Project title:	Improving the efficiency of spray application for protected ornamental crops: a study of current spraying methods and novel spraying technologies (phase 2: laboratory and nursery studies)
Project number:	PO 008
Project leader:	David Talbot, ADAS UK Ltd.
Report:	Final report, May 2014
Previous report:	Annual, May 2012
Key staff:	David Talbot, Project leader Bill Basford, Consultant to project Chris Dyer, ADAS Statistician
Location of project:	ADAS Boxworth Commercial nurseries throughout England
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Date project commenced:	1 February 2012
Date project completed (or expected completion date):	31 May 2014

DISCLAIMER

[The results and conclusions in this report are based on an investigation conducted over a one-year period. The conditions under which the experiments were carried out and the results have been reported in detail and with accuracy. However, because of the nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results, especially if they are used as the basis for commercial product recommendations.]

AUTHENTICATION

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

David Talbot

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Signature: Date 21/04/14

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GROWER SUMMARY

Headline

Spraying at 400 L/ha as opposed to 2,000 L/ha saves around £10 in labour per hectare by reducing the down time required to refill the sprayer with water.

Where crop protection products as are used at a set number of millilitres per litre of water (for example Dazide Enhance (daminozide) and Chess WG (pymetrozine)), reducing water volumes per hectare results in additional pro-rata savings in pesticides.

Background

This project follows the literature review undertaken in 2012 by the late John Buxton, the projects aims were to:

1. Improve the efficiency of spray application in ornamental crops,
2. Highlight novel technologies that ornamental growers can readily adapt.

Phase one of the project addressed both points, the second phase of the project focused on improving the efficiency of spray application. This included measurements of the droplet size distribution in the spray from a Ripa spray pistol using both 1.2 mm and 2.0 mm nozzles. Droplet characteristics were quantified by laser diffraction imaging (using a ‘‘Spraytec’’ laser produced by Malvern Instruments Ltd) at the NIAB/TAG Silsoe Spray Application Unit. In addition to this laboratory work visits to commercial nurseries across several regions of England examined and calibrated high volume sprayers as used in the production of protected ornamentals. A total of six nurseries were visited in The Vale of Evesham, Spalding and West Sussex; two nurseries were visited within each of these important production areas of the UK. Commercial nurseries included within this study were representative of large and small nurseries within England.

Summary

The first phase of the project reviewed the current methods of applying crop protection products to protected ornamentals within the UK and Europe, the second phase evaluated the research findings in context with current practice. Traditional nozzles and more recent, new nozzle developments were appraised for their suitability for use within the protected ornamentals sector. The following novel spraying systems were reviewed: electrostatic sprayers, ultra-low volume systems (ULV Systems), spray cabins (Degramec, Belgium), Micothon and CMW semi-robotic sprayers, gantry sprayers: these can be fully automatic or semi-automatic (Visser Spray-O-matic) and automatic self-propelled sprayers (Balsari and Visser Spray-O-matic). The second phase of the project measured the droplet size distribution from a Ripa spray pistol fitted with new 1.2 mm and 2.0 mm nozzles and a worn 2.0 mm spray nozzle at Silsoe Spray Applications Unit. An instrument using laser diffraction measured the droplet size distribution in the spray. This revealed that, as expected, increasing the operating pressure reduced the mean droplet size. A worn tip increased both droplet size and flow rate which further increased water volumes. Increasing operating pressure also increased droplet velocities. It was not possible to return the pistol to a setting that gave the same droplet distribution precisely or in a fully repeatable manner. Settings and pressure combinations to achieve the required spray quality are very different to the settings used by the agricultural industry. As suspected, all the participating nurseries visited were using very high water volumes to apply crop protection products. This is inefficient in terms of labour and applies more pesticide than is needed in some instances; which is wasteful and has environmental and cost implications.

Financial Benefits

Using a lower water volume to treat 1 ha (hectare) reduces the down time taken to fill the sprayer. Assuming that a 200 litre trolley sprayer is used, this will save around £10 in labour per hectare by spraying at 400 L (litres)/ha as opposed to 2,000 L/ha.

It is difficult to comment accurately on pesticide savings in financial terms as growers use a range of products and not all need to be applied in a set amount of water.

Improving the uniformity of spray application will also impact on crop uniformity and quality, especially when applying plant growth regulators.

Action Points

- Evaluate crop protection product application equipment when planning new production facilities and investigate the installation of automated boom systems.
- Do not spray to run off; it is wasteful and increases the risk of pollution.
- As it was not possible to reset a Ripa spray pistol to deliver a repeatable result it is recommended and considered best practice to set the gun from fully open to a lower setting each time to minimise variability.
- Worn nozzles used in such a pistol increased the average droplet size and have been proved to increase the flow rate, therefore inspect and change nozzles regularly.

- Growers should aim to achieve a medium to fine spray quality when spraying protected ornamentals (**Table 1**).

- Increasing pressure increases the flow rate and the amount of crop protection product and water used; use the minimum pressure required to achieve the necessary spray quality. High operating pressures can also result in a very fine spray quality that is prone to drift, and fine droplets that will also evaporate rapidly which can be undesirable.

Table 1: Spray quality that was achieved with 'as new' 1.2 mm and 2.0 mm nozzles in a Ripa spray pistol at Silsoe at the various settings and pressures.

	Spray quality when twist grip on spray pistol set as shown below (pressure in bar shown in brackets).			
Nozzle size	Fully closed	Open 90º	Open 180 º	Open 270 º
1.2 mm	Medium to fine (2 – 4), Fine (3 – 10)	Medium (2 – 4), fine (4 and above.)	Medium (3 – 6), fine (7 and above.)	Medium (6 – 8), fine (8 and above.)
2.0 mm	Medium (2 – 8), fine (8 – 10)	Medium (4 – 10). Adjust gun to achieve a fine spray.	Medium (5 -7), fine (7 - 9)	Medium (6 -8), fine (8 – 10)

SCIENCE SECTION

Introduction

The first annual report for this project is available on the HDC website (Project number: PO 008, Project title: Improving the efficiency of spray application for protected ornamental crops: a study of current spraying methods and novel spraying technologies (phase 1: desk study)) and is a useful reference for growers interested in new spray technology.

The second phase of the project focused on measurements of the droplet size distribution in the sprays from a Ripa spray pistol using both new 1.2mm and new and worn 2.0mm tips, using a laser based imaging instrument at the NIAB/TAG Silsoe Spray Application Unit.

The droplet size distribution in a horticultural spray is an important measure of performance that influences target deposition, efficacy and the risk of drift. Most systems for measuring the droplet sizes in a spray are now based on instruments that use laser light to sample sprays (Parkin, 1993) with different instruments using different operating principles, sampling methods and measurement volumes. Because of these differences, the use of numerical values relating to droplet size distribution parameters such as D10, D50 (VMD) and D90 are difficult to use in commercial environments. Doble *et al*., (1985) described a classification system that defined spray qualities of very fine, fine, medium, coarse and very coarse for a given candidate nozzle and operating pressure based on a comparison of measured droplet size distributions with the candidate nozzle with those of defined reference nozzles measured using the same protocol. The initial scheme used reference nozzles that were representative of each defined spray quality but the approach was subsequently revised such that the reference nozzle conditions now define the boundaries between spray quality classes, (Southcombe *et al*., 1997).

A number of studies have shown that the physical properties of the spray liquid can have a substantial effect on the droplet size distribution in the spray generated by a given nozzle operating at a defined pressure – see, for example, Miller and Butler Ellis (2000). The original British Crop Protection Council (BCPC) scheme as outlined by Doble *et al.,* (1985) specified that measurements should be made when spraying 0.1% of a nonyl phenol ethoxylate surfactant (Agral). However, this class of chemicals has now been withdrawn from use within Europe and proposals have been made to use a spray liquid containing

0.1% Tween 20 as a standard liquid representative of agricultural tank mixes (O'Sullivan *et al*., 2010). An American ASABE standard specifies that their equivalent classification should generally be based on spraying tap water but also indicates that a spray liquid having a dynamic surface tension of 40 ± 2 dynes/cm at 10 to 20 ms (no temperature range specified) should be used for nozzles designed to reduce drift, have a pre-orifice or have internal structures to generate turbulence particularly at conditions close to spray quality boundaries. The two additives specified in the American standard (isopropanol at 9% wt/wt or Surfynol™ TG-E surfactant at 0.1% v/v) have not been widely used in Europe.

The work described in this report has classified spray qualities by the BCPC methods based on spraying water only. Previous work has shown good similarity between droplet sizes from a range of nozzles spraying both water and Tween20 and therefore it was decided that a classification under the BCPC schemes when spraying water only would give results appropriate to the requirements in this case. The spray classifications relate only to droplet size distributions although the physical behaviour of a spray, and particularly the "throw" of the nozzle, will also be a function of the droplet velocity (speed and direction) distributions. There are currently no agreed standards relating to the measurement of droplet velocities within a spray or the way in which information from such measurements should be presented. In this report we have given some examples of the axial velocity/droplet size profiles measured within the spray with different nozzle settings.

In addition to this laboratory work visits to commercial nurseries throughout England examined and calibrated high volume sprayers and knapsack sprayers as used by the industry. A total of six nurseries were visited in three important production areas which included The Vale of Evesham, Spalding and West Sussex; two nurseries were visited within each of these regions. Commercial nurseries included within this study were representative of large and small nurseries within England.

Materials and methods

Laser based imaging at the NIAB/TAG Silsoe Spray Application Unit

All measurements were made in the specialised spray chamber in the laboratory on the Silsoe site operated by Silsoe Spray Applications Unit. An instrument using laser diffraction principles as a means of measuring the droplet size distributions in the spray from agricultural spray nozzles ("Spraytec" – Malvern Instruments Ltd) was used and was operated in accordance with a standardised protocol, copies of which are available on request. The main features of the measurement system were:

- the mounting of the spray nozzle on a computer-controlled x-y nozzle transporter with the nozzle orifice 350 mm away from the sampling laser of the measurement system;
- for the lower operating pressures (up to 5.0 bar), the supply of liquid (tap water) to the nozzles was from a pressurised container mounted on a balance connected to a computer enabling liquid flow rate to the nozzle to be monitored: for higher pressures a diaphragm pump was used to pump from a container mounted on the balance;
- the measuring of pressure with a transducer mounted immediately upstream of the nozzle;
- the recording of both air and liquid temperature close to the nozzle such that the liquid temperature was controlled to be within ± 3.0^{o}C of the ambient air and so minimise any temperature effects on the spray formation mechanisms (Miller and Tuck, 2005);
- programming the nozzle transporter such that the long axis of the spray from the nozzle used in the study passed through the sampling laser beam on the droplet sizing instrument at a speed of 20.0 mm/s;
- the estimation of spray fan angle based on the positions at which droplets are detected by the size analyser;
- control of air conditions within the spray chamber to minimise the accumulation of small droplets within the air;
- the transfer of recorded data on to a computer network system so that the results could be processed using established software approaches.

The measured droplet size information has also been used to give an indication of the spray quality classification for the nozzle settings studied by making comparative measurements with the conventional flat fan nozzles at defined pressures that are used as a reference to define the boundaries between spray classification classes (Doble *et al*., 1985; Southcombe *et al*., 1997).

Some additional measurements were also made using an instrument operating with laser-based imaging techniques as a means of measuring both the droplet size and velocity distributions in the sprays from horticultural nozzles ("Visisizer" – Oxford Lasers Ltd). This was operated in accordance with a standardised protocol. The system used a double imaging approach such that velocities could be determined by matching droplet images from two images taken with a defined small time interval between them.

Results for the measured droplet size distributions were summarised as a volume median diameter (VMD, µm) and a percentage of spray volume in droplets <100 µm in diameter. Measurements were made with a nozzle design a Ripa spray pistol – see Figure 1.

Figure 1. Nozzle design used in the study.

The main features of this nozzle assembly were:

a) operation via a trigger valve – for this study the valve was fixed in the "on" position and the supply of liquid controlled as indicated in Section 2.1 above;

b) The ability to fit different sizes of output orifice – this work used three different output orifices, namely:

- a "as new" 2.0 mm diameter orifice tip;
- a "as new" 1.2 mm diameter orifice tip; and

- a 2.0 mm diameter orifice tip that had been subjected to substantial wear;

c) The ability with a given output orifice to vary the spray characteristics by rotating the knurled section in front of the trigger valve – for this work a reference condition with this adjustment fully closed was defined together with angular rotations away from this fully closed condition.

Nursery Surveys

A survey visit record sheet was put together in order to record various aspects relating to the application of crop protection products, the results gathered from the participating nurseries is summarised within the results section of this report. This included a calibration of both a high volume sprayer and a knapsack sprayer. Water quality used for spraying was determined by taking a sample for analysis where a recent sample had not been taken. There is no real consistency between the results obtained from the small sample of nurseries included within this study, therefore the ADAS statistician has concluded that there are no statistical analyses worth doing.

Results

Results of the Laser based imaging carried out at the NIAB/TAG Silsoe Spray Application Unit are presented below, prior to the results of the nursery surveys.

Measurements with the "as new" 2.0 mm orifice tip

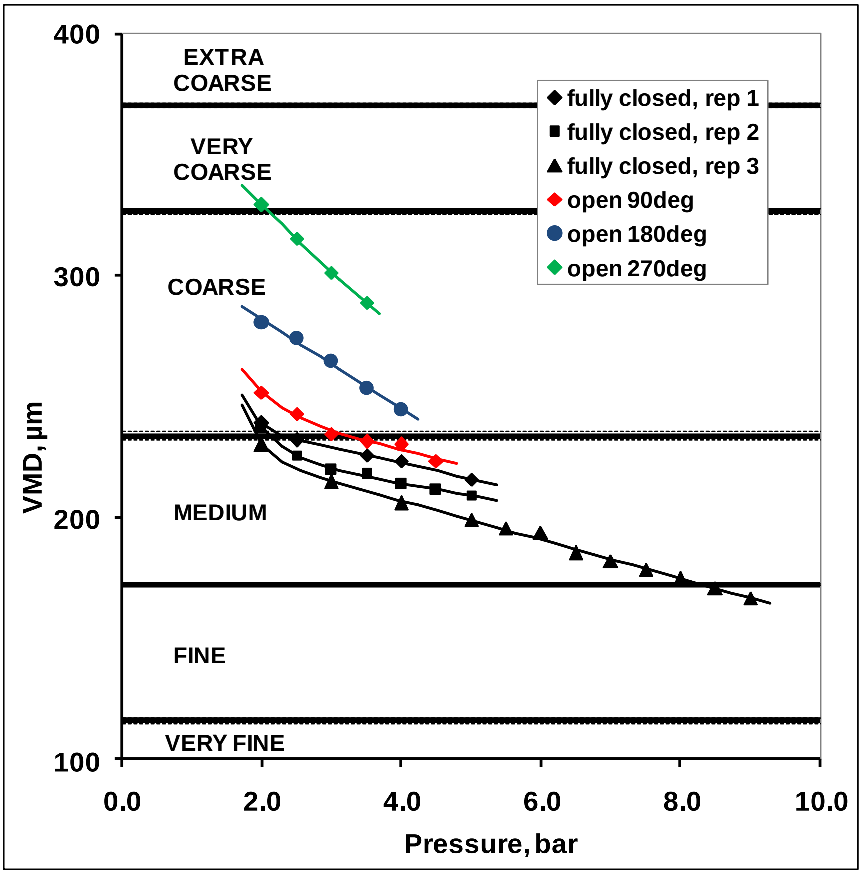

Figure 2. Measured mean droplet sizes for the “as new” 2.0 mm orifice tip at various settings at defined pressures resulted in spray qualities as defined by BCPC.

- Droplet sizes reduced with increasing operating pressure as expected;
- There was variation in the mean droplet sizes when the nozzle was re-adjusted to the “fully closed” position between replicated measurements;
- Droplet sizes increased as the knurled knob setting was “opened”;
- When operating in the “fully closed” position, a medium quality spray was generated at pressures of between 3.0 and 7.0 bar.

The percentage of spray volume present in small droplets is an indication of the tendency of a spray to drift away from the intended target and the results plotted in Figure 3 show trends that are consistent with those relating to the mean droplet size data plotted in Figure 2.

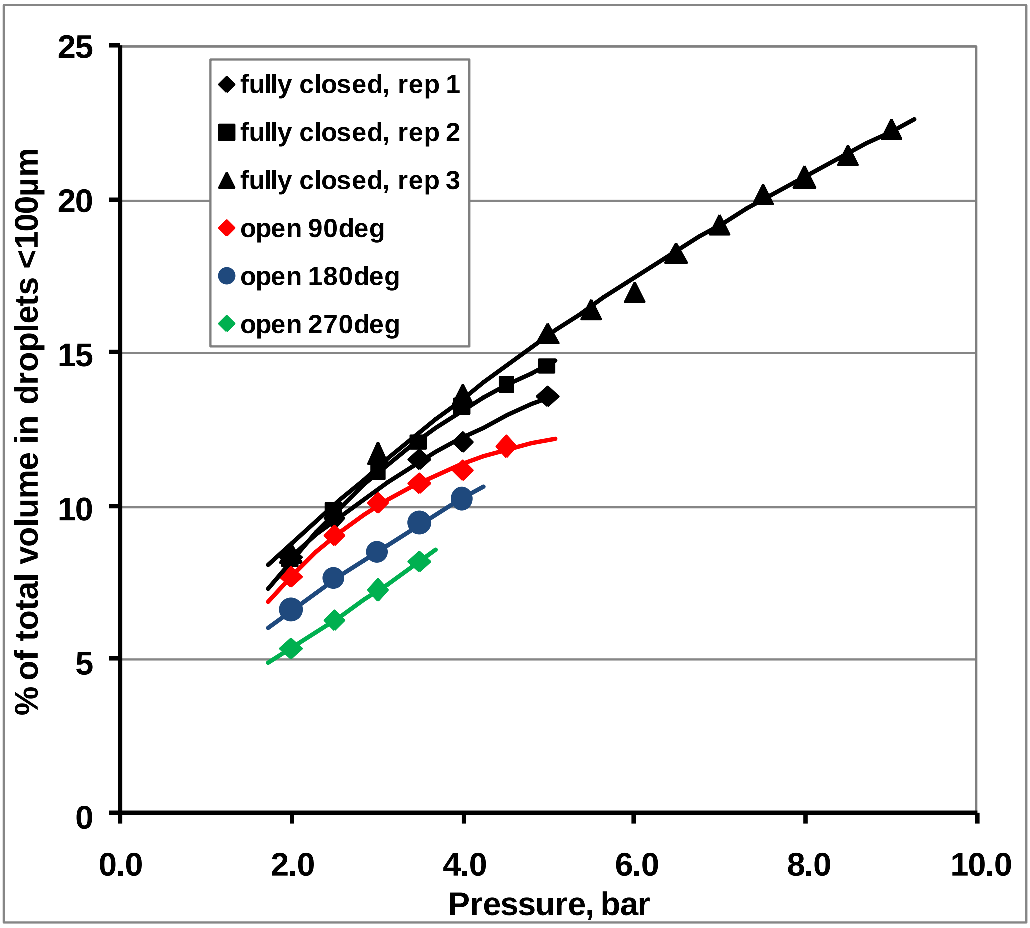

Figure 3. Measured percentage of spray volume in droplets <100 µm in diameter in the sprays from the "as new" 2.0 mm orifice tip.

Measured flow rates for the same settings shown in Figure 4 indicated that the setting resulting in the larger droplet sizes also gave the highest flow rates as expected with consistent trends over the measured pressure range and adjustment settings used.

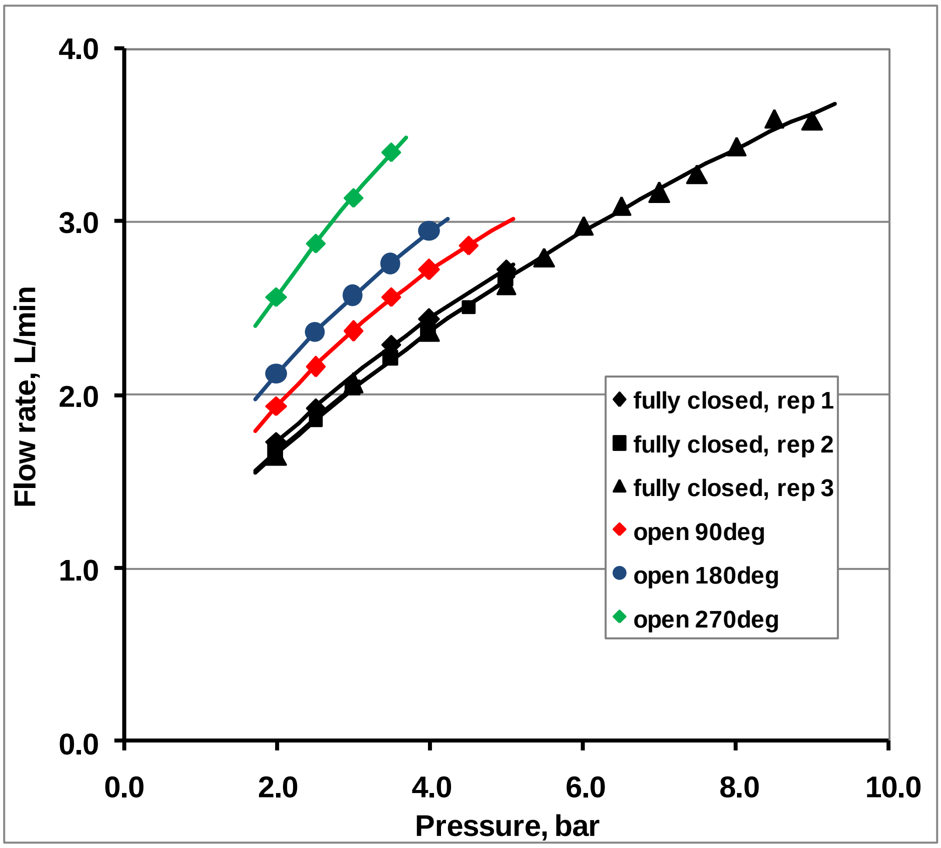

Figure 4. Measured flow rates for the “as new” 2.0 mm orifice tip.

Measurements with the “as new” 1.2 mm orifice tip

Data plotted in Figures 5, 6 and 7 are the equivalent to Figures 2, 3 and 4 for the 2.0 mm orifice tip but relate to the 1.2 mm tip. Very similar trends were observed but with smaller droplet sizes and lower flow rates when using the smaller orifice tip as expected. The nozzle fitted with the 1.2 mm orifice tip and with the knurled knob adjustment “fully closed” generated a fine spray at pressures of between 4.0 and 10.0 bar.

A comparison of the results for the nozzle when fitted with the 2.0 mm plotted in Figure2 with those when operating with the 1.2 mm tip plotted in Figure 5 indicates that the effect of adjusting the knurled knob on the droplet size distribution in the spray was greater when fitted with the smaller tip. A wider range of spray qualities was therefore measured when using the smaller orifice tip. Similarly, comparing the results shown in Figure 3 with those in Figure 6 indicates that the knurled knob setting had a greater influence on the percentage of spray volume in small droplets when the smaller orifice tip was fitted.

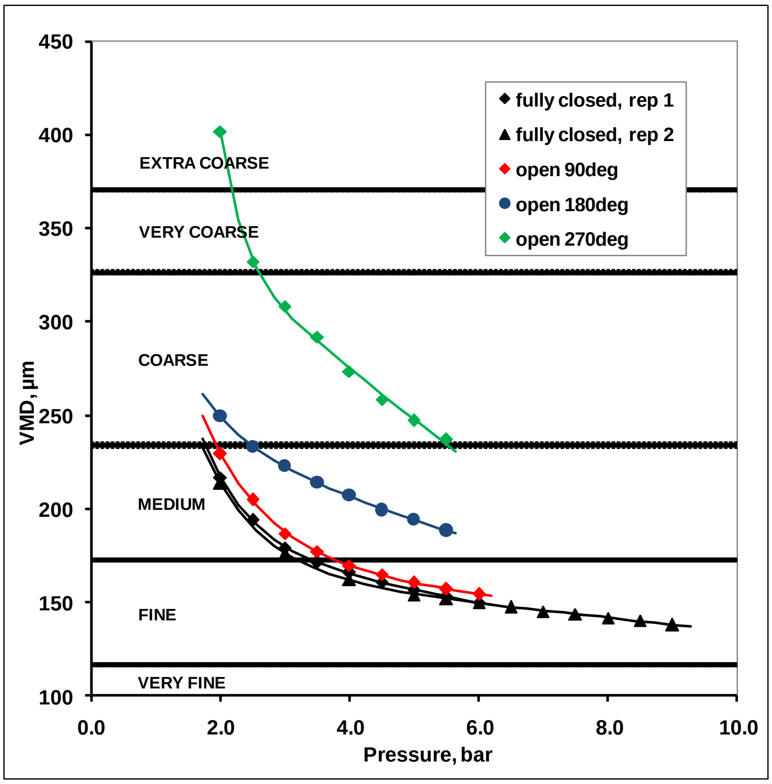

Figure 5. Measured mean droplet sizes for the “as new” 1.2 mm orifice tip.

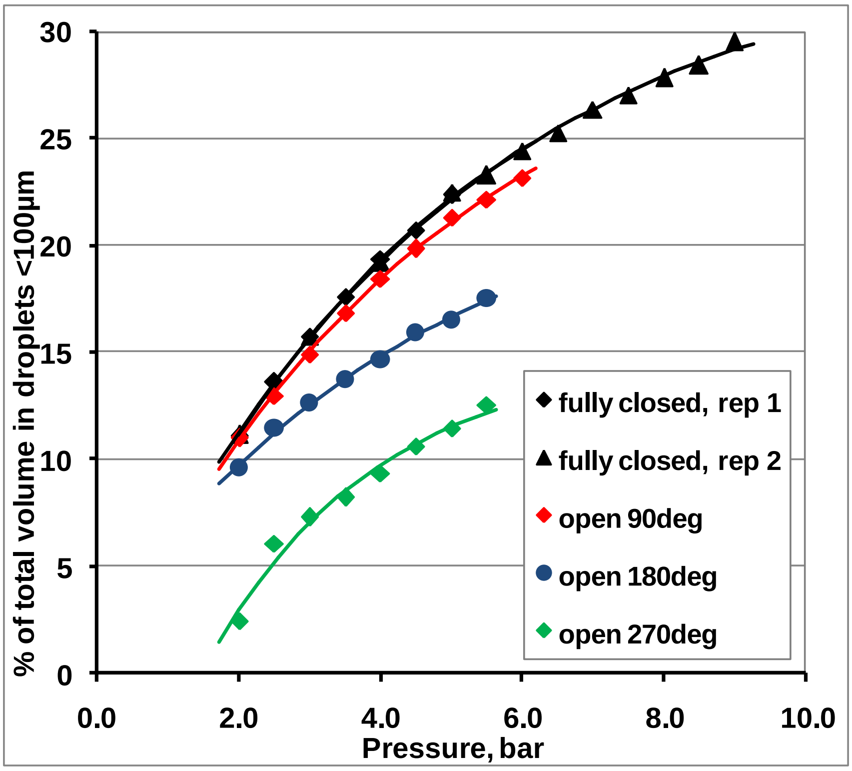

Figure 6. Measured percentage of spray volume in droplets <100 µm in diameter in the sprays from the “as new” 1.2 mm orifice tip.

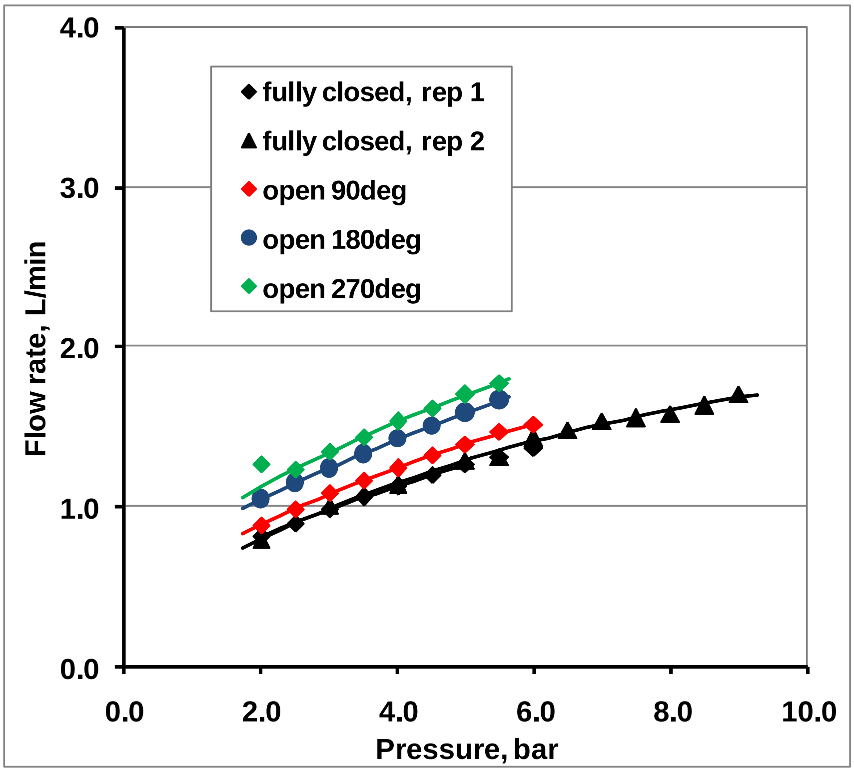

Figure 7. Measured flow rates for the “as new” 1.2 mm orifice tip.

Measurements with the worn 2.0 mm orifice tip

The results show that when using the worn 2.0 mm tip plotted in Figure 8 together with the results for the “as new” tip wear increased the droplet size as expected. Droplet sizes were increased by some 7.9% and flow rates by 9.6% when using the worn nozzle tip. The worn nozzle was provided by a grower, it had been in use for some time, probably at least one season’s spraying.

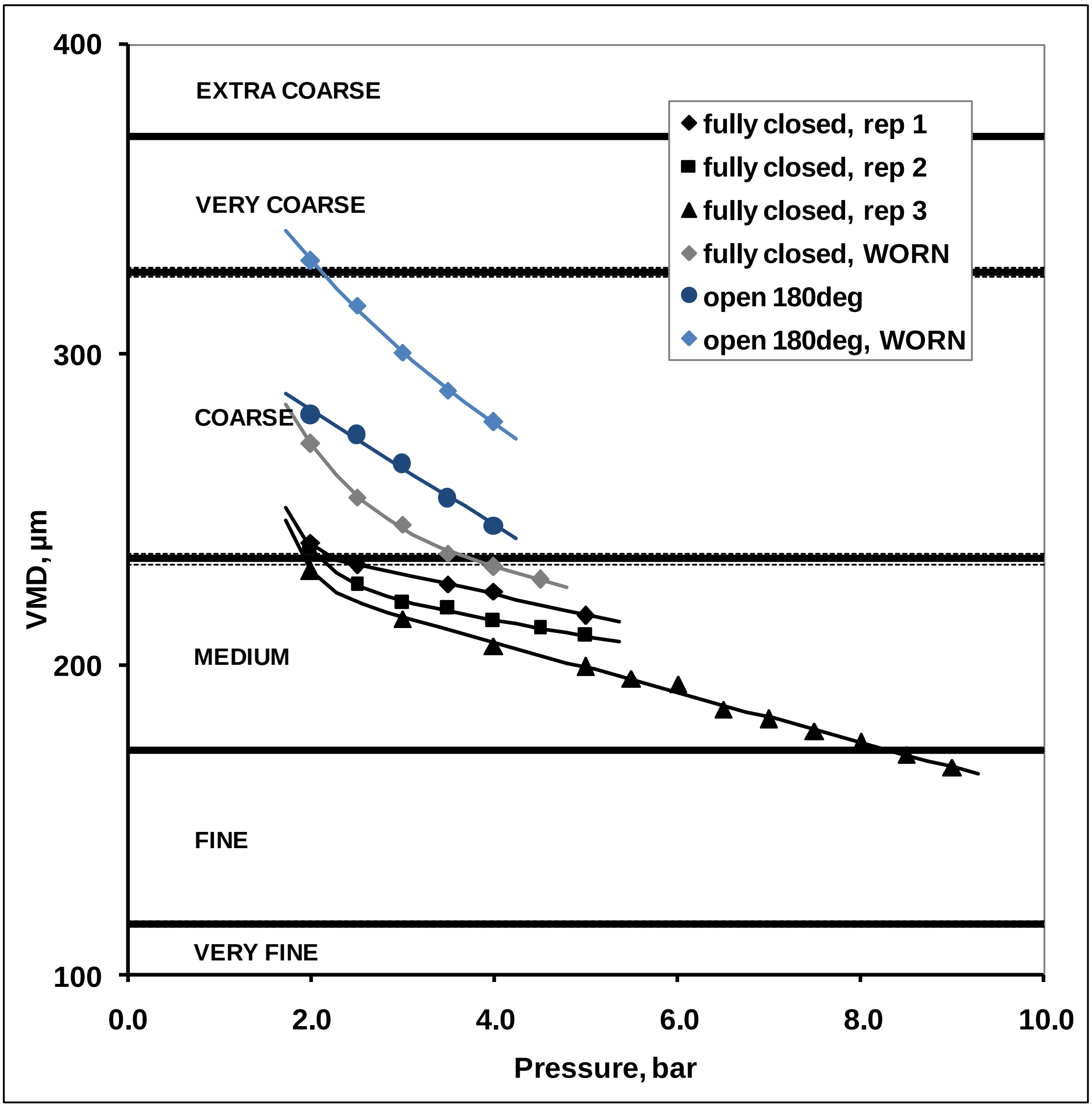

Figure 8. Measured mean droplet sizes for the worn 2.0 mm tip compared with the results when using the "as new" 2.0 mm tip.

Droplet size/velocity profile measurements with the "as new" 2.0 mm orifice tip

Measured droplet size/velocity profiles for three nozzle conditions at pressures of 2.0, 4.0, 6.0 and 8.0 bar are plotted in Figure 9.

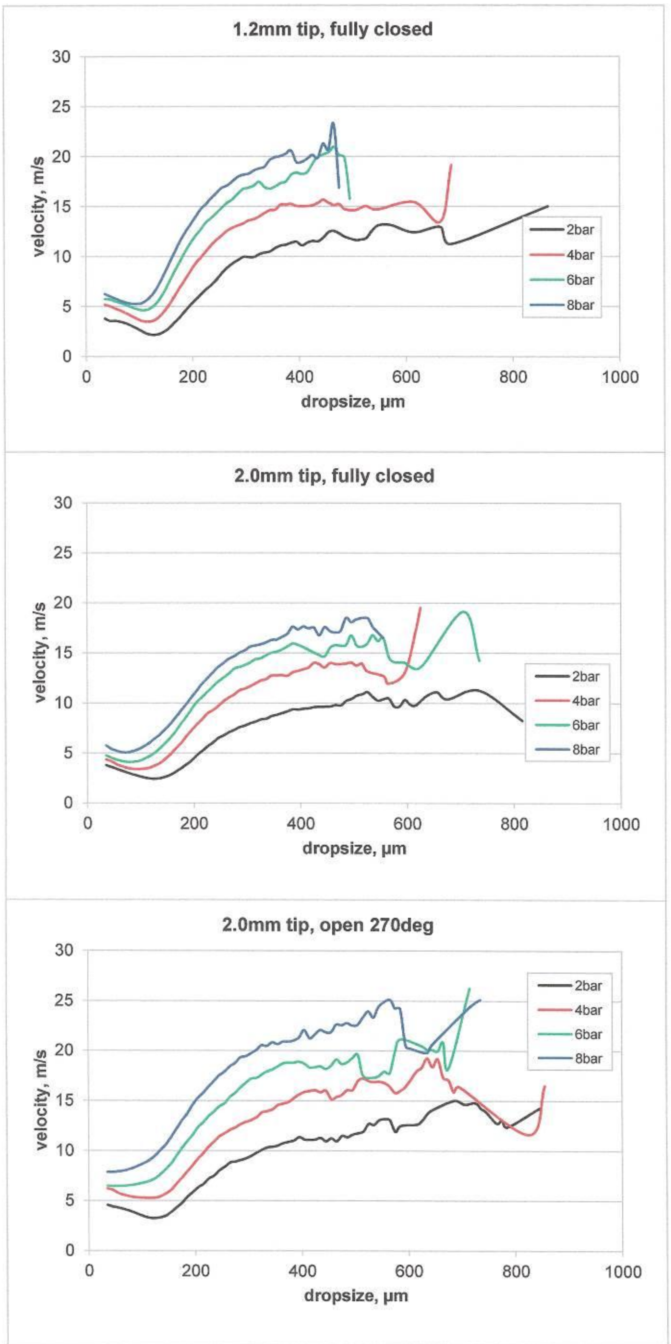

Figure 9. Measured droplet size/velocity profiles for three nozzle conditions at a range of pressures which show droplet sizes decreased as pressure increases.

Figure 9 shows that velocity of droplets produced from most settings with the Ripa spray pistol are higher than would be achieved with conventional spray nozzles. Clearly higher velocities may assist penetration into dense foliage but it is the larger droplets which are thus travelling further. So when spray is applied to very small plants with prostrate growth, such velocities may lead to spray patterns being deflected off leaves, some droplets will shatter but some will be lost. Thus the spray may be difficult to control; resulting in a reduction in potential coverage and exacerbating drift.

Nursery surveys

Nurseries visited as part of this study have been numbered to allow results to be compared without revealing individual nurseries identity. Calibration carried out on the commercial nurseries visited revealed that the following systems were being used to apply crop protection products at the water volumes shown in Table 2:

Table 2: Results of sprayer calibration carried out on participating nurseries

Nursery number (Time to spray 100m²)	Description of sprayer and nozzle	Crops sprayed (listed in order of significance)	Pressure used (bar) as indicated on the trolley unit, not verified.	Litres per Ha applied for pest and disease control	Litres per Ha applied when using plant growth regulators
1 (4 minutes, 3 seconds)	Proprietary Brinkman trolley sprayer with 200L tank, triple nozzle hand held boom with yellow Hypro 110º flat fan nozzle.	Pack *Primula, Petunia, Dahlia,* New Guinea *Impatiens, Tagetes,* Pansy.	10	1731	1731
2 (3 minutes, 23 seconds)	200L fruit juice tank with pump & Ripa spray pistol. 2mm nozzle, wear acceptable. (No agitation when spraying, ought to have some particularly when using	Cell grown seedlings, Pot grown *Poinsettia,* other pot grown crops e.g. *Cyclamen /* Summer bedding	9	2200 (Two way sprays applied to *Poinsettia* crops so 4400 L	1993 (Two way sprays applied to *Poinsettia* crops so 3986 L applied)

	powdered formulations)			applied)	
3 (1 minute 21 seconds)	Proprietary Vale trolley sprayer with 200L tank, Ripa spray pistol with 2mm nozzle, part worn. Tested under NSTS 09/11/12.	Pot grown crops of *Hydrangea, Cyclamen,* summer bedding, Herbacous perennials, Christmas cactus, *Chrysanthemums*	20	1269	1118
4 (1 minute, 1 second)	Proprietary Brinkman trolley sprayer with 200L tank, Ripa spray pistol with 2mm nozzle, wear acceptable.	*Pelargonium, Fuchsia, Petunia* cuttings & pot grown *Cyclamen, Senetti, Pansy*	10	658	559
5 (5 minutes, 46 seconds)	Proprietary Brinkman trolley sprayer with 200L tank, Ripa spray pistol with 2mm nozzle part worn.	Pot grown *Chrysanthemum, Poinsettia, Osteospermum, Senetti, Cyclamen,* Herbacous perennials.	18	450	450
6 (1 minute, 24 seconds)	Hortec Empas sprayer with ceramic hollow cone nozzle; believed to be 1.5mm nozzle. Nozzle wear acceptable.	Protected cut flowers *Stachys,* Stocks, *Aster, Chrysanthemum*	30	880	753

Table 3: Nursery two, calibrations using different sized nozzles on a Ripa spray pistol, set for pest and disease control or PGR application

Size of nozzle	Spraying for pest and disease control or PGR application	Pressure in bar	Litres / Ha applied
2 mm	Pest and disease	9	2200
2 mm	PGR	9	1933
1.5 mm	Pest and disease	9	1267
1.5 mm	PGR	9	917
1.2 mm	Pest and disease	9	767
1.2 mm	PGR	9	617

Table 4: Flow rate reduction and thus water volume applied with nozzle size and pressure reduction on nursery 1 (using a proprietary Brinkman trolley sprayer with 200L tank with a hand held boom to spray pack bedding).

Description of nozzle	Pressure used (bar)	Litres per Ha applied for pest and disease control
Blue Hypro 80º flat fan nozzle.	10	2397
Yellow Hypro 110º 02 flat fan nozzle.	10	1731
Yellow Hypro 110º flat fan nozzle.	7	1573
Yellow Hypro 110º flat fan nozzle.	5	1362
Orange Hypro 110º flat fan nozzle.	4	562
Orange Hypro 110º flat fan nozzle.	2	365

This nursery was using either 80º flat fan nozzles (primarily to drench plugs prior to potting), or 110º flat fan nozzles as alternative choices on the same boom. On boom based systems, 80º flat fan nozzles should be mounted at 45.7cm apart whilst 110º nozzles suit 50 cm spacing. This nursery used to use a yellow Hypro 110º flat fan nozzle at 10 bar to apply crop protection products, as a result of this study nursery 1 has changed to Orange Hypro 110º flat fan nozzle at 4 bar. This has reduced spray volumes by 1169 litres per hectare, no loss of efficacy has been noted and significant savings are being made in plant protection products with a rate per litre such as Dazide Enhance (daminozide)

Table 5: Calibration of knapsacks was also carried out on sites where these are used.

Nursery number	Litres per hectare applied via knapsack sprayer	Type of knapsack and nozzle
1	N/A	N/A
2	533	Unbranded knapsack with white hollow cone nozzle
3	981	Cooper Pegler (CP15) with green 1.2 Hardi reflex deflector nozzle.
4	191	Vermorel 2000 Pro with green Lurmark DT0.75 deflector nozzle.
5	394	Allman X-15 knapsack with yellow polijet hollow cone nozzle with black insert.
6	648	Cooper Pegler Classic (CP3) with Lurmark 15F 110º flat fan nozzle

Nurseries 3, 4 were using knapsacks primarily with deflector nozzles, the nozzle at nursery 3 was badly worn at the time of calibration with a fingered spray pattern, resulting in uneven application as shown below in Figure 10. This may explain the high volume of water being applied per hectare.

Figure 10: Worn deflector nozzle delivering a fingered spray patter

All nurseries were applying crop protection products via knapsacks at water volumes less than a 1000L/Ha which is encouraging. The spray operator at nursery 3 was advised to dispose of the worn nozzle and to obtain a replacement, this should reduce water volumes applied by knapsacks at this site.

Table 6: shows the results of water analysis carried out on water sources that would be used for spraying on participating nurseries

Nursery number	pH	Conductivity uS/cm	Alkalinity as HC03
1	7.60	659	165
2	7.74	508	151
3	7.18	717	282
4	7.28	567	281
5	5.90	855	24
6	7.50	684	283

In summary the water quality on all six participating nurseries was found to be acceptable for the application of crop protection products. Water with a pH below 5 impacts on the activity of active ingredients, limiting their function. Where nurseries have experienced their water pH dropping below pH5 it would be well worth collecting roof water, this would need to go through a fine typically 300 micron filter initially and then possibly through 100 micron filter prior to storage in a covered tank that excludes light. It is necessary to exclude light or algae is likely to be a problem which could result in blockages in sprayers.

Discussion

The maximum pressure used in arable boom spraying systems is generally 3 bar, table 2 shows the implications of excessive high pressure upon flow rate. High pressure increases the flow rate regardless of the spraying system. All of the nurseries visited as part of this study were spraying at high pressures (between 9 – 30 bars); resulting in high flow rates and unnecessary, excessive wear of equipment. The laboratory work at Silsoe was done before nursery surveys commenced, the limitations of the testing system prevented any work being done above 9 bar. Nursery number 3 thought that they were spraying at 2 bar, but were actually spraying at 20 bar (the one pressure gauge that worked on that trolley sprayer was obscured with splashes of glasshouse shading, obscuring the gauge face, not revealing the scale units. The lack of understanding of the impact of high pressure is a concern.

It is expensive to transport large volumes of water, regardless of spraying system, the need to fill up results in downtime reducing the operator’s efficiency. This is one of the reasons why the arable sector uses low water volumes; typically 100 – 200 L. Few horticultural producers have considered the down time associated with filling up the sprayer tank because water is generally readily available within or close to the production environment.

The cost implications associated with high spray volumes have not been considered to date by the majority of growers. Spraying a hectare of protected ornamentals with a 200 litre trolley sprayer at 4000 L/ha would require the operator to fill the tank 20 times, whereas spraying at 400 L/ha would only require the operator to fill the tank twice.

Although producers of protected ornamentals may not spray large areas of crops in one go, the increased efficiency in labour alone results in significant cost savings over the course of a year. It takes an average spray operator 5 minutes to mix and fill a 200 litre tank with water and the crop protection product, therefore spraying at 4000L/Ha as opposed to 400 L/ha takes an additional hour and a half to spray the same area (a hectare a 4000L/Ha as oppose to 400L/ha). Assuming that the average spray operator is paid £14per hour (inclusive of Tax and National Insurance) this equates to an additional £21 per hectare in labour every time a crop is sprayed.

Trolley sprayers on the nurseries visited were between 6 and 20 years old, with the average age approaching 10 years old. This does not matter as long as trolley sprayers are maintained and pumps are delivering the required pressure. Whilst all trolley sprayers were functional there was a lack of knowledge regarding the importance of maintaining pressure gauges and nozzles, particularly on nursery numbers 2, 3, 4, & 5 (the four nurseries using the Ripa spray pistol). Within the UK pesticide application industry nozzles that deviate from stated output (or output when new if this information is not available) by more than 5 percent should be disposed of. The nurseries using the Ripa spray pistol were replacing nozzles by default as the spray pistols were replaced when they broke. New spray pistols contained a new nozzle, usually a 2.0mm nozzle. Nursery number 1 replaces nozzles annually and nursery 6 replaces lances every 2 – 4 years. There seemed to be a lack of understanding as to which type of nozzle should be used for which purpose when knapsack spraying. One excessively worn nozzle was found on a knapsack (as shown in Figure 10). Selection of the appropriate nozzle and choosing one that is not worn is essential in order to achieve optimum results. Ideally in knapsack sprayers a hollow cone nozzle should be used to apply insecticides and fungicides, a flat fan to apply plant growth regulators and a deflector nozzle to apply herbicides to non-cropped areas.

Broken pressure gauges were found on virtually every nursery visited, broken pressure gauges are frequently encountered on other nurseries when delivering consultancy, these need to be replaced otherwise it is impossible to reset the sprayer to deliver a repeatable result. Where practical to do so it is advisable to fit a pressure gauge at the point of plant protection product delivery so that the operator is aware of the working pressure. It is also worth noting that pumps should not be run dry, a pressure gauge at the point of delivery would prevent this as the operator would detect a drop in pressure prior to the pump running dry. Pressure gauges should only operate at two thirds of the gauges capacity to prevent the gauge being damaged. For example if spraying at 8 bar the pressure gauge should go up to at least 12 bar.

Automated sprayers

Nursery number 2 uses the irrigation booms to apply nematodes for the control of Sciarid fly larvae control, however the irrigation booms contained different sized nozzles (both LP0380 & LP0580) with different flow rates within the same boom. This will result in an uneven distribution of nematodes and uneven watering, all nozzles should be the same size within a boom.

Nursery number 4 had booms installed for irrigation and expressed interest in using these booms to apply plant growth regulators. These booms were fitted with both 80º and 110º flat fan nozzles at 34 and 45cm spacing respectively. There were potential problems as the boom was too far away from the crop. This would result in uneven crop protection product deposition and the product having to travel further than it needed, which is likely to result in droplets loosing velocity and ability to penetrate the crops canopy. The floor of the glasshouse also sloped away so droplets would have to travel an extra 5cm at the end of the house. If vents were open at the time of application drift could have a significant effect on droplets that were losing velocity.

Some modern agricultural boom sprayers are fitted with automatic ground sensing so the boom is always a set distance above the crop, 45cm above the crop is the maximum distance before efficacy is compromised. The boom in question was up to twice this distance from the crop so was considered unsuitable for the application of crop protection products in its current form. The boom would need to be modified before being suitable for the application of crop protection products. The use of an air inclusion nozzle may help in this situation as this type of nozzle would produce a heavier droplet less prone to drift which would aid the penetration of the crops canopy.

Nursery number 5 had an automated spray boom, this was originally a Brinkman ally master with a Robor base. The automated boom is simply connected to a tank of dilute crop protection product. A linear actuator motor tilts the boom forward on the way out and back on return, resulting in similar coverage as a twin nozzle. Hollow cone TXA8002VK nozzles were fitted, the spraying height can be varied. The system runs on the heating pipes (but could run on wheels down concrete paths) so only one boom is required per house. Such systems can be very efficient as there is virtually no labour requirement, particularly where large numbers / whole houses of the same crop is produced. They result in good spray coverage, low operator exposure and low water volumes per hectare. Although not calibrated as part of this study this system was being operated at high pressure (20 bar) as it was felt by the grower that this was necessary to get movement in the crop canopy. The grower reported that this automated sprayer was delivering 1384 L/ha. There is potential to reduce the pressure in order to reduce water volumes applied per hectare.

Some nurseries leave the ventilation fans on whilst spraying, whilst this may create a better working environment for spray operators it can also speed up evaporation. This is undesirable, especially when applying plant growth regulators. The laboratory work at Silsoe has indicated that the high pressures used by much of the industry will result in fine droplets being applied; the finer the droplet the more prone they are to evaporation.

Table 7: NoRoSo and BASIS membership on nurseries visited

Nursery number	NoRoSo	BASIS
1	0	0
2	0	1
3	0	0 Thinking of getting one member of staff BASIS trained
4	0 (NoRoSo is seen as being angled towards agriculture, therefore a pesticide refresher workshop was organised through John Buxton & Bill Basford on 14/10/11	0
5	3	2
6	0	0

Only one of the participating nurseries had NoRoSo members, the scheme is seen as being too focused on agriculture by many in horticulture. Only two of the nurseries had BASIS registered staff; the majority of the nurseries use BASIS registered consultants to help keep them up to date with pesticide related issues.

Conclusions

The most common spraying system currently used in the protected ornamentals sector (spray pistols) is inherently inaccurate and applies too much water which can result in pesticide run off. Extensive research has shown that boom-based systems, some with air assistance can improve the accuracy and spray coverage whilst using less water. Spray booms have been shown to deliver the most even and uniform application, proven by widespread use on broad acre arable crops. The architecture of existing tunnels and glasshouses can and does limit the uptake of boom based systems however such systems should be considered as an alternative to variable pistol types such as the RIPA pistol. Some growers have solved the practical integration of boom spraying into their production systems. Automated booms have been installed on some holdings, particularly where mono cropping and these should be considered, particularly within new structures as they will result in improved application and significant savings in labour. Such automated systems also reduce operator exposure.

Nurseries should determine water volumes of automated systems and compare these with current methods of applying crop protection products prior to installation. This will enable growers to work out how long it will take to break even in order to facilitate investment decisions

The laboratory work carried out at Silsoe has demonstrated that:

- When using both 1.2 and 2.0mm nozzles, increasing operating pressure reduced mean droplet size as expected
- When adjusting the RIPA spray pistol using the knurled nut close to the tip, it was not possible to reliably reset the RIPA pistol studied to give the same result
- A smaller nozzle (1.2 mm) gave a smaller droplet size and lower flow rate than the 2.0mm nozzle in the “Fully closed” position. The 1.2 mm nozzle delivered a fine spray quality whilst the 2.0mm nozzle delivered a medium spray quality at 4 bar. Growers should aim to achieve a medium to fine spray depending on the product being applied; e.g. contact acting insecticides where good coverage is required should be applied as a fine spray, see Table 1 for guidance on spray quality.

- The effect of using a worn 2.0 mm nozzle was to increase the mean droplet size by 7.9% and mean flow rate by 9.6%. Growers should critically evaluate nozzles and spray outputs as part of a planned programme of sprayer maintenance. The frequency of which, depends on hours of use, any damaged nozzles should also be changed. Nozzles should be checked for wear in this way every 50 hours of use. Nozzles should also be visually checked every two months as dropping the lance or spray pistol can easily damage the nozzle. Investigate any uneven spray patterns to determine cause and to evaluate the case for nozzle replacement. Nozzles are relatively inexpensive compared to pesticides; a new nozzle for a Ripa spray pistol costs in the region of £10 - £12.00, nozzles for boom and knapsack sprayers are cheaper and generally range from between £1.50 - £5 per nozzle.

The work carried out at Silsoe confirmed that it is not possible to set a RIPA gun to a repeatable setting and that it is best practice to set the gun from fully open each time that it is used or reset. This prevents the nozzle binding to a thread on the spray pistol whilst under pressure which could be carried through the adjustment. If this were to occur the spray pistols output and performance could be affected. Narrowing of the spray angle was observed with increased pressure due to increased swirl within the gun itself. Therefore spray operators need to be more precise when applying pesticides at high pressure to ensure that good coverage is achieved, whilst taking care not to overdose by overlapping. As pressure increases droplet size decreases.

The 1.2mm nozzle behaved predictably but has a narrower angle and lower flow rate, so an operator would have to be much more precise when spraying to achieve good coverage without excessive overlapping. Some settings on the 1.2mm nozzle produced a spray angle in the lower 30º whereas the 2mm nozzle produced a spray angle in the low 50º. The test equipment's limitations prevented much work being carried out at the very high pressures currently used by the protected ornamentals industry. The nursery calibrations confirmed that the industry is using very high pressures to deliver high flow rates. Reducing the pressure that RIPA spray pistols are operated at would cut flow rates, helping to reduce spray volumes per hectare. Nurseries should calibrate spray pistols at different operating pressures to work out spray volumes applied per hectare.

There is the potential for most growers within the ornamentals sector to significantly cut water volumes through a change in mind set, by embracing new spraying technologies.

The agricultural sector is using between 100 – 200 l/ha for more challenging spray targets. This project has merely scratched the surface of spray application within horticulture; there is clearly a lot of work to be done to bring pesticide application within the horticultural sector to the level of efficiency used in the agricultural sector. Spraying to run off is wasteful and has environmental and cost implications, where growers are applying medium or fine droplets, spraying to run off is unnecessary. It is essential that individual spray operators know the volume of spray that they apply per hectare. If growers are basing spray volumes on 1000L/Ha and are applying a higher spray volume, they may be exceeding the maximum dose rate per treated hectare which has legal implications.

As knapsacks are generally only used to spot spray small areas, nurseries should focus on reducing spray volumes applied by their main method of spraying. Reduce spray volumes gradually to enable spray operators to get used to get used to applying lower water volumes at lower pressure. Pressure gauges are an essential tool to help set sprayers to deliver a repeatable result, broken pressure gauges should be replaced as a matter of urgency.

The NoRoSo is seen by many within the horticulture industry as being too focused on agriculture. This is a pity as the horticultural sector still has a lot to learn from the agricultural sector. Growers should embrace the chance to find out about new developments within the agricultural sector, with a view to adopting and making more use of boom based systems. Whilst automated booms are most appropriate for mono cropping it is possible to design hand held booms constructed out of carbon fibre for use where a mixture of crops are grown. This material is extremely lightweight enabling relatively wide beds to be treated in one pass. Changes to crop layout may be necessary in some production systems to facilitate the use of hand held spray booms.

Summary of conclusions

1. Spray pistols are inaccurate and apply too much water, where they are used it is best practice to set the gun from fully open each time to minimise variability.
2. Do not spray to run off, it is wasteful and has environmental implications.
3. Ensure that you are not exceeding the maximum total dose per hectare.
4. Check nozzle output every 50 hours of use and dispose of nozzles that deviate from stated output or output when new by 5%.

5. Reduce pressure when using spray pistols where ‘throw’ is not required and consider more efficient application methods.
6. Boom based systems (ideally with air assistance) can improve accuracy and spray coverage whilst using less water
7. Utilise novel nozzles such as Air inclusion types e.g. Guardian Twin Air nozzles or similar.

Knowledge and Technology Transfer

- Improving the efficiency of spray application for protected ornamental crops: a study of current spraying methods and novel spraying technologies. PO008 Annual report, May 2012
- PowerPoint presentation at the BPOA Technical seminar January 2014: PO 008 Improving the efficiency of spray application for ornamental crops: a study of current spraying methods and novel spraying technologies
- HDC News article ‘The right pattern for effective protection’ No. 201, March 2014 pp 24 – 25.
- HDC Factsheet 06/14 improving the efficiency of pesticide application to ornamental crops via hand-held sprayers
- Improving the efficiency of spray application for protected ornamental crops: a study of current spraying methods and novel spraying technologies. PO008 Final report, May 2014.

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Appendices

N/A

