The UK PACE Scheme for Adjusting the Dose to Suit Apple Crops

J. V. Cross and P. J. Walklate

East Malling Research, New road, East Malling, Kent ME19 6BJ

jerry.cross@emr.ac.uk peter, walklate1@ntlworld.com

ABSTRACT

Our research has shown that when sprays are applied at a fixed recommended dose rate as prescribed on pesticide labels, there is a greater than 6-fold variation in average pesticide deposits between different apple orchards at different growth stages due to variation in tree size and canopy density. In the work, LIDAR (Light Detection and Range) was used to rapidly characterise tree canopies, a breakthrough which enabled such relationships to be investigated and quantified. The work showed that canopy density accounts for 80% of this variation and canopy density and tree height combined account for over 90% of the variation. If the label recommended dose rate gives a certain average deposit which is effective on taller trees with a denser canopy, designated as a standard, then the same average deposit which can be achieved with a lower dose rate on smaller or less dense trees will be equally effective. Thus, there is an opportunity for making significant dose rate reductions in orchards with less dense canopies and/or smaller trees than the standard. In spring 2006, the PACE (Pesticide dose rate Adjustment to the Crop Environment) system of adjusting the dose rate according to tree height and canopy density so that constant average deposits are achieved in a wide range of different orchards throughout the season was launched in the UK. A series of seminars and training courses for growers were held which were attended by over half the industry. In this paper, the five steps that growers were instructed to follow to determine an appropriate dose adjustment are given including the crucial step where pictograms of apple trees of varying canopy density, reconstructed from LIDAR scans, are used to visually assess canopy density. Attendant advice on water volumes, spray quality and spray cover is also presented together with a worked example. Further work is being done currently to extend the scheme to cider apples and other fruit tree crops.

Keywords: LIDAR (Light Detection and Range), dose adjustment, pesticide dose, canopy structure, UK

1. INTRODUCTION

Pesticide labels commonly express the dose rate as an amount of product to be applied per unit ground area occupied by the crop. This method of dose expression is ideally suited to arable boom spraying applications where a target crop of limited height is located below the spray source but it is not so suitable for orchards which are typically sprayed from within the canopy using air-assistance and where the deposition of product varies greatly with tree size and canopy density. To mitigate the liability risk associated with the use of orchard spraying products, agrochemical companies tend to increase the margin-for-error on the dose rate in preference to using an improved method of dose expression that accounts for the variability of deposit. However, there are some very important benefits from adjusting the dose to suit the crop, as follows:

- Reduced pesticides residues on fruit
- Reduced environmental and bystander contamination
- Reduced operational costs by more efficient use of pesticide
- Reduce aquatic buffer zones

In this paper we overview our recent work to understand the factors that cause deposit variability and the development and operation of the Pesticide dose Adjustment to the Crop Environment (PACE) scheme where the dose is adjusted to suit the crop to give approximately constant deposits in orchards of widely varying tree size and canopy density at different growth stages. The five steps that UK growers were instructed to follow to determine an appropriate dose adjustment are given including the crucial step where pictograms of apple trees of varying canopy density, reconstructed from LIDAR scans, are used to visually assess canopy density. Attendant advice on water volumes, spray quality and spray cover is also presented together with a worked example.

2. EFFECTS OF CROP STRUCTURE ON SPRAY DEPOSITS

In order to investigate deposit variability and the factors that cause it, we conducted an extensive series of orchard structure and deposit measurements in the late 1990s and early 2000s using methods described by Cross *et al.* (2001a, 2001b, 2003). Spray applications were made to a wide range of orchards of widely varying tree size and canopy density at different growth stages using the same axial fan airblast sprayer (a Hardi TC1082) at the same forward speed (5.8 kmph) delivering the same fixed liquid flow rate (volume of spray emitted from the sprayer per second) at a constant spray quality. Constant flow rate and spray quality were achieved by using the same fine hollow cone nozzles at constant pressure throughout. Chelated metals were included in the spray tank so that amounts of spray deposited on leaves and fruits could be measured (Murray *et al.,* 2000). The fixed flow rate and forward speed delivered a fixed volume of spray per unit length of row.

A tractor mounted Light Detection And Range (LIDAR) was used to rapidly characterise the crop structure each time a deposit measurement was made (Walklate *et al.,* 2002). The LIDAR produces a scanning, pulse-modulated near infra red laser beam. The times of flight of the pulses to the points of interception with the crop are measured and the range and angle of interception calculated. Each recording, consisted of a standard data set of 5800 rotational scan sequences along a ~50 m transect along the centre line between two rows of trees. Each rotational scan sequence was made up of 200 range measurements with a scan angle of 100°. The tree-row cross-section was delineated by a two-dimension map where a threshold interception probability of $p \geq 1\%$ defined the local presence of a tree-row structure, shown in Figure 1 as the grey shaded cross-section bh. In accordance with this method, the tree-row parameters were given the following definitions: h - maximum height, b - width (i.e. the cross-section bh divided by the maximum height) and a - average of the canopy-density (the area of leaf and fruit surface per unit volume of canopy) within the cross-section was calculated from the interception probability using the methods described in Walklate et al. (2002).

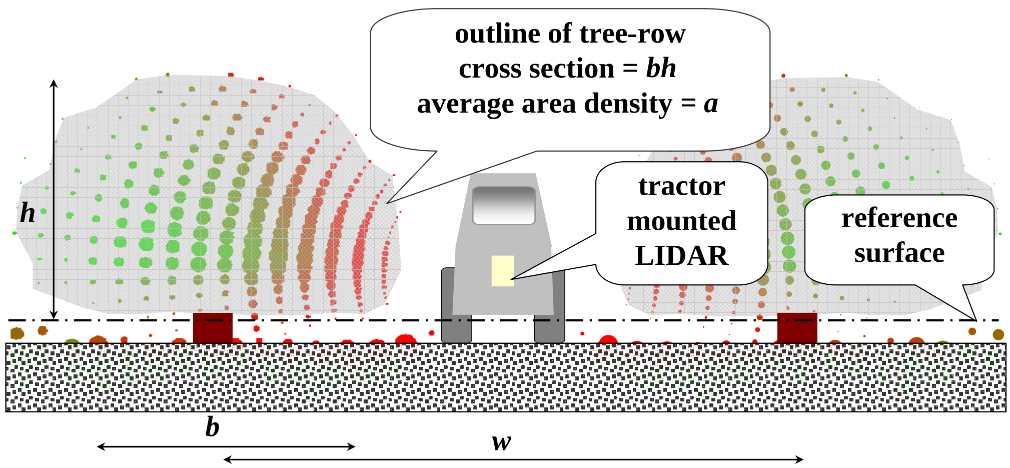

Figure 1. The tree-row characteristics derived from recordings with a tractor mounted system LIDAR. The grey shaded area of the trees represents the tree-row cross section where the local probability of interception is greater. A bubble plot is superimposed to represent the distribution of the canopy density (proportional to bubble diameter).

We measured a greater than 6 fold variation in average pesticide deposit between different apple orchards at different growth stages (Figure 2). If the applied dose gave an acceptable efficacious average deposit, nominally ascribed a value of 1.0, on larger trees with a dense canopy, 26% of orchards had this deposit, but the remaining 74 % of orchards, which had smaller trees with less dense canopies had deposits of 2 – 6 fold greater than the standard (Walklate *et al.*, 2006).

A statistical investigation was made of the percentage of the variability in average deposits caused by different tree structure parameters measured with the LIDAR. Row spacing (3.5 m - 6 m in the orchards surveyed), the standard method of adjusting the spray volume per metre of row to achieve a fixed dose per unit ground area, accounted for only 5% of the variability (table 1). Interestingly, simply reducing the sprayer dose per metre of row by 60% (multiplying by 0.4) ensured that 50% of orchards received the standard deposit (though in this case the 26% of trees that were previously considered to have received the correct deposit would now have only 40% of that deposit). As single factors, tree width and height accounted for 55 and 56 % of the deposit variability respectively. Canopy density had by far the greatest influence on average deposit accounting for 80% of the deposit variation. If two parameters are used, a combination of tree height and canopy density accounted for 93% of the variation, significantly better than the Tree Row Volume method of dose adjustment which uses three parameters, but not the crucial canopy density parameter. An overview of the different dose adjustment methods used in t tree fruit spraying is given by Walklate *et al.* (2006).

Thus this work showed that if dose rate is to be adjusted to suit the crop, canopy density and tree height are the most effective adjustment parameters.

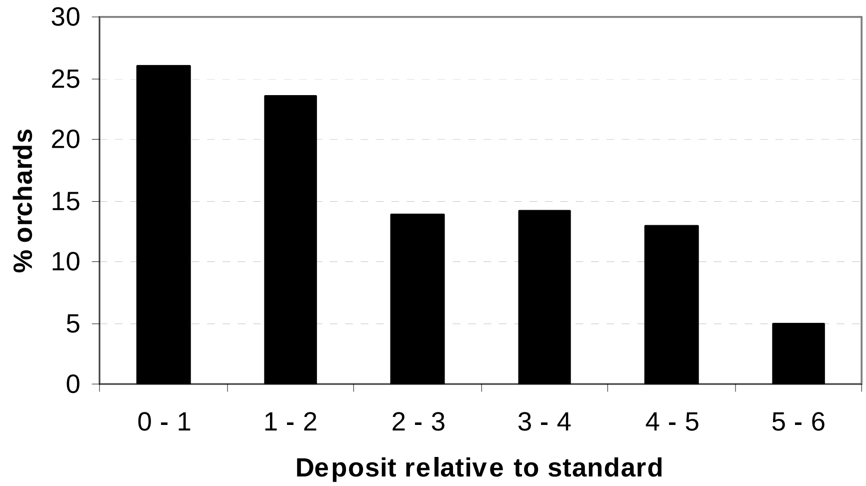

Figure 2. Variation in average pesticide deposits when a wide range of orchards at different growth stages were sprayed with the same axial fan airblast sprayer delivering a volume of spray per metre row.

Table 1. Ranking of factors to account for the % of orchards where dose adjustment is correct when a wide range of orchards at different growth stages were sprayed with the same axial fan airblast sprayer delivering a volume of spray per metre row

Scheme	Dose adjustment factor	% of orchards where dose adjustment is correct
label recommendation	row spacing	5%
0.4 x label recommendation	row spacing	50%
	tree width	55
	tree height	56
	canopy density	80
PACE	canopy density, tree height	93
Tree Row Volume	tree height, row spacing, tree width	66

3. OPPORTUNITIES TO REDUCE THE DOSE

The basic assumption of dose rate adjustment is that if the label recommended dose rate gives a certain average deposit which is effective on taller trees with a denser canopy, then the same average deposit which can be achieved with a lower dose rate on smaller or less dense trees will be equally effective. There is thus opportunity for making significant dose rate reductions in orchards with less dense canopies and/or smaller trees than the standard. The PACE (Pesticide dose rate Adjustment to the Crop Environment) scheme is a method of adjusting the dose rate according to tree height and canopy density so that constant average deposits are achieved in a wide range of different orchards throughout the season. The scheme was launched in the UK in spring 2006 in a series of seminars and training courses for growers which were attended by over half the industry. Here we give a step-by-step guide to the scheme. Many growers already make dose rate adjustments based on successful practice and on *ad hoc* trials with different orchard/product combinations. This scheme provides a dose rate adjustment system based on soundly derived scientific measurements.

4. THE PACE SCHEME

Below the 5 steps which are used to instruct UK growers on how to implement the PACE dose adjustment scheme are given:

4.1 Practical Steps

4.1.1 Step 1. Establish your Standard Orchard Sprayer Settings

To establish the standard sprayer operational setting for the reference crop structure, as a once only exercise, set the sprayer so that the top of the spray plume would hit the top of a standard height tree.

Standard height for dwarf and semi-dwarf apple orchards: 3m
Standard height for cider apple orchards: 5m

Adjust the number and position of nozzles and airflow to match the height of the spray plume for such trees and to ensure that the spray plume penetrates the canopy. Choose a sensible working forward speed (e.g. 6 kmph or 4 mph) that gives good work rates without significantly compromising deposit distribution within the canopy.

4.1.2 Step 2. Assess the Need to Spray and Select the Appropriate Pesticides

Monitor your orchards at least fortnightly for levels of pests and diseases and assess the potential risk of infection or infestation. Use the schedule in the Defra Best Practice Guides for Apple and Pear Production (Cross and Berrie, 2002, 2003). Take into account predictions from pest or disease models and weather forecasts. If spraying is justified, choose an approved pesticide which is as safe as possible to humans, wildlife and the environment but which at the dose rate recommended on the label will give effective control of the target pest or disease in trees of the standard height and high density at that growth stage. Check the product label for the dose rate recommendation.

4.1.3 Step 3. Assess Whether Dose rate Reduction is Appropriate

If pest or disease levels or risks are high, then it is likely to that the best option is to apply the pesticide at the maximum dose rate to achieve the maximum deposit. Dose rate reduction may be appropriate for low to medium pest or disease risk situations. Note that if you reduce the dose rate the manufacturer's warranty on the efficacy of the product may no longer apply. Check if your target water volumes are achievable using the standard sprayer settings and that any additional requirements do not compromise these settings.

4.1.4 Step 4. Reduce the Dose Rate for Lower Canopy Density

Check the canopy density in relation to growth stage. Use Fig 3 to determine the appropriate dose rate reduction for dwarf or semi-dwarf dessert or culinary orchards. Note that in the guidelines for growers a further figure is given for dose adjustments for cider apple orchards.

4.1.5 Step 5. Reduce the Spray Plume Height for Lower Tree Height

Switch off the upper-most nozzles to reduce the spray plume height for *pro rata* dose rate reduction (e.g. switching off the upper 25% of nozzles when the tree height is 25% smaller than the tallest trees will achieve a dose rate reduction of 25%).

4.2 Water Volume Rate, Spray Quality and Spray Cover

4.2.1 Adjusting the Dose Rate by Adjusting the Spray Volume at Fixed Concentration

The simplest way of adjusting the dose rate for sprays to different orchards at any given growth stage is to maintain a constant tank concentration (the one recommended on the label) and to adjust the dose rate by adjusting the spray volume. For instance, if a volume of 200 L/ha is recommended for the full dose, then applying a volume of 100 L/ha at the same concentration will deliver a ½ dose. However, it is important to maintain the same fine or very fine spray quality to maintain the same percentage cover.

There are three ways of reducing the spray volume:

1. Reducing the flow rate by reducing the number of nozzles
   As given in step 5, for smaller trees than the standard, the top nozzles should be switched off which will give a proportionate reduction in spray volume.

2. Increasing the forward speed.
   This is a good option on young trees on narrow row spacings, especially early in the season where spray penetration is easy. Spray volume and dose rate will be decreased in direct proportion to the increase in forward speed.

3. Every other row spraying
   Like option 2, this is also a good option on young trees and especially early in the growing season when spray penetration is easy. A two fold reduction in spray volume and dose rates will be achieved if forward speed and nozzle output are maintained. It is important that the spray plume penetrates at least two rows of trees in both directions from the sprayer for this option, which may be less appropriate if there is a cross wind.

4. Reducing the flow rate
   Where options 1, 2 or 3 are inappropriate or do not give a sufficient reduction in spray volume, consider the option of changing the combination of nozzle size and operating pressure by using the examples in the following table. These examples have been chosen to limit the variation in spray quality that may be possible and give a fine to very fine spray quality.

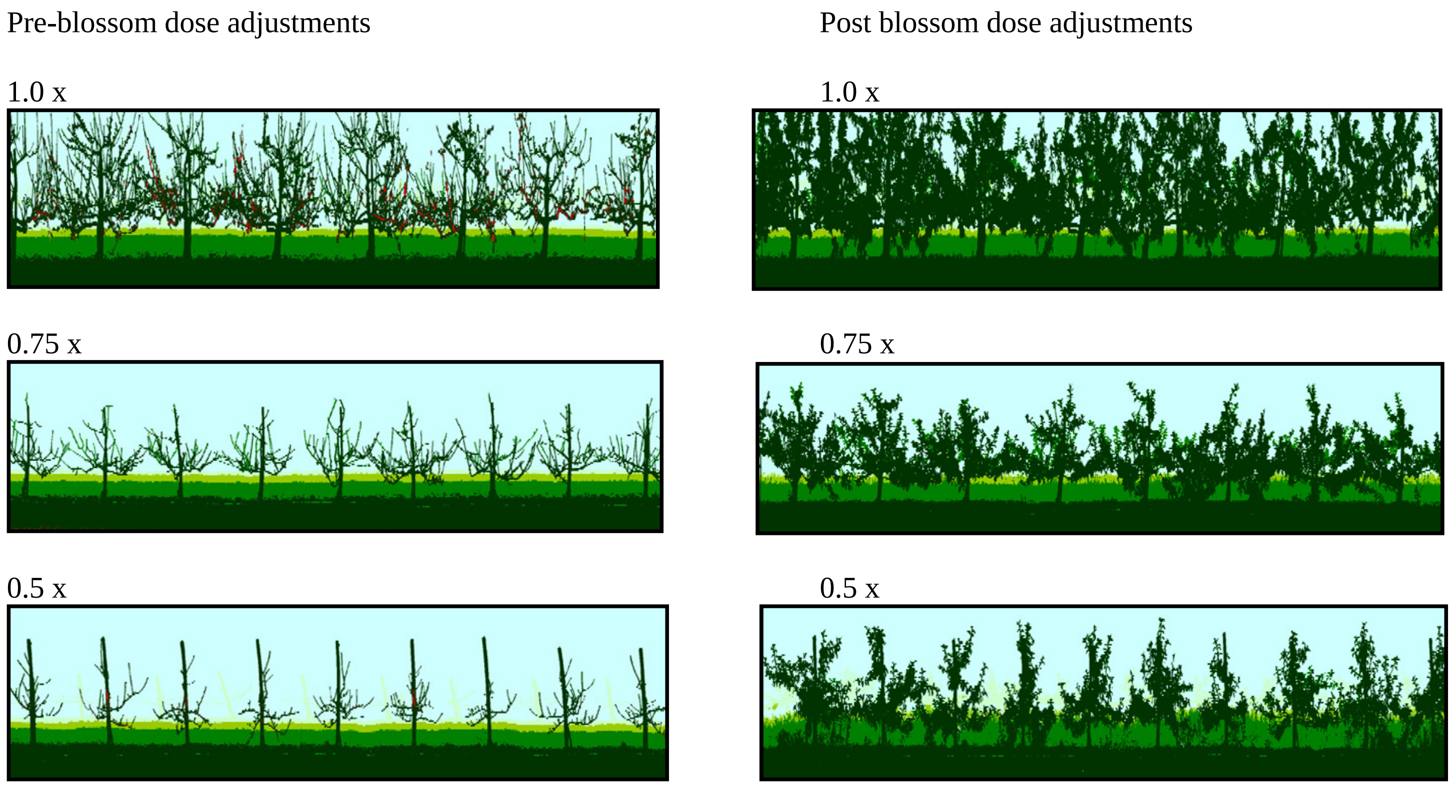

Figure 3. Pictograms indicating dose reduction factors for canopy density in dwarf and semi dwarf dessert and culinary apple orchards used in step 4 of the PACE dose adjustment scheme.

Table 2. Example nozzle selections and pressures which give different flow rates but maintain a constant fine to very fine spray quality

Nozzle examples	Pressure (bar)	Flow rate (l/min/nozzle)	Volume rate with 8 nozzles at 6 kmph on 4m row spacing	Dose rate adjustment given by changing nozzle flow rate only
		Albuz ATR ceramic hollow cone nozzles		
215 Orange	13.3	1.5	300	At full rate
215 Orange	7.1	1.125	225	¾ rate
212 Yellow	13.8	1.125	225	¾ rate
212 Yellow	6	0.75	150	½ rate
215 Orange	10.0	1.3	260	At full rate
212 Yellow	10.0	0.975	195	¾ rate
212 Yellow	4.1	0.65	130	½ rate
215 Orange	7	1.1	220	At full rate
212 Yellow	7.5	0.825	165	¾ rate
210 Brown	6.6	0.55	110	½ rate
212 Yellow	8.1	0.9	180	At full rate
212 Yellow	4.5	0.675	135	¾ rate
210 Brown	9.7	0.675	135	¾ rate
210 Brown	4.2	0.45	90	½ rate

4.2.2 Adjusting the Dose Rate by Adjusting the Tank Concentration

It is also possible to reduce the dose rate by reducing the tank concentration and maintaining the same spray volume, though this is likely to be a less practicable option. The disadvantage of this approach is that a different tank mix will be needed for each orchard that requires a different dose. Increases in concentration above the maximum on the label can be made under some circumstances within a UK government Code of Practice for the Safe Use of Pesticides on Farms and Holdings, but not where they are specifically prohibited on the label, where the pesticide is classed as Toxic or where there is a serious risk of damage to eyes. In general using much lower volumes of sprays at higher concentrations can lead to a significant reduction in spray cover and result in loss of efficacy of some products.

4.3 Worked Example

4.3.1 Dithianon 750 g/L SC (Dithianon Flowable) in Young Dwarf Orchards Pre-blossom

This scab fungicide is recommended to be applied from bud burst at a dose rate of 1.1 L/ha in a minimum water volume of 200 L/ha for low volume application or between 0.5 and 0.75 L/1000 L of water at high volume and repeated every 10 days until the danger of scab infection ceases. Providing that the risk of scab infection is low to moderate, serious scab infection periods are not forecast and there is an ability to respond to unforeseen infection periods, reduction from full-dose rate down to ½-dose rate for lower canopy density with a further proportional reduction for tree height less than 3 m would be appropriate. The reduced dose rate could be implemented by every other row spraying with the top nozzles switched off in young trees where the spray plume can penetrate multiple rows.

5. CONCLUSIONS

This work has demonstrated that spray deposits vary greatly between orchards due to variation in crop structure. Canopy area density and tree height have been shown to be the parameters that give rise to this variation and that can be used to adjust dose to minimise variation in deposits. A practical PACE scheme has been devised for implementation by growers.

6. ONGOING WORK

Further work is ongoing at East Malling Research to develop the scheme further for use in other tree fruits and it is hoped in future to a wide range of other row crops.

7. ACKNOWLEDGEMENTS

This work was funded by the Pesticides Safety Directorate of the UK Department for Environment, Food and Rural Affairs. The authors are grateful for the opportunity to present this work at the 9th Workshop on Sustainable Plant Protection Techniques in Fruit Growing at Alnarp, Sweden on 11-14 September 2007.

7. REFERENCES

Cross, J. **V.** And A. M. Berrie. 2002. Best practice guide for UK apple production; Section 2: Integrated Pest and Disease management in apple production. Guide book, East Malling Research, New Road, East Malling Kent ME19 6BJ UK, 94pp.

Cross, J. V. & A. M. Berrie. 2003. Best practice guide for UK pear production; Section 2: Integrated Pest and Disease management in pear Production. Guide book, East Malling Research, New Road, East Malling Kent ME19 6BJ UK, 102pp.

Cross, J. V., P. J. Walklate, R. A. Murray and G. M. Richardson. 2001a. Spray deposits and losses in different sized apple trees from an axial fan sprayer: 1. Effects of spray liquid flow rate. *Crop Protection* 20: 13-30.

Cross, J. V., P. J. Walklate, R. A. Murray and G. M. Richardson. 2001b. Spray deposits and losses in different sized apple trees from an axial fan sprayer: 2. Effects of spray quality. *Crop Protection* 20: 333-343

Cross, J. V., P. J. Walklate, R. A. Murray and G. M. Richardson. 2003. Spray deposits and losses in different sized apple trees from an axial fan sprayer: 3. Effects of air volumetric flow rate. *Crop Protection* 22: 381-394.

Murray, R. A.; J. V. Cross and M. S. Ridout. 2000. The measurement of multiple spray deposits by sequential application of metal chelate tracers. *Annals of Applied Biology* 137: 245-252.

Walklate, P. J. And J. V Cross. 2005. Orchard spraying: Opportunities to reduce dose rates. Horticultural Development Council Factsheet 20/05, 4 pp.

Walklate, P. J., J. V. Cross, G. M. Richardson, R. A. Murray and D. E. Baker. 2002. Comparison of different spray volume deposition models using LIDAR measurements of apple orchards. *Biosystems Engineering* 82 (3): 253-267.

Walklate, P. J., J. V. Cross, G. M. Richardson and D. E. Baker. 2006. Optimising the adjustment of label-recommended dose rate for orchard spraying. *Crop Protection* 25: 1080-1086.