Factsheet **14/06 (revised)**

Protected Ornamentals

Horticultural Development Council

Bradbourne House
East Malling
Kent ME19 6DZ
T: 01732 848383
F: 01732 848498
E: hdc@hdc.org.uk

Guidelines and best practice for pesticide spray application in protected ornamental crops

John Buxton and Andrew Hewson, ADAS UK Ltd

This factsheet deals with the safe and effective use of pesticide spray machinery under protection. It covers the use of insecticides and fungicides but not herbicides. Additionally, it aims to inform growers about factors influencing spray distribution and coverage, machine calibration, operation and trouble shooting.

Background

Environmental concerns and new legislation relating to pesticide use have strengthened the need for best practice advice covering all aspects of spray application. Of particular note are the Groundwater Regulations (1998) which cover the disposal of waste pesticides and sit within the Water Resources Act (WRA) 1991, legislation that enables prosecution for water pollution. Industry certification schemes geared towards major retailers that demand best practice and, legal compliance are a further consideration. Also, the Voluntary Initiative (VI), the National Sprayer Testing Scheme (NSTS) and the National Register of Spray Operators (NRoSO) have been recently introduced to promote professional, responsible practice.

The increasing costs of pesticide products and the staff resources needed to apply them correctly, mean that particular care and attention should to be paid to the task of spraying. Many growers now prefer to use Integrated Pest Management (IPM) rather than simply spraying routinely or when a problem occurs. However, when spraying is considered necessary, it is important that an appropriate pesticide is chosen with due regard to the crop, situation and problem concerned, and that it is used correctly. Attention to such detail will yield dividends in terms of improved efficiency, and environmental safety. In IPM situations, pesticide compatibility with biological control agents must be considered and carefully checked.

1 Correct spray application ensures more effective control of the target pest or disease and reduces pesticide use and spraying costs

Types of machinery

The main types of commercial spray applicators used under protection are:

1 High volume (HV) trailed sprayers
2 Motorised knapsack applicators ('blowers')
3 Hand pumped knapsacks
4 Ultra low volume/low volume (ULV/LVM) misters

Each type of equipment has limitations and for best results it is likely that several types of machine will be required. For instance, the trailed high volume (HV) applicator is normally used for treating larger areas, such as a whole tunnel or glasshouse, whereas a motorised knapsack, or a hand pumped knapsack, can treat much smaller areas. ULV/LVM misters cannot be used for small areas and the whole greenhouse has to be treated.

1 HV sprayers

These machines all operate on the same principle, using a compressor to force air into the tank, and push the spray solution out under pressure through a nozzle, which atomises the spray into fine droplets. They normally have a filter in the top of the tank, and usually an in-line filter at the outlet end of the pump. Most machines also have an agitation system built in, which re-circulates the spray solution within the tank, preventing any settling out from occurring and keeping the pesticide in solution correctly. Tank sizes vary from 50 litres to over 500 litres.

Normal operating pressures are shown on the pressure gauge fitted to the machine, and vary between 2 and 5 bar (30 – 75 psi), although many machines are capable of operating at much higher pressures, up to 20 bar (300 psi). If the pressure gauge is broken or inaccurate, this should be fixed, as it is important to know the working pressure when spraying. The pressure that occurs at the nozzle, however, may be very different and this pressure is seldom actually known. The pressure setting has a major effect on the droplet size produced and also the amount of water applied in a given time. Exact flow rates depend on the diameter of the spray hose, and the type of spray pistol or nozzle used but typical figures for the Ripa spray pistol (with the no. 2 nozzle) are 5.8 l/min at 5 bar and 10.2 l/min at 15 bar.

The droplet size produced by HV machines is variable and may contain both very small and very large droplets, but the median droplet volume is larger than that produced by motorised knapsacks or ULV machines. Water volumes applied by these machines vary from as little as 250–300 litres per ha for crops such as young pansies, to as much as 1000 litres per ha on dense crops such as, containerised nursery stock. The water volume used must be tailored to the crops concerned.

All the HV machines have wheels and pneumatic tyres, enabling them to be moved within the greenhouse, either by hand or pulled by a tractor. They may be stand alone machines, or the tank may be mounted on a frame and held by the tractor three-point linkage. The hose is normally on a reel at the end of the tank and this can be manually operated, or reeled in and out using an electric remote control. Lengths of hose also vary and can be as long as 30–50 metres to enable a polythene tunnel or glasshouse to be sprayed completely while the machine stands at the entrance.

The internal hose diameter varies from 25–40 mm, and this diameter can also affect the pressure at the nozzle; at any given pump pressure, smaller diameter hoses reduce the pressure at the nozzle and larger diameter hoses increase it.

2 Large capacity HV trailed sprayer

3 Small capacity HV sprayer, suitable for treating areas up to 0.5 ha

4 Spray booms like this can be fitted to HV sprayers to help improve spray coverage on dense crops

A range of spray guns, spray lances or spray nozzles are available and these have a large influence on the droplet size produced, the spray coverage, and the water volume used to treat a crop. A spray boom may be fitted to the hose instead of a spray gun (Figure 4), and in some situations, such as spraying a dense crop from a central pathway, can improve spray penetration into the crop and thus improve control. However, a boom may be heavy and cause operator strain if used for long periods.

To ensure effective HV spraying:

- Choose the correct dilution rate
- Choose the correct pressure and volume
- Apply spray evenly to the point of run off
- Ensure spray quality is medium-fine
- Aim to get good underleaf coverage

2 Motorised knapsacks or 'blowers'

These machines are versatile and very common on nurseries. They are worn on the back and have a small tank (up to approx.15 litres), with a two-stroke motor, which forces air at high speed through a wide tube (Figure 5). It meets the spray solution at the mouth of the tube, causing it to atomise into small droplets before forcing them out in a directed air stream towards the target.

In practice, these machines are noisy, and can be heavy when used for long periods. However, when only a small area of crop needs to be treated, they are quick to fill, and enable treatment to be carried out in a short space of time. Both the flow rate of solution and the motor running speed can be adjusted, and the optimum combination of these two factors needs to be calculated by practical experimentation, using water only in the tank.

The droplet sizes produced by these machines are generally smaller than those produced by HV sprayers and the total water volume applied per unit area is usually much less. The spray cloud can be prone to drifting, even under protection, and operators should be aware of this possibility.

3 Hand pumped knapsack sprayers

There are several manufacturers of these machines, and also different model ranges. They differ in the tank size, (which may vary from 5 – 20 litres), and features such as nozzle type and pumping method. Some machines have an electric pump, although most have a handle (Figure 6), which is pumped up and down to create the correct pressure. All are worn on the back and the operator walks down pathways between crops and applies the spray at sufficient water volume to obtain good spray coverage.

The actual operating pressure depends on the amount of pumping that the operator does, and the pressure

5 Motorised knapsack sprayer in use

6 Hand pumped knapsack sprayer in use

7 Constant pressure valve which can be fitted to a knapsack sprayer

at the nozzle may not be constant. A simple flow valve can be inserted before the nozzle (Figure 7) and this maintains a constant pressure no matter how much the handle is pumped. Valves for pressures from 2–4 bar are available and are inexpensive.

These machines usually have a changeable nozzle set within a plastic moulding. Hollow cone and flat fan nozzles are available, and some types of knapsack sprayer have an adjustable nozzle that can change the spray pattern.

Water volumes applied by knapsack sprayers (including 'blowers') are usually lower than those applied by HV machines, generally between 50 and 150 litres of water per ha, but this depends on the size of the crop being treated and the density of the foliage. In very dense crops, coverage may not be as efficient as with HV sprayers. The droplet sizes produced are in line with those of HV sprayers but contain larger droplets than those from a motorised knapsack machine.

4 ULV/LVM machines

The concept of these machines (common makes include the Enbar (Figure 8), Wanjet and Nightstar) is completely different from that of other sprayers. The machine is static and treats the whole house from one position, because the droplets produced are very small and are carried by a powerful fan to all areas of the tunnel or greenhouse, including the walls, floor, and benches as well as the crop.

Normally the operator mixes the spray solution in a tank of small capacity (maximum 10 litres) and uses a timer to set the machine to run in the evening, when there is nobody inside the glasshouse or tunnel. A robust pump drives the spray solution at very high pressure through a venturi effect nozzle just in front of the fan. The fan then atomises the spray into tiny droplets, which are forced out in a constant air stream. The total volume of spray solution actually applied may be as little as 10–20 litres per ha. Once the spray distribution is completed, an automatic washing cycle is initiated and the tank is thereby cleaned.

The concentration of pesticide applied is much higher with this method of spraying than any other, and for this reason some products are not allowed to be used in ULV/LVM machines. Normally, application is made in the evening when conditions are cooler and the vents are set to come on automatically in the early morning, so the glasshouse is vented before personnel are allowed in. Some products have a minimum re-entry period of 12 hours, before staff are allowed back into the glasshouse after application.

Tests have shown that the droplet size produced by these machines is much smaller than HV sprayers or knapsack sprayers and even smaller than motorised knapsacks. However, the droplets are more even in size. A disadvantage of ULV/LVM misters is that, in high temperatures, the tiny droplets may not last long before they evaporate. Some growers use an additive with the solution to reduce this evaporation problem. Also, most droplets land on upper leaf surfaces and so under-leaf coverage is generally less than that from HV applications.

ULV/LVM misters do have some advantages over HV applications in

8 Enbar LVM machine, twin fan model

Table 1 Main types of sprayer used with protected ornamental crops

The table below summarises the main types of sprayer for use in protected ornamental crops, including tank size, operating pressure and size of structure each is suitable for.

Sprayer type	Tank size	Optimum operating pressure	Size of structure suitable for	Comments
HV Large	500–750 L	2–5 bar	Up to 2 ha	Time to refill is reduced so work rate increased
HV Small	50–300 L	2–5 bar	Up to 0.5 ha	Suitable for smaller structures
Motorised knapsacks	15 L	5–8 bar	For use on small areas of crop	Can be used to spot spray, and provides good air movement
Hand pumped knapsacks	5–20 L	2–4 bar	For use on small areas of crop	Can be used to spot spray, pressure can be uneven
ULV/LVM machines	10–20 L	n/a	For use in closed structures usually at night	Ideal when treatment of the whole structure is needed

certain circumstances, for instance when a crop is in bud or flower and an HV fungicide application might mark the flowers. They are also useful when a sterilant needs to be applied to an empty glasshouse or tunnel, as the whole structure (floors/walls/benches) is treated, as well as the crop canopy.

Types of nozzle

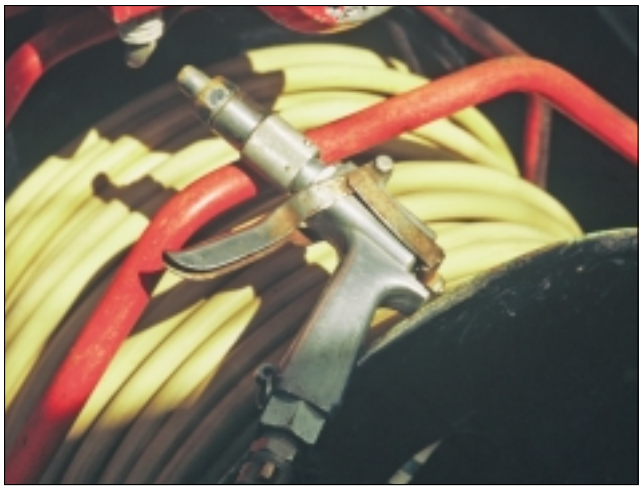
Many HV machines used in protected ornamentals do not have a conventional spray nozzle, but instead use a **spray pistol** (Figure 9). The most common type is the Ripa spray pistol, which is made of stainless steel and has an infinitely variable spray pattern, from a solid jet to an extremely fine mist. The actual spray pattern and droplet size depends on the setting of the twist ring on the spray pistol, and also the operating pressure. A similar spray pistol is the Alumax that operates in the same manner but produces a swirl in the spray cloud (Figure 10).

Conventional spray nozzles, using flat fan or cone nozzles, usually made of plastic or brass can also be used, either in a single nozzle, or sometimes in a 'trident' arrangement (Figure 11), designed to allow a wider spray pattern and increase the spray penetration into the crop. With this arrangement, the output per nozzle is fixed at a set pressure, and only varies when the pressure is altered. Normal operating pressures vary from 2–5 bar; but spray pistols are capable of operating at much higher pressures. Increasing the pressure decreases the droplet size and can cause drift even in protected crops, and increases the risk of very small droplets evaporating before they reach the target.

The **hollow cone nozzle** (Figure 11) is normally used to apply insecticides and fungicides, as the spray is confined at the outer edge of a conical pattern generated by a swirl plate, which creates a swirling motion in the spray liquid, ensuring better cover of foliage. A maximum pressure of 4 bar is advised for cone nozzles. Hollow cone nozzles are normally fitted as standard to most knapsack sprayers that have only a single nozzle.

Flat fan nozzles (Figure 12) are best used in a boom arrangement, mounted to ensure correct overlap and normally fitted to automated or tractor mounted boom sprayers. Flat fan nozzles operate at pressures of 1–3 bar, and tend to give an uneven spray pattern in which the majority of the spray is deposited immediately under the nozzle, which makes them less suitable as single nozzles on a knapsack sprayer.

Nozzles should be replaced regularly as they will wear out. Further detailed information is available from nozzle manufacturers.



9 Ripa spray pistol

10 Alumax spray pistol

11 Hollow cone nozzles in a trident arrangement on a spray lance

12 Flat fan nozzle

The influence of droplet size on leaf coverage

The term used to describe droplet size is Volume Median Diameter (VMD) and this is the average droplet size produced by a machine, measured using specialised apparatus. Most spray machines produce a mixture of small, medium, and large droplets, which behave differently when they impact on the plant target.

- HV sprayers, using a spray pistol at normal pressures of 2–4 bar, produce a range of droplet sizes from tiny droplets of 50 microns (a micron is a thousandth of a millimetre) to large droplets of around 1,000 microns, but the VMD (Volume median diameter) is 200–300 microns.

- Motorised knapsacks produce smaller droplets, VMD 50–150 microns,

- ULV/LVM misters produce even smaller droplets of VMD 50–100 microns.

The droplet size has a significant effect on the potential leaf coverage. Table 2 illustrates the relationship between droplet size and leaf coverage (though, this is a theoretical calculation and in reality such droplet density would be difficult to achieve).

The table shows that very small droplets (assuming they reach the target) can give excellent coverage (although they may drift, even inside a glasshouse) and large droplets may roll off the leaf and may not contact the target at all. For example, Diagram 1 opposite shows how one 400 µm droplet may touch one leg of an insect pest but halving the droplet size to 200 µm can increase the chances of it contacting the pest or disease by eight times. By a similar calculation, decreasing the droplet size to only 50 microns increases the chances of it contacting the pest by 512 times. For reference, 50 µm is the smallest droplet size the eye can see.

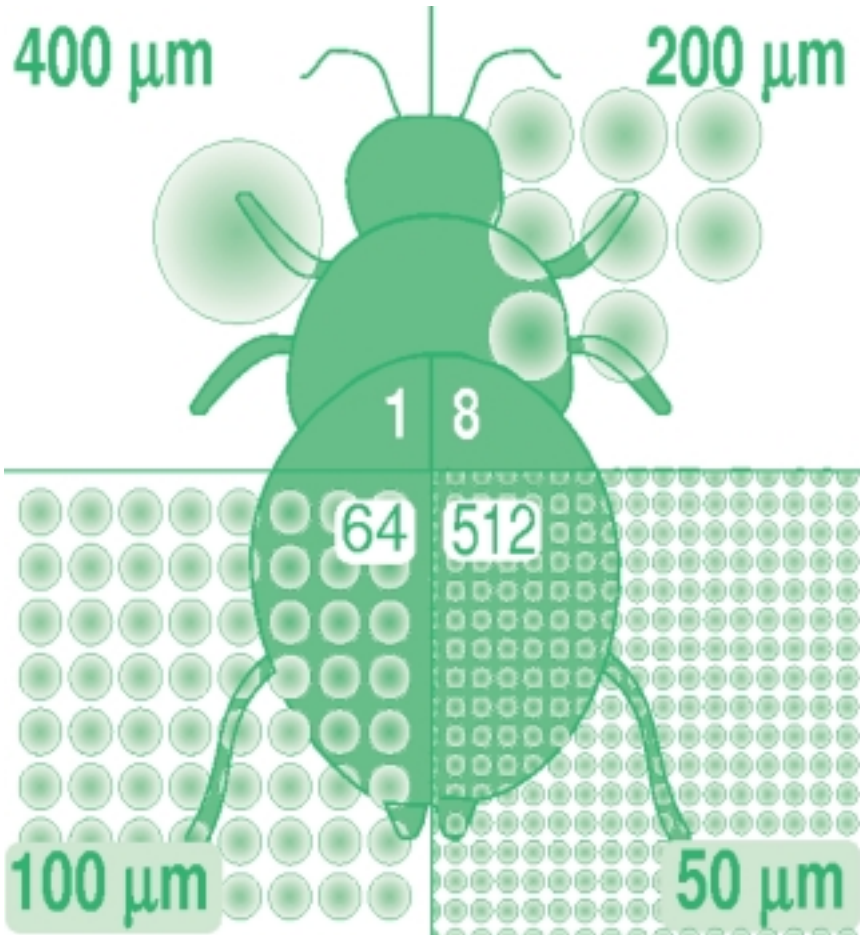
Table 2 also shows that sprays are also classified in a more practical way: very fine (VF), fine (F), medium (M), coarse (C) and very coarse (VC). For most purposes, spray applications under protection would aim for the fine–medium (F–M) category of spray for optimum biological effects on the target pest or disease.

One problem with very small droplets is the risk of evaporation in high temperatures, so that it is common practice when using equipment that generates very small droplets (eg ULV/LVM misters) to add an oil-based adjuvant to the tank to reduce evaporation problems. However, application is normally scheduled for the evening when temperatures in the glasshouse or polythene tunnel are cooler and the vents are closed to prevent droplets escaping. Equally, very large droplets tend to coalesce and roll off the leaves, leading to loss of efficacy and possible pollution. A compromise is needed to ensure a medium droplet size, which will provide the best

Table 2 Relationship between droplet size and theoretical leaf coverage

Drop diameter (Microns)	Number of drops per cm^2	Spray category
20	2,400	Very Fine
50	150	Fine
100	19	Medium
200	3	Coarse
400	0.5	Very Coarse

Diagram 1 Effect of droplet size on potential coverage of a target pest



Courtesy of HARDI International

Courtesy of HARDI International

biological efficacy. The optimum droplet sizes for different targets have been calculated and are shown in Table 3.

Influence of air movement on spray distribution

Spray coverage of leaves is also dependent on other factors such as air movement. Too much air movement and the spray solution may flow past the leaf as the foliage moves rapidly. Too little, and under-leaf coverage will be inadequate. The ideal air movement is one which 'wafts' the foliage, moving the leaves gently upwards, so that the spray can reach the leaf undersides, which is exactly where many pest and disease problems are located. Experienced operators move the spray pistol or nozzle in a regular 'up and under' motion to improve deposition of spray on lower leaf surfaces. Good spray application takes time and cannot be rushed.

Influence of flow rate/pressure on droplet size and distribution

The setting on spray pistols has a major effect upon the droplet size and distribution. Figures 13–16 illustrate these effects; the optimum pressures and settings may need to be established for each machine by experimentation, using only water in the HV spray tank. In Figure 13 the spray cloud is too fine and is also too high above the crop. Coverage of leaf undersides is likely to be poor.

In Figure 14, the spray jet is too coarse and hits the crop in a narrow stream, with many large droplets, which tend to cause run off and may even cause crop damage.

In Figure 15, effective setting of the spray pistol and correct pressures (in this case 4 bar) gives a medium spray cloud, and the pistol directs the spray into the crop without being too close to it. Tests using water sensitive paper revealed that the coverage of leaf undersides was the highest with these settings.

Similar factors affect the spray distribution and droplet size produced by motorised knapsacks. Here, both the output and droplet size can be altered

Table 3 Optimum droplet sizes for pest and disease targets

Target	Optimum droplet diameter (microns)
Flying insects	10–50
Insects on foliage	50–100
Good spray coverage	100–150
Plant pathogens	100–200

(Source Matthews, 1992)

13 Ripa spray pistol in use: the spray cloud is too fine and prone to drift

14 Ripa spray pistol in use: the spray jet shown here is too coarse

15 Ripa spray pistol in use: setting correct, spray cloud moving into foliage and increasing coverage of leaf undersides

by amending flow rates and motor speed, whereas for a normal knapsack sprayer, the droplet size tends to stay fairly constant and only the pumping frequency alters flow rate and thus water volume applied. With ULV/LVM misters, the flow rate is constant, although different pesticide formulations of varying viscosity can have some effect upon flow rate and droplet size. Crop morphology is very important and must be considered when applying any pesticide. Low growing crops such as pansy and primula hold their leaves flat, and so it may be more difficult to ensure adequate under leaf coverage. Others, such as phormium and cyclamen have waxy leaves, which tend to shed spray droplets. In such cases, the addition of an adjuvant can help spray retention on the leaves.

Estimating spray coverage

Because most pesticide solutions are colourless, it is hard to estimate the degree of foliage coverage when spraying has been carried out. Visual estimates are inaccurate and can be misleading, although some fungicides leave a white deposit and the spray coverage can be seen if leaves are examined closely.

There are various methods of assessing spray coverage but the easiest and simplest method is to use water-sensitive paper, which comes in small yellow coloured strips (Figure 16). These can be stapled to undersides of leaves, or set within the plant canopy. The paper shows up any droplet that contacts it as a blue dot. Even tiny droplets are shown and the overall effect is very helpful in highlighting inaccurate spray application, or equally good spray application. This method should be used at the start of each season, or when a new machine has been purchased. Water sensitive papers are available from:

Spraying Systems Ltd
Farnham
Surrey GU9 8QT
www.spray-uk.com

Ultra violet 'tracer' dyes are also available for assessing spray coverage, such as Saturn Yellow and Fluorescein Yellow but these are not as easy to use as the water sensitive paper and the deposits are difficult to remove. For this reason, they are not widely used by growers.

A hand lens is also invaluable in helping growers to estimate the control given by a pesticide application. For instance, spider mites are very hard to see with the naked eye, but with a x 10 hand lens, dead bodies can be seen and the effectiveness of controls determined. Similarly with pathogens such as downy and powdery mildew, a hand lens can be used to see if the fungal mycelium or sporulation has dried up and is inactive. The mode of action of a pesticide relative to the target pest or disease should also be taken into account when seeking to determine spray effectiveness (ie systemic, contact, or translaminar). Contact acting pesticides for example, require the most accurate application for maximum effect.

16 Water sensitive paper is an easy and simple way of quickly assessing spray coverage

Water volumes and spray application timing

The time taken to apply the spray will determine how much water is actually applied, and this is influenced greatly by the crop type and size. A good example is the poinsettia crop: newly potted cuttings can be sprayed using around 250–300 litres of water/ha; whereas a finished crop potted into 3 litre pots may require 1000–1500 litres of water per ha to achieve adequate spray coverage and control of diseases such as *Botrytis* or pests such as whitefly. In such crops, it is always good practice to apply the spray in the morning, so that the crop can dry before evening; this helps reduce the risk from disease pathogens, many of which are dependent on high humidity for infection.

Some products eg plant growth regulators and systemic products require the crop to remain wet for a certain period of time after application – if they dry too quickly they are not taken up by the plant. Such products should not be applied in bright sunny conditions.

Most pesticide labels will specify the range of water volumes recommended for use with that product, and will also usually recommend the spray quality needed (eg very fine, medium/fine etc). There is no restriction on the maximum water volume used,

but there are restrictions with some products on the minimum water volume which can be used. This is because of the risk from certain toxic pesticides when used at low volumes, because the concentration of active ingredient in the spray solution is much higher.

Important note: before applying any pesticide with a ULV/LVM mister, the label must be consulted. If the product label prohibits reduced or low volume spraying or requires the use of Personal Protective Equipment (PPE) when the pesticide is diluted normally or carries any of the warnings **CORROSIVE/TOXIC/RISK OF EYE DAMAGE** then it **MUST NOT** be used in LVM equipment.

Soil/Growing media drenches

Techniques for applying fungicide/insecticide drenches to root systems/pots vary between nurseries. The important thing is to achieve even and accurate application of the required dose using a water volume sufficient to ensure the drench solution penetrates the pot/root system to gain control of the target pest or disease. As a guide, for container grown plants 10% of the pot volume is usually the minimum requirement (eg 300 mls for a 3 litre pot). Drench applications are however usually very time consuming and not widely popular. However, for the control of certain soil dwelling pests like sciarids/vine weevil or disease problems like *Phytophthora* they are sometimes necessary. Some nurseries use a Dosatron to apply drenches whilst others use the normal sprayer, fitted with a rose instead of a spray pistol.

Dose rates

When pesticides are used on protected crops, the rate is normally given as a high volume rate, which is in ml or g per 100 litres of water. Some labels use the term 'hectolitre', which just means 'per 100 litres'. The label recommendation usually states that the product should be applied to the point of run-off (the point at which spray starts to drip from the foliage). Operators should practice with water in the tank, using normal pressure and nozzle settings, to establish the water volume needed to reach the run-off point. Once this volume is known, then the correct amount of pesticide can be mixed and surplus spray solution kept to a minimum.

Calibration

This is an essential part of accurate and effective spraying and detailed guidance can be obtained from several sources including manufacturers information, the British Crop Protection Council (BCPC) and the Voluntary Initiative at the following web address: **www.voluntaryinitiative.org.uk**

The standard calibration method involves simple measurement of the amount of spray solution that a machine emits over a set time (the flow rate). This is combined with a calculation of the time taken to cover a set distance and the width sprayed to give the area treated. A worked example is shown below.

Example using a knapsack sprayer

Check the output of the sprayer by collecting and measuring the spray liquid emitted during one minute. When using lever operated sprayers, the pressure gauge should be fitted as close to the nozzle as possible and the lever operated evenly with a full stroke to maintain as uniform a pressure as possible. The operator will need to practice before achieving an even pumping rate.

Once the nozzle output in litres per minute is known, then measure the cropping bed width and walking speed so that the volume of spray applied can be calculated. For example, with a cropping bed width of 1.5 m, walking speed of 10 m per minute and a flow rate of 0.6 litres per minute, the volume of spray per square metre is 0.6 ÷ (1.5 x 10) = 0.04 litres per metre squared x 10,000 = 400 litres per ha. If the spray volume is +/- 15% of the label recommendation, make small adjustments in speed or pressure and repeat the exercise. If this is not sufficient, change the nozzles and recalibrate.

Calibration of motorised knapsacks can be carried out in the same manner, but these machines apply much less water than HV sprayers. LVM misters do not need calibration, as the machine is set to apply the pesticide solution to the whole house, and if the amount of solution used in the tank (eg 10 litres) and the glasshouse area is known, then the volume of pesticide per ha can be easily determined. Note that LVM machines tend to accumulate pesticide at the fan outlet and these deposits must be cleaned off regularly, whilst wearing protective clothing.

For further detail see the Voluntary Initiative leaflet on calibration available at: **www.voluntaryinitiative.org.uk**

Machine operation and trouble shooting

Accurate mixing and filling of the sprayer, ensuring its correct operation and maintenance are vital to achieve efficient and effective application.

1 Mixing and filling the sprayer

The mixing site must be away from staff facilities and watercourses; and have access to a clean water source. A well ventilated, labelled, lockable shed is ideal, with power so that electronic scales can be used to weigh out wettable powder formulations. A sturdy bench is also important, so that pesticides can be measured accurately. The following points are particularly important:

- **ALWAYS READ** the product label before using any pesticide.
- Always conduct a Risk or COSHH assessment before starting spraying and ideally have someone else on site in case of emergency.
- Make sure you have the correct equipment to accurately measure small amounts of pesticide. Graduated measuring jugs, beakers and disposable syringes are all useful, and a set of scales measuring to 0.1 g is essential. Stand any measuring equipment on a plastic tray with raised edges so that any spills can be contained.
- Wear appropriate Personal Protective Equipment (see later section for PPE to be used when spraying protected ornamentals).
- Check if wettable powders need precreaming before being added to the tank. Measure out the correct quantity with care, and try to avoid spills. If minor liquid spills occur, absorb the material with sand or other absorbent material, place the contaminated material in a sealed, labelled container and dispose of it through a specialist waste disposal contractor. Spilt powders or granules should be disposed of in a similar way.
- Half fill the sprayer with clean water and add the measured product. Rinse the measuring vessel (and the product container if it has been emptied) and add to the spray tank.
- Start agitation (or shake the sprayer tank thoroughly if using a motorised knapsack or a hand pumped knapsack) and then complete filling the tank up to the correct level.
- If using a knapsack or motorised knapsack machine, stand it on a suitable bench and then lift it carefully onto your back. Adjust the carrying straps so that the shoulders take the weight and feel comfortable.
- Wearing the correct PPE, move the sprayer to the area to be treated.

2 Effective machine operation

- Check for any leaks, eg from hoses or spray pistols that have occurred since routine maintenance checks and repair them if necessary.
- Ensure the pressure gauge is working and adjust the pressure to working levels.
- Check for worn nozzles and use compressed air to clear any blockages, never use a piece of wire, as this will affect the aperture.
- Adjust the spray pistol or motorised knapsack so that the spray quality is medium/fine and work methodically through the crop, ensuring that dense crops receive adequate coverage. Good spray application takes time and cannot be rushed. An up and under motion should be used for pest and disease problems that occur on the undersides of the leaf eg spider mite.
- If using a ULV/LVM mister, set the timer to run long enough for the spray bottle to be completely emptied and set the timer for the evening when no-one is present in the greenhouse. Always ensure that the house is vented early in the morning and before staff re-enter. Place a warning sign before commencing operation.

3 Maintenance

Regular equipment maintenance is essential for ensuring accurate pesticide application and reducing environmental impact. This is vitally important regardless of whether the spraying equipment is a simple knapsack sprayer or a more complex ULV/LVM machine.

For further details on routine operator checklists and for various pieces of spray equipment see the Voluntary Initiative website: **www.voluntaryinitiative.org.uk**

Spraying and safety to nursery staff/ visitors

Always place a warning notice by the treated area/crop so that nursery personnel do not enter during or after spraying. An example of a suitable Notice is shown in Figure 17.

It is good practice to indicate the actual time of spraying and when it is safe to re-enter (for instance, most nurseries use a 12 hour re-entry interval for insecticides, and allow re-entry for fungicides once the spray has dried on the crop). By law, the details of all applications of pesticides must be recorded, and the records kept.

17 Warning signs notifying staff or visitors not to enter treated areas/crops for a set period following spraying should be clearly displayed

Personal Protective Equipment (PPE)

The following points need to be borne in mind when spraying protected ornamental crops:

- Unlike arable spraying, where the operator is inside a closed cab, spray operators in protected crops are in close direct contact with the spray cloud, so PPE is very important, especially when application is carried out for prolonged periods.

- **READ THE PRODUCT LABEL**, as this will list the PPE required for tasks such as measuring out the concentrate, mixing and then applying the dilute solution.

- Always keep PPE stored away from pesticides, and clean all PPE after use. Keep a record of respirator cartridge hour ratings and ensure they are replaced regularly.

- Ensure that the correct respirator cartridge is chosen, according to the type of product used. The categories of product that each cartridge type will protect against are listed on the pack.

- The 'air flow' systems, whereby a special face mask is worn with a cartridge and battery worn on a belt around the operators waist, and which creates a positive air flow down around the wearers face, are more comfortable than straight respirator masks. This is particularly so with the high temperatures encountered in glasshouses and tunnels (Figure 18).

- Some products only require a face-mask, coveralls and neoprene or rubber gloves (normal household gloves are NOT suitable) rather than an air flow respirator, but often the operator may use the full PPE as a matter of routine.

- Always clean and put away PPE safely after use.

- When spraying in protected structures, the MINIMUM PPE to be used includes a coverall, gloves, boots, face shield and hood.

18 Air flow helmet and full protective suit in use when spraying a glasshouse crop

Further information

The following are useful sources of further information and advice.

Publications

1 *Pesticide application methods* by G A Matthews. Published by Longman Group, ISBN 0-582-40905 5

2 *Code of Practice for Using Plant Protection Products 2006*. Priced publication available from Defra Publications or can be downloaded free of charge from the Pesticides Safety Directorate website **www.pesticides.gov.uk**

3 *Code of Good Agricultural Practice for the Protection of Water. 1998*. Available from Defra Publications **www.defra.gov.uk**

4 *The UK Pesticide Guide* published by BCPC annually, ISBN 1 84593 045 2. **www.ukpesticideguide.co.uk**

There are also several other recently revised practical guides available from the BCPC as priced publications see: **www.bcpc.org**

- *Using Pesticides – a complete guide to safe, effective spraying*
- *Small scale spraying* (formerly the *Hand-held and Amenity Sprayers Handbook*). This includes information on how growers can service and calibrate spray equipment themselves.
- *Field scale spraying* (formerly the *Boom and Fruit Sprayers Handbook*)
- *Safety Equipment Handbook – a practical guide to safety requirements*

Organisations and websites

The Health and Safety Executive (HSE) have detailed information on many topics relating to pesticides, including guidance on storing pesticides, PPE and the safe use of pesticides. Leaflets can be ordered from the HSE by mail order from:
HSE books
PO Box 1999,
Sudbury Suffolk,
CO10 2 WA
www.hse.gov.uk

The Crop Protection Association
www.cropprotection.org.uk

The British Crop Protection Council
www.bcpc.org

Pesticides Safety Directorate (PSD)
www.pesticides.gov.uk

Industry best practice schemes

The voluntary initiative (VI), National sprayer testing scheme (NSTS) and National register of sprayer operators (NRoSO) schemes have been devised to show government that the industry is adopting a completely professional and responsible approach to pesticide use. As part of the Voluntary Initiative (VI), the industry is committed to ensuring that 80% or more of spray machines are tested annually for satisfactory operation by independent testers. This is the purpose of the NSTS.

The Voluntary Initiative
www.voluntaryinitiative.org.uk

National Sprayer Testing Scheme (NSTS)
www.nsts.org.uk

National Register of Spray Operatives (NRoSO)
www.nroso.nptc.org.uk

May 2007

Design and production: HDR Visual Communication