows) on the boundary adjoining the sensitive area.
- Using air baffles at the top section of the sprayer manifold so that air generated by the sprayer is directed into the tree canopy and not above it (Figure 12). Air lost between the row and above the tree entrains droplets resulting in spray losses.
- Using a single sided tower sprayer and only spraying the outer 1 or 2 rows from one direction, that is away from the sensitive area (Figure 6c).



**Figure 12. An airblast machine spraying apple trees. The sprayer is fitted with top baffles so the air is parted and directed to match the tree height. This attachment reduces spray loss between rows.**

### ***Matching spray volumes and pesticide dose to tree canopy size.***

The two most common issues raised by growers in all production areas were: (1) physically matching the nozzle outputs of the sprayer so that the distribution of pesticide within the tree is as even as possible and (2) determining the quantity of chemical to use on a given size tree.

If the nozzle outputs on a sprayer or the spray distribution is not matched in the best possible way to evenly dose trees then there is little value in determining or recommending methods that match chemical dose to tree size. In fact this could be risky and result in extreme overdosing in lower parts of the canopy producing fruit residue problems. If changes to pesticide labels result in recommendation of product based on tree size then the types of equipment that should, or should not be used must be specified.

The difficulty in achieving an even spray distribution within a tree canopy relates to the size of the canopy and the type of sprayer used. Figure 13 shows the vertical spray distribution up to 5m from a low profile airblast sprayer. Cotton string was used as a collector to measure the spray profile without canopy interference for a sprayer applying about 1000 L/ha. The deposit on the left-hand side of the sprayer is shown by red bars and the right-hand side by green bars. Although not all the spray was caught at the highest point the maximum spray deposit occurred at about 2.75 to 3.5m. Above 3.5m the spray deposit on the string starts to decline. These types of sprayers are used extensively to spray trees that are 7m or taller.

The vertical deposit from a low profile sprayer fitted with a single sided conveyor is shown in Figure 14. Two nozzle systems were used here, Spraying Systems grey nozzles (TX-VK8), the grey bars and Albus red nozzles (1299-16) the red bars. Both configurations were set up to emit the same volume. The highest sampling height in this trial was 8m. Compared with Figure 13, the distribution is more even and the deposit extends much higher. There are differences between the deposit distributions for the 2 nozzle types and this may relate to the droplet spectrums produced by each nozzle. Further work is required to determine whether this difference would produce a real effect within a tree canopy.

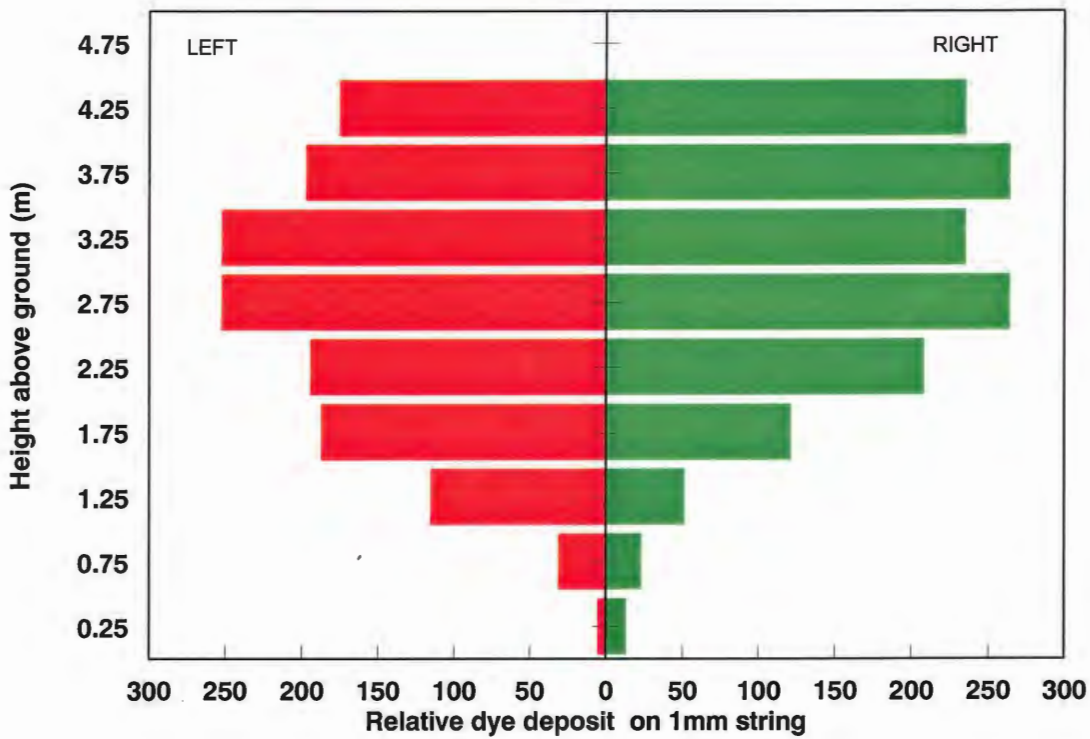


Figure 13. Distribution of spray caught on 1mm string emitted by a low profile airblast sprayer fitted with air baffles in apples.

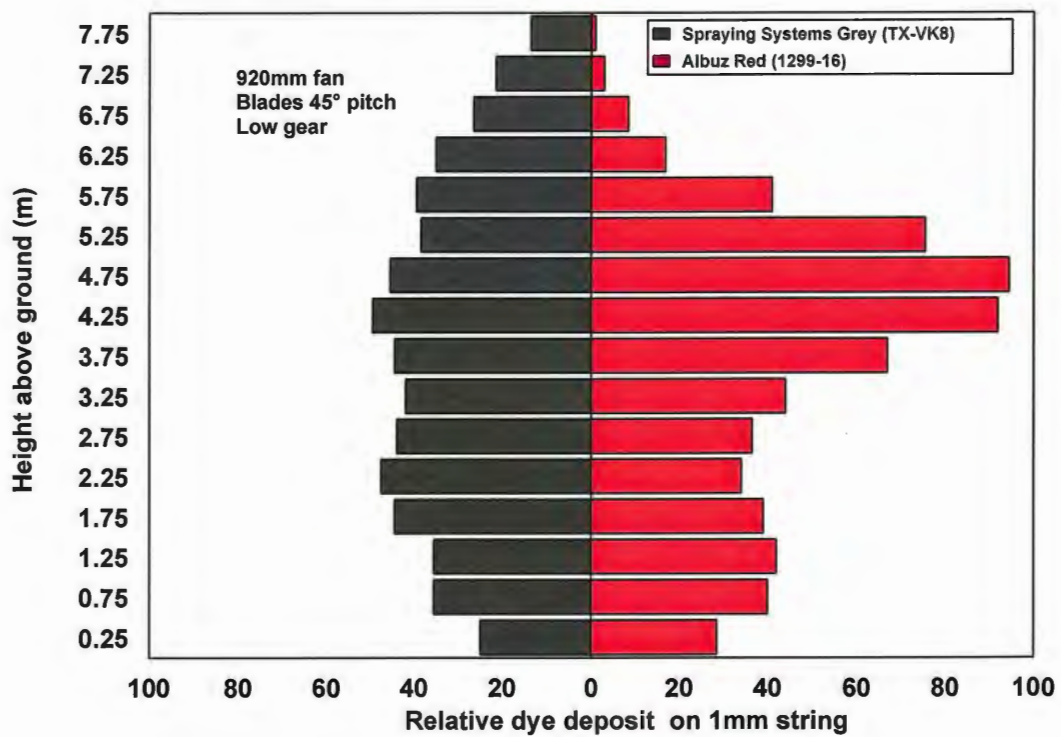
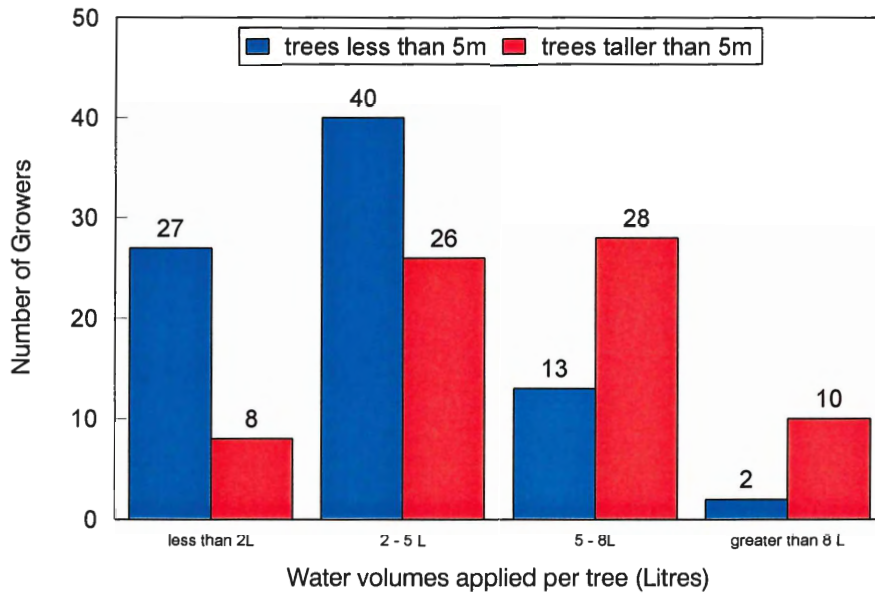


Figure 14. The spray distribution on cotton string from 2 different nozzles types fitted to a low profile sprayer fitted with a single sided conveyor.

The use of appropriate pesticide rates in tree crops is paramount as it has economic, legal, environmental and occupational implications and yet the issues regarding label recommendations in tree crops remains unresolved. Growers can not see the logic in having chemical recommendations listed per hectare when this suggests the same amount of active ingredient be applied to both small and large trees. The hectare rate would seem more appropriate if it was applied to a mature orchard with dimensions specified with a reduced rate in smaller trees. There are also differences in the legislation regarding pesticide rates between Australian states. In Queensland, growers may legally apply lower rates than the hectare amount however must not exceed the hectare rate, whereas in NSW growers can not go below or above the hectare rate. An alternative method for recommending pesticide rates appearing on pesticide labels is the dilution rate. As discussed previously the dilution rate gives growers flexibility to manipulate water volumes applied to increase pesticide doses as the canopy size increases. This however is not an option for users of low volume sprayers as that type of equipment are specifically designed to operate at much lower flow rates than conventional hydraulic nozzle technology. There is also confusion amongst growers as to the appropriate volumes to be applied for a given tree size. Macadamia growers manipulate water volumes according to tree size. Figure 15 shows that actual water volumes used by a sample of growers for trees less than and greater than 5m tall. For trees less than 5m tall most growers are applying between 2-5 L/tree and in trees taller than 5m there are more applying between 5-8 L/tree (Battaglia and Harden 1997). Manipulating water volumes to increase pesticide doses in larger trees will be inadequate if sprayers are not configured to evenly spray large trees. All that will result are excessive spray deposits, pesticide residues and increased run-off losses.

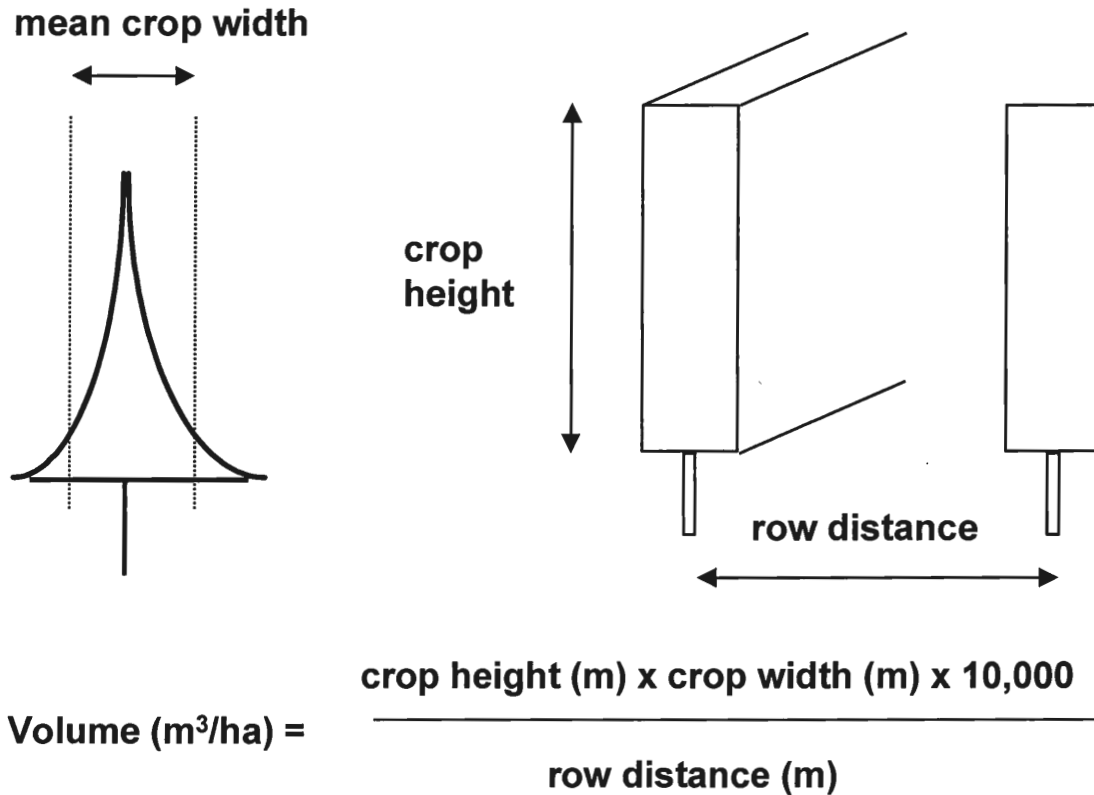


**Figure 15. Water volumes applied by a sample of macadamia growers for tree canopies less than 5m and taller than 5m.**

Growers frequently ask what water volume do they need to apply per tree with their sprayer. The question should be what pesticide dose is required to achieve the desired biological response? Different volumes may be required for specific pests, however with many products providing the application to the tree is even, there is scope to use a range of volumes to deliver the dose required. This however can not be legally done when labels only specify dilution rates.

One approach would be to match pesticide rates (dose) to tree size or a measure of tree bulk or surface area. Two such measures are the tree row volume (TRV) or leaf area index (LAI) or surface area index (SAI). The LAI is difficult to determine and requires costly equipment. The TRV is relatively easy to calculate if you assume that the row of tree is a rectangular box. Figure 16 shows the measurements required and a formula that can be used to calculate tree row volume in  $\text{m}^3/\text{hectare}$ . A procedure that uses canopy volume ( $\text{m}^3/\text{ha}$ ) to calculate pesticide rates may also be flawed as many large trees contain large void sections in their centres.





**Figure 16. Formulae for calculating tree row volume. The only measurements required are row distance, tree height and mean canopy width.**

When using a fixed rate of product per hectare how much do pesticide deposits vary with tree size? This is illustrated with some actual data from a range of tree crops. Table 2 shows the calculated tree row volumes for a range of tree crops in which trials have been conducted measuring the dye deposit distribution for different application systems. The TRV volumes range from 13,448 m<sup>3</sup>/ha for a high density apple orchard to 51,071 m<sup>3</sup>/ha for some large macadamia trees.

Table 2. Calculated tree row volumes (TRV) for a range of tree crops.

Crop	Canopy mean width (m)	Tree Height (m)	row distance (m)	Canopy Volume (m <sup>3</sup> /ha)
Apple (open vase)	2.5	4	5.5	18,205
Apple* (central leader)	2	2.5	3.5	13,448
Apple*	2.5	4	5.5	15,800
Macadamia* (15 yr)	6	5.5 (ex skirt)	9.1	36,260
Macadamia*	5.5	6.5	7	51,071
Macadamia*	7	6.4 (ex. skirt)	10	44,800
Lychee*	5.7	4 (ex skirt)	9	25,333

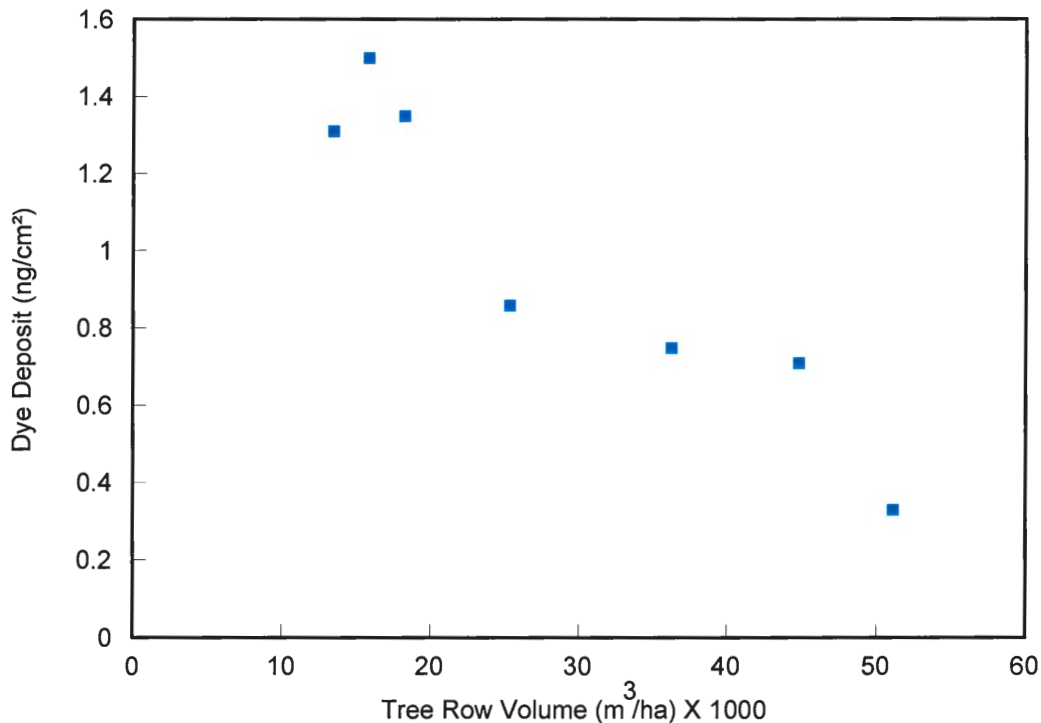
\* Tree formed a hedge

The water volumes applied to trees in these crops are shown in Table 3. The application volumes are presented per hectare, per tree and per 1000m<sup>3</sup> of canopy.

Table 3. Tree row volumes and water volumes applied to various tree crops.

Crop	TRV (m <sup>3</sup> /ha)	Trees/ha	L/ha	L/Tree	L/1000 m <sup>3</sup> Canopy
Apple (open vase)	18,205	330	25	0.76	14
Apple* (central leader)	13,448	1905	22	0.12	17
Apple* (hedge)	15,800	606	57	0.95	37
Macadamia* (15 yr)	36,260	240	196	8.2	54
Macadamia*	51,070	408	81	2	16
Macadamia*	44,800	200	167	8.4	37
Lychee*	25,333	222	76	3.4	9

For each row shown in Table 3., a comprehensive trial was conducted using fluorescent tracer to evaluate the spray deposit in 6 positions in the tree canopy. Three heights were samples and two canopy positions (inner and outer). The average dye deposit on leaves in nanograms of dye per square centimetre (ng/cm<sup>2</sup>) for each gram of dye applied per hectare versus calculated TRV are shown in Figure 17. This figure shows a linear relationship between the amount of dye recovered and the range of tree row volumes shown. As TRV increases there is a decline in the average amount of dye recovered per unit area of leaf.



**Figure 17. Average dye deposit (ng/cm<sup>2</sup>) on leaves versus tree row volume (m<sup>3</sup>/ha). Data from apple, lychee and macadamia tree crops.**

If the objective is to dose the target area evenly, then a regression model that describes the relationship between dose and canopy volume for the data in Figure 17 may be used to determine how much the chemical rate needs to be modified. This assumes the required dose on the target is known.

The regression model describing the scatter of points in Figure 17 is:

$$\text{Normalised dye deposit in (ng/cm}^2\text{)} = 1.76 - 0.000027 \times \text{TRV (R-sq =89.1\% p = 0.001)}$$

Where TRV = tree row volume in m<sup>3</sup>/ha

This model can be used to predict normalised dye deposit based on tree row volume. In this case for every increase in 10,000 m<sup>3</sup> of canopy there is a reduction in the average deposit by 0.27ng/cm<sup>2</sup>. If the average dose on the largest tree size was adequate then the dose that should be applied to smaller trees may be reduced by manipulating spray volume or pesticide

concentration so that the same dose is deposited on the target as in the larger trees. Further work needs to be done to determine whether this relationship holds true when using data from one crop only. Research is being undertaken in pomefruit to evaluate procedures that match pesticide dose to tree canopy size.

Procedures have been published in the scientific literature describing methods to calculate application volumes for different size tree canopies but none have been universally adopted in Australia. These formulae are based on calculating a tree-row-volume and specify defined water volume per unit canopy volume ( $\text{m}^3$ ). Sutton et al (1984) evaluated a tree-row-model for full season pesticide application in apples with adjustments made for canopy density. The model they used specified that 1 L of dilute chemical suspension was sufficient to wet  $7.48\text{m}^3$  of foliage to the point of run-off. The trials conducted by Sutton et al (1984) showed consistent deposits were maintained on the same size trees within an orchard and over three pruning methods. Similar deposits of tracer were recovered per square centimetre of foliage even though the amount of material applied per hectare was reduced by 30-50% in well pruned trees.

Furness et al (1998) proposed a sprayer calibration method for fruit trees and vines based on height, width of canopy and row length. They used the concept of canopy retention volumes for a unit canopy row (UCR), which is defined as ( $100\text{m}^3$  of foliage), 1m high x 1m wide by 100m of row length. They specify 8L of water per UCR could be considered a standard volume for crops such as citrus and avocados but further research is required to determine actual canopy retention volumes on a wide range of crops.

Byers et al (1984) investigated copper deposits on apple foliage using an airblast sprayer on apple trees of increasing size. They found higher deposits as tree size decreased. Copper deposit was related to tree-row-volume with a quadratic regression equation  $y = 552 - 9.8x + 0.05X^2$  ( $y$  = copper deposit and  $X$  = tree-row-volume). They calculated tree row volume assuming trees were a rectangular box (tree height x tree width x area of orchard/row width) and classified a mature orchard to have a TRV of  $40,600\text{ m}^3/\text{ha}$ .

The canopies of mature macadamia and avocado trees are large with tree row volumes approaching 30,000m<sup>3</sup>/ha or greater. If the water volumes proposed by Sutton et al (1984) or Furness et al (1998) are calculated for a canopy of this size, then application volumes of 2,400 to 4,000L/ha or approximately 12 to 20 L/tree would be required. Such volumes are well above current industry practice. It may be that these volumes in a dilute spray contain the correct amount of active ingredient for the size of the tree but if this is the case then most growers are grossly under-dosing their trees. Further work is required to resolve chemical rates for different canopy sizes and the efficiency of different sprayers in delivering that dose in either a dilute or concentrate form.

### 3. RECOMMENDATIONS

Many of the issues discussed in this report are common to numerous tree crop industries. Although specific research has been undertaken in pomefruit (Dullahide 1997) and Citrus (Cunningham and Harden 1997), spray application research is required for the avocado and macadamia industries to address their own specific problems. The principals of operation for spraying equipment used in orchards are the same irrespective of the crop however each crop and often production areas have their own specific problems that require addressing. There are distinct differences in management practices from farm to farm, making blanket recommendations on equipment set-up and strategies for spraying impossible.

In order to resolve some of the issues relating to pesticide application highlighted in this report and promote sustainable and efficient orchard production systems, the avocado and macadamia industries should consider:

- Undertaking research that provides more specific information to growers on the coverage performance of different types of sprayers used by the avocado and macadamia industry and the equipment configurations that will give these crops the best pest and disease control. This will require investigating the interactions between canopy size and structure, droplet size, air volume and water volume. Improving target coverage does not necessarily guarantee better control therefore coverage will need to be linked with biological efficacy, yield and quality improvements.
- Evaluating and promoting best practice strategies so that growers can reduce the risk of off-target losses (airborne and run-off losses).
- Providing specific data where required to support the Avcare working party submission to NRA on the issue of concentrate spraying for products that only specify a dilute spray rate. This may require collating existing data or generating additional efficacy, occupational exposure and crop residue data.
- Encouraging the use of lower pesticide rates by evaluating methods that can be used to match *pesticide dose* to tree size. This will complement existing and future IPM programs.

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**Appendix 1**

**Media Coverage of Workshops**

## Spray workshops promote efficiency in orchards

**A**vocado and macadamia growers from throughout south east Queensland, north Queensland and northern New South Wales have attended a series of field days to learn the latest industry advances in spray technology.

Spray Project team leader and Queensland Horticulture Institute horticulturist, Robert Battaglia, said the workshops had been held in key avocado and macadamia growing regions, with a further workshop scheduled for Western Australia later this year.

"The workshops, funded by the avocado and macadamia industries in conjunction with HRDC, are being held to promote efficient spray application in orchards.

"There are no two orchards the same and this means sprayers need to be set up appropriately and matched to the trees in your orchard," Mr Battaglia said.

"By improving spray deposit, spraying systems can be more efficient. First measure sprayer air volume and match it to the tree canopy size. If you require higher flow rates use more nozzles of the same size instead of larger size nozzles," advised Mr Battaglia.

"A major aim is to help growers ensure when they spray their orchards they do so in the most efficient and practical way, posing least risk to the environment and their own safety."

Each workshop involves a background briefing of the latest spray trial results, a practical exercise with spray equipment to measure water and sprayer air volume outputs and a night

inspection of fluorescent spray deposit patterns on trees.

"When the growers saw the results of the fluorescent sprays on the trees, the message really hit home," said Mr Battaglia.

A special kit containing orchard calibration equipment was supplied at each workshop and left for growers to calibrate their sprayers in the field.

Mr Battaglia said growers, crop consultants, spray equipment and chemical resellers will have access to the kits should they want to do their own sprayer calibration.

He said sprayers need regular calibration so growers know what their sprayers are doing.

Individual nozzle outputs need to be checked and compared with manufacturers specifications.

Nozzle outputs increase as they wear resulting in changes to the overall range of droplet sizes produced. This can result in poorer coverage and pest control, due to increased leaf or fruit run-off and cause unwanted ground contamination.

**Top right - Gympie DPI horticulturist Paul O'Hare demonstrates to growers how to check spray air inflow volume readings, while streamers graphically show the spray path out of the machine.**

**Bottom right - DPI Spray Technology Project leader Robert Battaglia (L) discusses features of an electrostatic sprayer with Russ Stephenson, senior principal horticulturist, Maroochy Horticulture Research Station.**



# Spray technology workshops

MACADAMIA and avocado growers from throughout South East Queensland, North Queensland and Northern NSW are attending a series of field days to learn the latest industry advances in spray technology. Spray Project team leader and Queensland Horticulture Institute horticulturist Robert Battaglia said the most recent workshop was held at Como Park near Gympie. The events are being funded by the macadamia and avocado industries and the Horticultural Research and Development Corporation (HRDC).

"The workshops are being held to promote efficient spray application in orchards. There are no two orchards the same and this means sprayers need to be set up appropriately and matched to the trees in your orchard. Measuring sprayer air volume and matching this to tree canopy size and using more nozzles of the same size

instead of larger sized nozzles where higher flow rates are required can make spraying systems more efficient by improving spray deposit," Mr Battaglia said.

"A major aim is to help growers ensure when they spray their orchards they do so in the most efficient and practical way, that poses the least risk to the environment and their own safety."

Each workshop involves a background briefing of the latest spray trial results, a practical exercise with spray equipment to measure water and sprayer air volume outputs and a night inspection of fluorescent spray deposit patterns on trees.

A special kit containing orchard calibration equipment is supplied at each workshop and left for growers to calibrate their sprayers in the field. Growers, crop consultants, spray equipment and chemical resellers will have access to the kits



**Nozzle outputs increase as they wear, resulting in changes to the overall range of droplet sizes produced. This can result in poorer coverage and pest control due to increased leaf or fruit run-off and cause unwanted ground contamination.**

should they want to do their own sprayer calibration, Mr Battaglia said. He said sprayers need regular calibration so growers know what

their sprayers are doing. Individual nozzle outputs need to be checked and compared with manufacturers' specifications.

## Spray technology workshops benefit macadamia and avocado growers

Macadamia and avocado growers from throughout south east Queensland, North Queensland and Northern NSW are attending a series of field days to learn the latest industry advances in spray technology.

Spray Project team leader and Queensland Horticulture Institute horticulturist, Robert Battaglia, said the most recent workshop was held at Como Park near Gympie. The events are funded by the macadamia and avocado industries and the Horticultural Research and Development Corporation, (HRDC).

"The workshops are being held to promote efficient spray application in orchards. There are no two orchards the same and this means sprayers need to be set up appropriately and matched to the trees in your orchard.

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"A major aim is to help growers ensure when they spray their orchards they do so in the most efficient and practical way, that poses the least risk to the environment and their own safety," Mr Battaglia said.

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and left for growers to calibrate their sprayers in the field. Growers, crop consultants, spray equipment and chemical resellers will have access to the kits should they want to do their own sprayer calibration, Mr Battaglia said.

He said sprayers needed regular calibration so growers knew their sprayer capacity. Nozzle outputs need to be checked and compared with manufacturer specifications.

Nozzle outputs increase as they wear resulting in changes to the overall range of droplet sizes produced. This can result in poorer coverage and pest control, due to increased leaf or fruit run-off and cause unwanted ground contamination.

Contact: Robert Battaglia, Department of Primary Industries



Gympie DPI horticulturist Paul O'Hara demonstrates to growers how to check spray air inflow volume readings, while streamers show the spray path out of the machine.