Factsheet 06/15
(HDC project PO 008)

Cross sector

Improving the efficacy of plant protection applications to ornamental crops via hand-held sprayers

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Improving spray application efficacy will lead to improvements in crop uniformity, quality and growth, especially in the case of chemical growth regulator applications. This factsheet aims to help growers of ornamental crops improve the efficacy of plant protection applications via hand-held sprayers by providing a range of practical and best practice suggestions, some of which are based on the outcome of a recent HDC funded project (PO 008), while building on the content of the previous HDC Factsheet 14/06.

Action points

- To optimise application to ornamental crops, a medium to fine spray quality should be adopted when using most equipment (including hand-held spray pistols).
- Avoid a very fine spray quality as it increases the risk of drift and the fine droplets can rapidly evaporate, potentially limiting the activity of the plant protection product applied or its absorption by the plant. Adoption of high pressures, above 10 bar, with hand-held spray pistols will result in very fine sprays.
- Use the minimum pressure required to achieve the necessary spray quality.
- With some hand-held spray pistols it is difficult to re-set them to deliver a repeatable result, it is therefore considered best practice to ensure the swivel grip adjuster is always set to fully open first and then adjusted to the setting required to minimise variations in delivery.
- Carry out flow rate checks (every 50 hours) by collecting output from a nozzle at a given pressure to compare output with published figures.
- Undertake an annual inspection of all sprayers and replace any worn or damaged parts.
- Examine the potential of hand-held or frame mounted booms or an automated boom application system, which although challenging for adoption, should provide more uniform application.

1. Spray application via a hand-held spray pistol

Background

Many nurseries involved in the production of ornamental plants use hand-held spray pistols in combination with powered trolley sprayers to apply plant protection products. This is because of the need to apply such products to a range of crops with different growth habits, the frequent requirement to treat individual crops within the confines of a larger production environment, the need to apply the products over relatively long distances because of limited accessibility within production areas and an historical lack of alternative, flexible application methods.

Other systems, including knapsacks and hand-held, frame mounted and automatic boom application systems, are also used to apply plant protection products depending on the scale of operation and the product being applied. These are also mentioned within this factsheet.

Several hand-held spray pistols are available including the Alumax spray pistol, but the Ripa spray pistol is one of the most common spray pistols in use and was studied specifically in the recent HDC funded project (PO 008). A Ripa spray pistol is operated by a trigger valve and can be fitted with different nozzle apertures; the 2 mm nozzle aperture being the most common. Regardless of nozzle aperture, operators have the ability with most spray pistols to vary the spray characteristics by rotating a swivel grip adjuster on the pistol. This variable setting, alongside the effect of small wrist and hand movements during application, can result in highly variable deposition at 3-5 m from the spray pistol. Over and under-lapping of spray patterns can often be problematic as a consequence.

To achieve adequate spray coverage over the crop (both in terms of the distance to be covered between the operator and target and the water volume applied) spray operations within the ornamentals sector are often undertaken at high pressures with spray pistols, resulting in high water volumes per hectare. As many product application rates are stated per volume of water (as opposed to area), high water volumes not only result in potential run-off from plants but also in growers possibly exceeding the maximum legal rate of a plant protection product that can be applied per hectare. Alternative approaches are therefore required that improve efficacy and minimise potential wastage.

2. Close up of a hand-held spray pistol

Key elements of any hand-held sprayer

Pressure gauges

To determine spray quality and flow, a reliable pressure gauge is critical in understanding the output from any spray application system. A pressure gauge on the actual spray pistol or hand-held application device is essential so that operators can see what the pressure is at the point of application. Thus not only can spray quality be determined, but comparisons can also be made to manufacturer's flow rate data which is particularly useful during the process of calibration.

Where long hoses are used there will be a pressure loss caused by the frictional resistance of flow within the hose. A pressure gauge on the application device allows the operator to compensate for this by adjusting the pressure delivered by the pump in order to achieve the desired pressure at the point of application. Where it is not practical to mount a pressure gauge at the point of application, it is possible to work out the pressure loss for the length and diameter of pipe. Pipe friction loss can be checked at http://www.engineeringtoolbox.com/pressure-loss-plastic-pipes-d_404.html.

For example, where a spray pistol has a flow rate of 6.5 L/min and 50 m of 12 mm internal bore hose is used, the pressure loss will be approximately 0.6 bar. Thus for a working pressure of 8 bar at the pistol, 0.6 bar must be added where the pressure gauge is mounted near the pump. In survey work as part of PO 008, spray pressures of 20 bar were identified. Pressure gauges are often damaged by exceeding their normal working range and should not exceed two thirds of their indicated range, otherwise their internal system may be damaged which will result in faulty readings.

3. Pressure gauge at the point of application in a hand-held lance

Some types of pumps in sprayers should not be run dry; a pressure gauge at the point of application also allows the operator to detect a drop in pressure indicating that the spray tank needs re-filling. This will help to prolong the working lifespan of pumps. Where a pressure gauge cannot be fitted at the point of application, the operator should work out how many square metres a tank will cover in order to enable them to cease spraying before the pump runs dry.

Nozzles and nozzle selection

Hand-held spray pistols

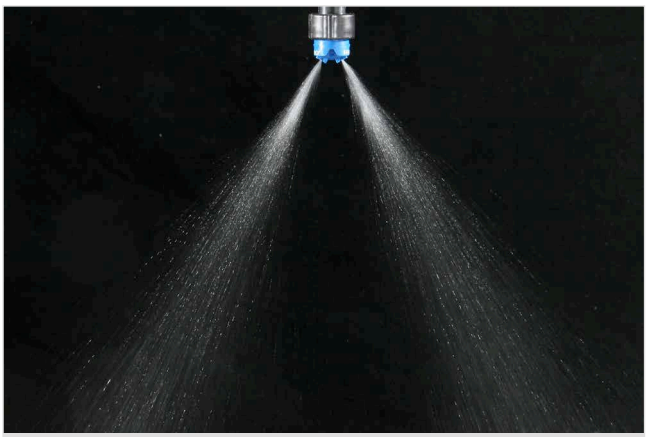
Ripa spray pistols and other types of spray pistol are fitted with an adjustable system which behaves like a hollow cone nozzle, adjusting the swivel grip allows the operator to alter the spray throw and quality. With the Ripa pistol, very coarse, coarse, medium and fine spray qualities can all be produced by altering the swivel grip; note however that the operating pressure also impacts upon spray quality. The HDC study highlighted that movement of the swivel grip on the Ripa pistol did not result in repeatable flow outputs. No provision is included for any pre-set points on the equipment, so simple marked points are recommended. Any adjustment should be made by fully opening the swivel grip first and then adjusting it down to the setting required to minimise variations in delivery. Other hand-held spray pistols, such as the Birchmeier spray pistols ('Gun media' for powered sprayers and 'Vario gun' for knapsacks) and the Dramm 'Hydra trigger gun' are described as having repeatable settings, but haven't been tested.

Hand-held lance and boom sprayers

In the case of 'normal' hydraulic nozzles, as fitted to knapsack applicators, a hollow cone nozzle results in a coverage that is best suited to the application of insecticides and fungicides. An anvil (sometimes called a flood jet) or flat fan nozzle should be used to apply herbicides.

Flat fan nozzles are generally used in boom-based systems, particularly where the spray target is not very challenging. Such nozzles, when used in agricultural applications, would normally result in successful treatments with only 100-300 L/ha water volume being applied.

However, there is now commercially available spray nozzles designed to fit boom systems which would give better coverage than conventional flat fan or even cone nozzles. These may be angled at 30° from the vertical or may have two apertures mounted on each nozzle facing 30° forward and back; this results in spray droplets angled both forward and backwards in the same pass giving better coverage. Such a nozzle is particularly useful for more challenging spray targets, such as pests on the underside of foliage.



4. Angled spray output from a Guardian Air Twin nozzle

Air inclusion nozzles may have some relevance for outdoor ornamental crops with erect and variable foliage. This nozzle type allows air into the nozzle during application creating droplets within droplets. Such droplets are less prone to drift when applied to outdoor crops or well ventilated polythene tunnels. When such droplets hit the crop canopy they separate into a large number of smaller droplets, improving the level of coverage.

Checking pressure gauges and nozzles, and general maintenance

It is essential that all pressure gauges work, otherwise it is impossible to set the sprayer up to achieve a repeatable result. Note that where the needle does not return to zero when not in use, the gauge is faulty and should be replaced.

5. Illegible dial on a pressure gauge

The calibration process (see the following section) should highlight where nozzle flow rates deviate from the manufacturers published figures at known pressures. Where output does deviate by more than 5% from the published figures, nozzle performance and output are likely to be compromised; such nozzles should be replaced as a matter of urgency.

If there isn't any published data on the output of a specific nozzle, the sprayer should be calibrated using a new nozzle and the output recorded at different working pressures. This data should be retained in order to compare the outputs achieved when using older nozzles. A new set of replacement nozzles should be held in stock so that any worn nozzles can be quickly replaced as soon as problems are identified.

Simple nozzle flow checks should be undertaken at least every 50 hours of use and nozzles should be visually checked prior to each application as accidentally dropping the lance or spray pistol can easily cause damage. Any uneven spray patterns should also be investigated to determine the cause.

All sprayers should be subject to an annual inspection and any worn or damaged parts such as pressure gauges, perished hoses and leaking connections repaired or replaced, the condition of the tank should also be checked. Best practice is demonstrated by using the National Sprayer Testing Scheme (NSTS). However, this is not appropriate for knapsack sprayers as it may be considered cost prohibitive, in this case recorded 'in-house' checks are sufficient. The NSTS website offers a downloadable list for both checking and calibrating a knapsack sprayer (www.nsts.org.uk/static/assets/downloads//knapsackchecklist.pdf).

Calibration of any hand-held sprayer

The basics of sprayer calibration

Many plant protection products used on ornamental crops have label recommendations which state the application rate in ml or g per litre of water without specifying the area, although sometimes a maximum amount per hectare is provided. This information needs to be converted into a rate per water volume for the area to be covered. It is essential therefore, that individual spray operators regularly calibrate their sprayers so that a known quantity of water can be applied to a given area of crop to ensure that product application rates are not exceeded.

Calibration is undertaken by first of all collecting the output delivered by a nozzle (of plain water), set at the normal operating pressure, generally in one minute; this gives the flow rate in litres per minute. The spray operator is then timed whilst a known area is sprayed with water at the same settings as measured. These measurements enable the volume of spray applied per square metre to be calculated.

6. Spraying for one minute into a collection receptacle to measure nozzle output

The calibration calculation using a spray pistol as an example is as follows:

Calibration calculation

Mean output collected from the spray pistol in one minute = 9.38 L

Mean time to spray a given area = 45 seconds (area covered: 2.9 m width, 19.1 m length = 55.39 m^2)

Water sprayed = 9.38 x 45/60 = 7.035 L

Application per m^2 = 7.035/55.39 = 0.127 L/m^2

Output per ha = 10,000 x 0.127 = 1,270 L/ha

This calibration may be compared to one using a three nozzle hand-held boom system resulting in a water volume reduction of 48% relative to the spray pistol:

Calibration calculation

Mean output collected from one nozzle in one minute = 0.94 L. Total three nozzle output = 3 x 0.94 = 2.82 L

Mean time to spray a given area = 45 seconds (area covered: 1.6 m width, 20 m length = 32 m^2)

Water sprayed = 2.82 x 45/60 = 2.115 L

Application per m^2 = 2.115/32 = 0.066 L/m^2

Output per ha = 10,000 x 0.066 = 660 L/ha

The nozzle type and pressure used during the calibration process should also be recorded.

Optimising spraying practices

Creation of the correct spray droplet size

An appreciation of the optimum spray droplet size to best target a particular pest, disease or weed or to control plant growth is important. A medium to fine spray quality should be the target for adoption (depending on the spray target), as defined by the British Crop Production Council (BCPC) classification system (Table 1).

To monitor spray droplet size and the coverage achieved, use can be made of water sensitive paper which can be attached in various locations within the crop canopy prior to spraying with water. See the previous HDC Factsheet 14/06 for further information on the use of water sensitive paper and estimating spray coverage over a crop.

Table 1. Spray qualities suitable for use in the production of ornamentals

Spray quality	Justification
Medium	Should be used where no other advice is available or where spray quality is not specified on the plant protection product label. Gives the best mix of effective droplet sizes, resulting in good retention on difficult leaf surfaces whilst controlling drift.
Fine	Gives good retention on the target and is useful for contact acting plant protection products or where good coverage is specified on the plant protection product label. A fine spray must **not** be used if the plant protection product is labelled 'Toxic', 'Very toxic', 'Corrosive' or 'Risk of serious damage to the eyes', or if drift would be damaging or would cause public concern, such as where spraying close to susceptible crops, gardens, near to sensitive areas such as houses, schools, hospitals, Sites of Special Scientific Interest (SSSI) or watercourses.

Adjustment of spray application water volumes

Reducing the application water volume need not compromise spray efficacy. Adoption of the correct nozzle, application pressure and application method can still provide good coverage whilst using significantly lower water volumes than are currently used. This can offer cost savings in plant protection products, particularly where products are applied at a set concentration per litre of water. The process of application also becomes more efficient when handling lower volumes of water, as spray operators spend relatively less time filling sprayers with water as opposed to the actual process of application.

The nursery visits undertaken as part of PO 008 highlighted the fact that many growers were applying plant protection products in more water than was necessary, sometimes up to 2,400 L/ha and above. An appreciation of the spray volumes being applied is vitally important in order not to exceed product dose rates per area. Conversely, maintaining high water volumes and applying the appropriate rate of plant protection product per area, may result in a product being applied in a very dilute concentration. This could potentially result in poor levels of control and may well increase the risk of pesticide resistance occurring.

Water volumes closer to the volumes used in agriculture should be the target for plant protection applications to the majority of ornamental crops. Application water volumes should be reduced gradually to permit the development of both confidence and expertise without compromising application efficacy.

Optimising operating pressures

Too high a pressure generally increases the droplet velocities and the number of fine droplets, which can be prone to drift. High spraying pressures may also lead to premature nozzle wear. A worn nozzle was found in the HDC study to increase the flow rate by almost 10% whilst also increasing the droplet size by around 8%. Operators should refer to nozzle manufacturer's data for optimum operating pressures. This data should also give the output at various different operating pressures. The desire to reduce water volumes may dictate the size of the nozzle aperture and the pressure that is used. Pressures and settings to achieve both a medium and fine spray quality with a 1.2 mm and a 2 mm nozzle on a Ripa spray pistol are listed in Table 2 and the corresponding outputs in Table 3. The work carried out at NIAB Silsoe was done at pressures below 10 bar which proved that both fine and medium spray qualities can be generated from a Ripa spray pistol at these operating pressures.

Table 2. Swivel grip position and pressure settings required to achieve medium and fine spray qualities with a Ripa spray pistol for two nozzle apertures

Nozzle aperture	Spray quality when swivel grip on spray pistol set as shown below (pressure in bar shown in brackets)			
	Fully closed	Open 90º	Open 180º	Open 270º
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 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)

Table 3. Output (litres/minute) from two nozzle apertures on a Ripa spray pistol (swivel grip fully closed)

Nozzle aperture	Pressure (bar) and output (L/min)				
	2	4	6	8	10
1.2 mm	0.75	1.2	1.4	1.6	1.8
2 mm	1.6	2.3	2.8	3.3	3.8

Information contained in Tables 2 and 3 from HDC project PO 008: 'Improving the efficiency of spray application for protected ornamental crops: a study of current spraying methods and novel spraying technologies'.

Appropriate spray coverage

Spraying to run-off is often used as a spray deposit indicator. This should be challenged as unnecessary as this represents wastage; such losses add to production costs whilst potentially contributing to pollution. Plant protection products that run onto concrete paths and production beds will eventually degrade in sunlight, but during this time may still cause problems. Other products may persist and build up after each application on absorbent surfaces such as capillary matting leading to potential problems with subsequent crops. Product residues may also eventually find their way into surface or ground water, potentially leading to issues with pollution. It is best to avoid these problems by accurate application of plant protection products; placing the product where it is required.

Getting the best from a hand-held sprayer

Where Ripa type spray pistols are used, the settings and pressures detailed within Table 2 will aid the selection of the correct spray quality. Note that a smaller nozzle aperture will help to reduce flow rates and water volumes applied per area. It should be noted that an operators' small wrist movement during application causes large deviations in any spray pattern the greater the distance the spray is being applied over. This may be mitigated by the use of a long lance with a single or multi-nozzle head. In the survey carried out as part of the HDC project, various operator spraying techniques were observed; some included the continual adjustment of the spray pattern whilst walking forwards and backwards. This coupled with the large distances between nozzle and target, may well result in a highly variable application which other operators may find difficult to replicate. Ultimately the operator must fully understand the limitations of any equipment used.

Where operators have been able to adopt hand-held lances or hand-held spray booms the variation in spray deposition has been significantly reduced, limiting the main variable to walking speed. However, there may be site specific challenges associated with the transition to boom-based systems.

Other potential types of spray application systems

Hand-held lances and hand-held boom systems

Where single lances are used it may be possible to adopt a double or triple nozzle head allowing different spray trajectories. Hand-held booms can be purchased or even constructed. Hand-held booms are more ergonomically suited to ground-level beds than benching constructed at waist height. The size of the boom will depend on the bed width adopted by the nursery and there will be a need to standardise bed dimensions throughout the nursery. Smaller booms are the most user-friendly, flexible option; larger hand-held booms are best constructed from carbon fibre in order to keep the weight down.

7. Plant protection application via a hand-held boom to a ground-level bed

Frame mounted booms

Booms can also be mounted on a wheeled frame which can be pushed/dragged or powered by an electric motor to give a constant forward speed to maintain a constant output. A wheeled frame also ensures that the boom is mounted at the optimum height above the crop - 45 cm. Utilising wheeled frames removes the need to leave frequent pathways for operators to spray from, although other obstructions such as glasshouse stanchions may dictate spraying options.

8. Frame mounted boom applicator (right)

Automated boom systems

Automated spray booms are ideal where large numbers of the same crop are produced. Linear actuator motors which tilt the boom forward on the way out and back on return can be used instead of using forward/backward facing twin nozzles. Such systems can be installed to run on pre-existing overhead heating pipes, but could also run on wheels along concrete paths. The boom system is generally connected directly to the spray tank. Such systems can be very efficient, resulting in good spray coverage and low water volumes per hectare.

Automated booms are relatively expensive to install, but offer significant benefits:

- They can offer one of the most even methods of spray application which can lead to improvements in crop uniformity and quality.
- They cut operator exposure to plant protection products by physically removing the operator from the application process.
- They reduce the need for pathways to allow access into the crop to apply plant protection products which may result in an increased return per square metre.
- Operating at lower water volumes, their use results in less down time filling sprayers and mixing plant protection products.

However, it is often difficult to retrospectively install an automated spray boom system, especially in glasshouse structures, so it may prove more cost effective to invest in an automated spray boom system when planning new growing structures.

9. Visser Spray-O-Matic II system

In summary, a hand-held spray pistol will always be subject to variability in terms of spray deposition across a treated area. Booms apply a more uniform distribution of spray droplets compared to a spray pistol. Studies from Europe (for example, Foque, D., et all 2012) have shown that systems, either hand-held, frame mounted or automated systems, apply plant protection products more evenly, use lower pressures and can achieve better under leaf coverage. In the case of automated booms, there is also less operator exposure compared with the use of hand-held spray pistols, lances or booms. Nozzle selection is important in order to achieve the best possible results from spray booms. Conventional flat fan nozzles should deliver good results where the spray target is flat and uniform in habit. Forward and backward facing angled nozzles would result in better coverage where the spray target is more upright in terms of growth habit.

Conclusions

All sprayers, regardless of type, must to be maintained in order to obtain the best possible results from them. A common theme from the nursery visits undertaken as part of PO 008 was a lack of understanding of the implications of not maintaining spray equipment on subsequent application performance.

Whilst hand-held spray pistols have a number of shortcomings their efficacy could be improved on simply by following the advice contained within this factsheet. Improving the efficacy of spray pistols should be seen as a first step towards improvement in plant protection product application. However, while spray pistols are flexible, enabling small batches of stock to be treated there are more efficient ways of applying plant protection products. There has been a general lack of investment by many businesses in more advanced and efficient technology to apply products more efficiently and effectively.

Research and practical experience has demonstrated that boom-based systems can improve spray uniformity whilst reducing water volumes, resulting in savings in both labour and plant protection products.

Further information

HDC Factsheets and publications

HDC Factsheet 14/06. 'Guidelines and best practice for pesticide spray application in protected ornamental crops'.

Spray Check. A tutorial DVD for spray operators (DVD and guidance notes).

HDC Grower summaries and reports

HDC Project PO 008: 'Improving the efficiency of spray application for protected ornamental crops: a study of current spraying methods and novel spraying technologies'.

Other publications

Foque, D., Pieters, J, G., Nuyttens, D., (2012). An integrated study to improve spray deposition in a dense crop. AAB conference proceedings, Aspects of Applied Biology, 114, pp 355-362.

Knapsack sprayer checklist and calibration. www.nsts.org.uk

Knapsack sprayers and water protection - Do's and don'ts, The Voluntary Initiative. www.voluntaryinitiative.org.uk/media/549430/handheldsprayer.pdf

Small scale spraying, BCPC. www.bcpc.org/shop/Small-Scale-Spraying.html

Manufacturers and distributors

Spray application equipment

Spray equipment is also available from a range of UK agents and local horticultural distributors.

Berthoud
website: www.berthoud-store.co.uk/knapsack-sprayers--36--n.htm

Birchmeier
Website: www.birchmeierbackpacks.com

Brinkman (Horticultural Service) UK Limited
Tel: 01482 842123
E-mail: sales@brinkman.co.uk
Website: www.brinkmanuk.co.uk

Cooper Pegler
Website: www.cooper-pegler.com

Dramm
Tel: (00) +1 920 6840227
E-mail: information@dramm.com
Website: www.dramm.com

Hardi
Website: www.hardi.co.uk

Norman Smith Equipment (UK) Ltd
Tel: 01949 843186
E-mail: sales@normansmithequipment.co.uk
Website: www.normansmithequipment.co.uk

Spraying Systems Ltd
Tel: 01252 727200
E-mail: info.uk@spray.com
Website: www.uk.spray.com

Team Sprayers
Tel: 01353 661211
E-mail: sales@team-sprayers.com
Website: www.team-sprayers.com

Visser Horti Systems
Tel: (00) +31 786 739800
E-mail: info@visser.eu
Website: www.viscongroup.eu

Nozzles

Local agricultural distributors normally hold stocks of a wide range of nozzles. Given that only relatively small numbers of new nozzles will be required by most horticultural businesses, obtaining new nozzles from a local supplier is recommended rather than approaching manufacturers directly.

Hypro EU Limited
Tel: 01954 260097
E-mail: info@hypro-eu.com
Website: www.hypro-eu.com

Agratech
Tel: 01706 211399
Website: www.agratech.co.uk

Spraying Systems Ltd
Tel: 01252 727200
Website: www.teejet.com

Water sensitive paper

Dove Associates
Tel: 01379 741200
E-mail: info@dovebugs.co.uk
Website: www.dovebugs.co.uk

Spraying Systems Ltd
Tel: 01252 727200
Website: www.teejet.com/english/home/tech-support/nozzle-technical-information/calibration--adjustment-accessories.aspx

Syngenta UK Limited
Tel: 0800 6524216
Website: www.syngenta-crop.co.uk

Organisations

British Crop Production Council (BCPC)
www.bcpc.org

City & Guilds National Proficiency Test Council
www.nptc.org.uk

City & Guilds National Register of Spray Operators
www.nroso.org.uk

The Voluntary Initiative (VI)
www.voluntaryinitiative.org.uk

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