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Selecting nozzles for hand-held applicators

TECHNICAL NOTE

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SUMMARY

This Technical Note provides guidance on the selection of appropriate spray nozzle(s) for use in the application of pesticides. Influences on selection, such as type of target, weather conditions, pesticide formulation, spray equipment and spray quality, are described. Information is provided on the British Crop Protection Nozzle Code. Types of nozzle and their functions, care and maintenance, and calibration of equipment to ensure accurate application of product are also described.

INTRODUCTION

The hydraulic spray nozzle used in the application of pesticides has several functions. One of its main purposes is to convert the spray solution into droplets for efficient target coverage. The target may be foliage, bark, stumps, soil or insects. In association with other variables, e.g. height above target, travelling speed, operating pressure, the nozzle also has a role in spray pattern delivery, volume rate delivered and spray quality produced. Various nozzle types are required to accomplish these roles within a range of operating variables.

Figure 1

Application of herbicide using knapsack sprayer fitted with appropriate nozzle.

The optimum size of droplet that can be retained by the target can vary greatly and this will critically affect the performance of the pesticide solution. Large droplets tend to bounce or run off leaves and can be lost. The goal for foliar targets is to produce medium sized droplets which will be more readily retained by the plant. When applying a pesticide the correct choice of nozzle can make the difference between successful or mediocre control or failure.

Several different designs of nozzle are available: deflector, flat fan, cone (hollow and full) and twin-fluid, all fully described on pages 4–10. The majority of pesticide applications in forestry utilise the deflector nozzle. Droplet sizes have been defined by the British Crop Protection Council (BCPC) and are referred to as fine, medium and coarse spray quality. Further details about spray quality are given on page 4, and the specification of nozzles providing spray quality types can be found on pages 4–10.

Nomenclature

Box 1 lists and defines the main terms used in this Note.

Box 1 Nozzles in pesticide application: useful definitions.

Term	Definition
Volume rate	A specified mixture of pesticide concentrate and dilutant, usually water, and in some conditions special additive(s), which must be applied in litres per hectare as instructed by the manufacturer.
Pesticide concentrate	Herbicides and insecticides supplied by the manufacturer in containers for mixing with dilutant.
Spray pattern	The shape in which the volume rate is delivered to the target by the nozzle.
Spray quality	The size of volume rate droplets delivered by the nozzle using the BCPC classification system.
Product rate	The amount (weight or volume) of active ingredient or product applied per unit area.
Flow rate / nozzle rate	Delivery rate in millilitres per minute through the nozzle.

NOZZLE SELECTION

Nozzle selection will be influenced by:
- label recommendation;
- type of target;
- minimum volume rate;
- reduced volume rate;
- weather conditions;
- pesticide formulation;
- spray pressure;
- spray equipment, pattern and quality.

Label recommendation

Some pesticide labels will include a recommendation for a preferred spray quality (see Table 4). For example, the Roundup Biactive label suggests the use of medium or coarse spray quality. However, while this recommendation will be helpful in general terms, the operator is not obliged to follow the advice unless the recommendation appears in the Statutory Box on the label but the operator may be at risk if the manufacturer's recommendation is not followed. If there is no specific advice to the contrary in this Statutory Box the operator can use a fine spray quality if other parameters such as spray pressure and volume rate are met.

Type of target

Small droplets will adhere to the target more readily than large droplets, which tend to bounce or roll off the target and are lost. Where foliar sprays are applied using coarse spray quality, up to 80% of the pesticide may be wasted because it bounces or rolls off the leaf. A medium spray quality will therefore be preferable for most foliar applications.

A fine spray quality may be considered in the following three situations:
1. narrow leaved grasses such as purple moorgrass, matgrass or sheep's fescue;
2. waxy leaves such as rhododendron, ragwort or creeping thistle;
3. narrow and waxy leaved plants such as broom or gorse.

The first situation is more species specific than the general advice given by the British Crop Protection Council (BCPC) which identifies the use of medium spray quality for general herbicide application. Table 1 shows the relationship between spray quality and retention on target vegetation (leaf surfaces) using BCPC terminology.

The spray quality of a particular nozzle at a set pressure can be identified: see Types of nozzle, Tables 8–20, which incorporate manufacturers' information. Where soil residual herbicides such as propyzamide (no foliar activity) are appropriate, a coarse spray quality can be used without any loss of performance.

Insecticide performance is generally improved with the use of fine quality nozzles, using a spray pressure of up to 3 bar. The resulting fine spray can wrap around foliage and stems leading to improved contact with the crop and insect.

Minimum volume rate

As a general rule, finer spray qualities reduce the volume rate that is applied per hectare. The pesticide label will always specify the maximum and minimum volume rates that can be applied and the operator *must* follow this specification by using an appropriate nozzle type, spray pressure and walking speed.

It may not be possible to use a fine quality spray where the label requirement specifies a minimum volume rate of 200 l/ha because an impractical low walking speed would be required to achieve the minimum volume rate.

Reduced volume rate

In certain circumstances the statutory minimum volume rate may be reduced on a sliding scale to 10% of the recommended volume rate, e.g. if the minimum is 200 l/ha, then 20 l/ha could be used. This is legally acceptable where the pesticide is not toxic and protective clothing is not required when spraying the diluted material, and the label permits a reduction in volume rate.

Table 1 Spray quality and retention on leaf surfaces.

Spray quality	Retention on leaf	Use
Very fine	Very good	Unlikely to be used in forestry situations
Fine	Very good	Insecticides Waxy targets such as gorse, broom and rhododendron
Medium	Good	Most foliar herbicide spraying
Coarse	Moderately poor	Soil residuals Foliar herbicides in windy conditions
Very coarse	Very poor	Rarely used except with liquid fertilisers

Table 2 identifies the products currently (May 2006) approved for use in forestry, which can be applied at reduced volume rate. **Product labels are under constant review and therefore this information must be checked with each new batch of product purchased.**

Table 2 Reduced volume rate products.

Product	Minimum label volume rate/ha (l)	Permitted minimum volume rate/ha (l)
Asulox	90	9
Freeway Diuron	200	20
Fortrol	100	10
Kerb Pro Flo	200	20
Roundup Pro Biactive	100	10
Shield (Dow)	80	8

The following products are examples where protective clothing is required when applying the diluted material and therefore reduced volumes are not permitted: Atrazine, Broadsword/Nu-Shot, Challenge, 2, 4-D, Laser, Roundup Pro, PDQ/Gramoxone.

Weather conditions

Weather conditions, particularly wind, rain and sun, have a great influence on the choice of spray quality.

Wind

With increased wind speed, larger droplets have to be created to minimise spray drift. Spraying in higher wind speeds may result in an efficacy penalty because a more coarse spray quality is used (coarser spray droplets are more likely to roll off the target). Table 3 shows the relationship between spray quality and drift, using BCPC terminology.

Table 3 Spray quality and drift potential.

Spray quality	Drift potential
Very fine	Very high
Fine	High
Medium	Moderate
Coarse	Low
Very coarse	Very low

Rain

Ideally, the water element of an applied pesticide evaporates, which reduces the incidence of active pesticide wash-off due to rainfall. The water from small droplets will evaporate more quickly, therefore it can be advantageous to use a fine or fine/medium spray quality when the weather is showery. Care must always be taken to avoid the risk of rain causing pesticide run off, and possible environmental damage.

Smaller spray droplets may have greater concentrations of pesticide, especially if used with reduced volume rates.

Sun

In hot conditions, some pesticides have a tendency to ‘scorch’ the crop and may physically damage it before lethal concentrations are absorbed. This unwanted physical damage is more prevalent with the higher concentrations of pesticide found in fine droplets at reduced volume rates. In these hot conditions, the recommendation is to use medium spray quality droplets at an increased volume rate, even though this will result in slower walking speeds compared to coarser spray qualities.

Pesticide formulation

Pesticides are formulated with wetters, solvents and adjuvants, which in a minority of products can have a dramatic effect on spray quality. Some of these additives can significantly reduce the width of the spray swath. To overcome this effect, a smaller nozzle can be fitted and the spray pressure increased to the point where the desired spray volume is reached.

Spray pressure

Higher spraying pressures will produce smaller droplets, giving a finer spray quality that is more susceptible to drift. It is therefore preferable to use a pressure of 1 to 1.5 bar to produce a medium spray quality, assuming it can give good target cover in the conditions encountered.

Where soil or ground level foliage is to be sprayed, a low pressure of 1 to 1.5 bar should normally be used to minimise the production of small droplets which can drift. It may be necessary to increase the pressure to 2 or 3 bar where the penetration of foliage is required, for instance with insecticides or spraying dense scrub such as gorse.

Spray equipment

Knapsack sprayers

Most knapsack sprayers have the flexibility to apply fine, medium or coarse spray quality. However, a higher rated pressure control valve may be required to monitor pressures for the emission of fine quality sprays.

Spot guns

Spot guns are normally provided with a solid cone jet (see page 10), which produces a fine spray quality. This is very effective with foliar applied herbicides such as glyphosate. However, when applying soil residual herbicides, where a coarse spray is satisfactory, operator fatigue may be reduced by using a medium/coarse evenspray nozzle to produce a ‘square’ spot.

Spray quality

Table 4 gives an indication of the size of droplet that is related to the spray quality classification defined on the product label. Table 5 gives examples of types of nozzles and their spray quality. Table 6 suggests suitable nozzles for use in knapsack applications.

Table 4 Droplet size/spray quality classification.

Spray quality classification	Droplet size (µm)
Very fine	< 119
Fine	119 – 216
Medium	217 – 353
Coarse	354 – 464
Very coarse	> 464

Table 5 Nozzle design and spray quality.

Situation	Spray quality	Nozzle design	Comments
Foliar sprays	Medium	Deflector Evenspray fan Flat fan	Consider fine quality on fine leaved grasses or waxy leaves, needles or stems
Windy conditions	Coarse	Deflector Evenspray fan	This may result in a performance penalty on foliar applications
Insecticides	Fine/medium	Solid cone Hollow cone Evenspray fan Flat fan	Increased pressure may be required to achieve coverage throughout the plant
Residual herbicides	Coarse	Deflector Evenspray fan	Small droplet size is not required

Table 6 Typical knapsack spray operations and suggested nozzles.

Pesticide	Spray quality	Typical nozzle*	Pressure (bar)
Asulam	Medium	D/0.75/1 D/1.0/1	1.0–1.5
Glyphosate	Medium	D/0.75/1 D/1.0/1	1.0–1.5
Propyzamide	Medium/ coarse	D/1.5/1 D/2.0/1	1.0–1.5
Triclopyr	Medium	D/1.0/1 D/1.5/1	1.0–1.5
Alphaguard (*Hylobius* top-up)	Medium	02/E80 90 B1 FP 1.0	1.0–1.5

* BCPC system for identifying nozzles and operating parameter, e.g. D/0.75/1 = deflector nozzle rated 0.75 l/min at 1 bar. See British Crop Protection Council Nozzle Code and Table 7.

BRITISH CROP PROTECTION COUNCIL NOZZLE CODE

Different nozzle manufacturers use different numbering systems and colours to indicate nozzle types, spray angles and flow rates. Nozzle codes and colours for deflector and hollow cone nozzles vary between manufacturers, while flat fan numbers and colours follow the ISO standard and will be the same irrespective of manufacturer. The British Crop Protection Council (BCPC) have adopted a universal system, so it is now possible to compare nozzles from different manufacturers.

To minimise the risk of spray drift, nozzles classed as medium or coarse spray quality by the BCPC *Hand-held and amenity sprayers handbook* (BCPC, 2001) should normally be used. Any nozzle spray quality can be compromised by a change in the operating pressure of the spraying equipment. Nozzle suppliers can provide information on droplet classification for their products. Low drift hydraulic nozzles are available, but do not have a BCPC nozzle code at present. Table 7 shows the BCPC system for identifying nozzles and operating parameters. For example: BCPC D/1.2/1 = deflector nozzle, rated 1.2 l/min at 1 bar.

Table 7 BCPC system for identifying nozzles and operating parameters.

Type tip	Spray angle	Tip output	Rated pressure
Hollow cone (HC) Fan (F) Deflector (D)	degrees (°) if known	litres per minute (l/min)	bar (normally 3 bar but 1 bar for deflector nozzles)

It is important that the nozzle chosen for a given pesticide should give the spray quality identified by the product label.

TYPES OF NOZZLE

The list of products/manufacturers in Tables 8–20 is not comprehensive; other manufacturers may be able to provide products with equivalent characteristics. Reference to a particular manufacturer or product does not imply endorsement or recommendation of that manufacturer or product by the Forestry Commission.

Deflector nozzles

Deflector nozzles are also known as flood or anvil nozzles. This type of nozzle consists of a circular orifice, through which the liquid jet passes to bounce off a deflecting surface, resulting in a wide-angle fan spray with a narrow rectangular spray pattern. Rated at 1 bar pressure, these nozzles produce a relatively even distribution.

Deflector nozzles should be attached to the spray lance so that the spray is directed downwards onto the target. The spray swath can vary between 0.2 m and 2 m depending on the height of the nozzle position above the target. To ensure the desired swath width is achieved, the nozzle must be held at a constant height as indicated in the deflector nozzle application rate chart at the specified operating pressure.

The deflector nozzle is widely used with a knapsack sprayer for application of herbicides. A low operating pressure of 1 bar tends to produce coarse droplets which are less prone to drift, reducing off-target contamination. When the operating pressure is raised to 1.5–2.0 bar, these nozzles will tend to produce a medium quality spray. The smaller sizes (D/0.5 or D/0.75) are particularly suitable for very low volume (VLV) applications of herbicides where reduced volume rates can provide substantial cost savings in terms of water use and application time.

It is critical that any pre-set pressure regulator fitted to the knapsack sprayer or hand lance is set for low pressure operation. It is essential to read the equipment manufacturer's operating manual. Figure 2 shows a typical deflector nozzle, typical spray pattern and the flow of liquid through the nozzle.

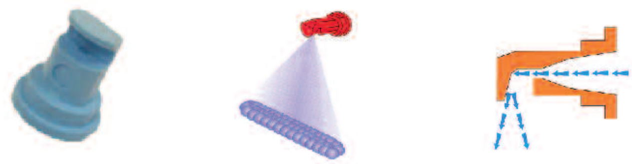

Figure 2

Deflector nozzle, spray pattern and liquid flow.

Tables 8, 9, 10 and 11 refer to deflector nozzles only. Blanks in the tables indicate that information was not available from the manufacturer.

Table 8 Deflector nozzles: very low volume (VLV) 10–49 l/ha.

	Sprays International	Sprays International	Hypro/ Lurmark	Teejet	Sprays International	Hypro/ Lurmark	Teejet
Tip reference	**DEF-01**	**DEF-01**	**DT 0.5**	**TK-VP3-0.5**	**DEF-015**	**DT 0.5**	**TK50-VP3**
Colour	Orange	Orange	Orange		Green	Orange	
BCPC code	D/0.23/1	D/0.23/1	D/0.23/1	D/0.23/1	D/0.35/1	D/0.28/1.5	D/0.28/1.5
Spray angle	110	110	90		110	90	
Variables pressure (bar)	1	1	1	1	1	1.5	1.5
Flow rate (l/min)	0.23	0.23	0.23	0.23	0.35	0.28	0.28
Height (m)	0.5	0.35			0.5		
Swath width (m)	1.4	1	1	1	1.4	1	1
l/ha @ 1 m/s	27	38	38	38	42	46	46
Spray quality (E=estimate)	Medium (E)	Medium (E)	Medium	Medium (E)	Medium (E)	Medium (E)	Medium (E)

Table 9 Deflector nozzles: low volume (1) 50–99 l/ha.

	Sprays Internat.	Hypro/ Lurmark	Hypro/ Lurmark	Teejet	Teejet	Teejet	Hypro/ Lurmark	Hypro/ Lurmark	Teejet	Hypro/ Lurmark	Hypro/ Lurmark
Tip reference	**DEF-02**	**DT 0.5**	**DT 0.75**	**TK75-VP3**	**TK50-VP3**	**TK75-VP3**	**DT 0.75**	**DT 1.0**	**TK1-VP3**	**DT 0.75**	**DT 1.0**
Colour	Yellow	Orange	Green				Green	Yellow		Green	Yellow
BCPC code	D/0.46/1	D/0.33/2	D/0.34/1	D/0.34/1	D/0.4/2	D/0.42/1.5	D/0.42/1.5	D/0.46/1	D/0.46/1	D/0.49/2	D/0.56/1.5
Spray angle	110	90	105				105	110		105	110
Variables pressure (bar)	1	2	1	1	2	1.5	1.5	1	1	2	1.5
Flow rate (l/min)	0.46	0.33	0.34	0.34	0.4	0.42	0.42	0.46	0.46	0.49	0.56
Height (m)	0.5							0.5			0.5
Swath width (m)	1.4	1	1	1	1	1	1	1.4	1	1	1
l/ha @ 1 m/s	55	55	58	58	66	72	72	77	77	84	94
Spray quality (E=estimate)	Coarse	Fine	Coarse	Coarse (E)	Medium (E)	Medium (E)	Medium	Coarse	Coarse (E)	Medium	Coarse

Table 10 Deflector nozzles: low volume (2) 100–149 l/ha.

	Hardi	Hypro/ Lurmark	Sprays International	Hypro/ Lurmark	Hypro/ Lurmark	Hardi	Hardi
Tip reference	**4598-10**	**DT 1.0**	**DEF-04**	**DT 1.5**	**DT 1.5**	**4598-10**	**4598-12**
Colour		Yellow	Red	Blue	Blue		
BCPC code	D/0.23/1	D/0.23/1	D/0.23/1	D/0.23/1	D/0.35/1	D/0.28/1.5	D/0.28/1.5
Spray angle		110	110	115	115		
Variables pressure (bar)	1	2	1	1	1.5	2	1
Flow rate (l/min)	0.6	0.65	0.92	0.68	0.84	0.85	0.87
Height (m)		0.5	0.5				
Swath width (m)	1	1	1.4	1	1	1	1
l/ha @ 1 m/s	100	109	110	114	141	142	145
Spray quality (E=estimate)	Coarse (E)	Medium	Coarse (E)	Coarse	Medium	Medium (E)	Coarse (E)

Table 11 Deflector nozzles: low volume (2) 150–199 l/ha.

	Teejet	Hypro/ Lurmark	Sprays Internat.	Teejet	Hypro/ Lurmark	Sprays Internat.	Hypro/ Lurmark	Teejet	Sprays Internat.	Sprays Internat.
Tip reference	**TK2-VP3**	**DT 0.2**	**DEF-04**	**TK1.5-VP3**	**DT 1.5**	**DEF-06**	**DT 0.2**	**TK2-VP3**	**DEF-05**	**DEF-025**
Colour	Red	Red	Red		Blue	Grey	Red	Red	Brown	Dark yellow
BCPC code	D/0.91/1	D/0.91/1	D/0.92/1	D/0.97/2	D/0.97/2	D/1.39/1	D/1.12/1.5	D/1.11/1.5	D/1.15/1	D/1.58/1
Spray angle		115	110		115	110	115		90	53
Variables pressure (bar)	1	1	1	1	2	1	1.5	1.5	1	1
Flow rate (l/min)	0.91	0.91	0.92	0.97	0.97	1.39	1.12	1.11	1.15	1.58
Height (m)			0.35			0.5			0.5	0.5
Swath width (m)	1	1	1	1	1	1	1	1	1	1.4
l/ha @ 1 m/s	151	152	153	162	162	166	187	187	192	193
Spray quality (E=estimate)	Coarse (E)	Coarse	Coarse (E)	Medium (E)	Medium	Coarse	Coarse	Coarse (E)	Coarse (E)	Coarse (E)

Flat fan nozzles

Flat fan

Flat fan nozzles have an orifice that produces a narrow, elliptical spray pattern, available in a 65°, 80° and 110° spray angle. They are suitable for single nozzle applications with knapsack sprayers, where concentration of spray in the centre of the swath is desirable with insecticide application or scrub spraying. Low pressure flat fan jets for 1 bar operation are available which produce a medium to coarse spray quality and may be considered for some knapsack applications.

Even flat fan

The most suitable flat fan nozzle for hand-held sprayers is the even flat fan. This produces an even distribution of liquid across the spray pattern. For even flat fan nozzles the set spray pattern at a particular pressure and working height is typically 0.6 m to 0.8 m above the target vegetation. Because these nozzles have to be placed directly over the target, their use is restricted to trees under 0.5 m in height. It is important to check that they are suitable for the product, crop and target. Figure 3 shows a typical even flat fan nozzle, typical spray pattern and the flow of liquid through the nozzle.

Figure 3

Even flat fan nozzle, spray pattern and liquid flow.

Tables 12, 13, 14 and 15 refer to flat fan nozzles only. The list of manufacturers is not exhaustive; blanks in the tables indicate that information was not available from the manufacturer.

Table 12 Even flat fan nozzles: Sprays International Evenfan 80.

	Sprays International			
Tip reference	**80-EF-015**	**80-EF-02**	**80-EF-03**	**80-EF-04**
Colour	Green	Yellow	Blue	Red
BCPC code	FE80/0.5/2	FE80/0.6/2	FE80/1.0/2	FE80/1.3/2
Spray angle	80	80	80	80
Variables pressure (bar)	2	2	2	2
Flow rate (l/min)	0.5	0.6	1.0	1.3
Height (m)	0.6	0.6	0.6	0.6
Swath width (m)	1.0	1.0	1.0	1.0
l/ha @ 1 m/s	83	100	167	217
Spray quality	Fine	Fine	Med./Fine	Medium

Table 13 Even flat fan nozzles: Lurmark Evenspray 80.

	Hypro/Lurmark				
Tip reference	**01E80OR**	**015E80GR**	**02E80YE**	**03E80UB**	**04E80RE**
Colour	Orange	Green	Yellow	Blue	Red
BCPC code	FE80/0.3/2	FE80/0.5/2	FE80/0.6/2	FE80/1.0/2	FE80/1.3/2
Spray angle	80	80	80	80	80
Variables pressure (bar)	2	2	2	2	2
Flow rate (l/min)	0.3	0.5	0.6	1	1.3
Height (m)	0.5	0.5	0.5	0.5	0.5
Swath width (m)	0.8	0.8	0.8	0.8	0.8
l/ha @ 1 m/s	69	102	137	205	273
Spray quality	Fine	Fine	Medium	Medium	Coarse

Table 14 Even flat fan nozzles: Hardi 4680E.

	Hardi							
Tip reference	**4680E-7E**	**4680E-7E**	**4680E-9E**	**4680E-9E**	**4680E-11E**	**4680E-11E**	**4680E-13E**	**4680E-13E**
Colour	Black	Black	Black	Black	Black	Black	Black	Black
BCPC code	FE80/0.2/1.5	FE80/0.25/2	FE80/0.3/1.5	FE80/0.35/2	FE80/0.4/1.5	FE80/0.5/2	FE80/0.6/1.5	FE80/0.7/2
Spray angle	80	80	80	80	80	80	80	80
Variables pressure (bar)	1.5	2	1.5	2	1.5	2	1.5	2
Flow rate (l/min)	0.2	0.25	0.3	0.35	0.4	0.5	0.6	0.7
Height (m)								
Swath width (m)								
l/ha @ 1 m/s								
Spray quality (E=estimate)	Fine (E)	Fine (E)	Fine (E)	Fine (E)	Fine (E)	Fine (E)	Fine (E)	Fine (E)

	Hardi							
Tip reference	**4680E-15E**	**4680E-715**	**4680E-21E**	**4680E-21E**	**4680E-25E**	**4680E-25E**	**4680E-27E**	**4680E-27E**
Colour	Black	Black	Black	Black	Black	Black	Black	Black
BCPC code	FE80/0.8/1.5	FE80/0.95/2	FE80/1.2/1.5	FE80/1.4/2	FE80/1.5/1.5	FE80/1.75/2	FE80/1.85/1.5	FE80/2.15/2
Spray angle	80	80	80	80	80	80	80	80
Variables pressure (bar)	1.5	2	1.5	2	1.5	2	1.5	2
Flow rate (l/min)	0.8	0.95	1.2	1.4	1.5	1.75	1.85	2.15
Height (m)								
Swath width (m)								
l/ha @ 1 m/s								
Spray quality (E=estimate)	Medium (E)	Medium (E)	Medium (E)	Coarse (E)	Coarse (E)	Coarse (E)	Coarse (E)	Coarse (E)

Information on height, swath width and volume rate was unavailable.

Table 15 Even flat fan nozzles: Teejet.

	Teejet				
Tip reference	**TP8001**	**TP80015**	**TP8002**	**TP8003**	**TP8004**
Colour	Orange	Green	Yellow	Blue	Red
BCPC code	FE80/0.3/2	FE80/0.5/2	FE80/0.6/2	FE80/1.0/2	FE80/1.3/2
Spray angle	80	80	80	80	80
Variables pressure (bar)	2	2	2	2	2
Flow rate (l/min)	0.3	0.5	0.6	1.0	1.3
Height (m)					
Swath width (m)					
l/ha @ 1 m/s					
Spray quality	Fine	Fine	Medium	Medium	Medium

Information on height, swath width and volume rate was unavailable.

Cone nozzles

Cone nozzles are available as hollow cone or full (solid) cone versions. Some types of cone nozzle enable the operator to change the spray from a hollow to a full cone.

Hollow cone

The hollow cone consists of a swirl plate surrounded by a swirl core with the swirl chamber between the two (Figure 4). Liquid passes through the spiral slots in the swirl core, and into the swirl chamber where it acquires a high rotational velocity, discharging from the nozzle in a hollow cone spray pattern. This nozzle is widely used with knapsack sprayers: the fine droplets ensure that it is very suitable for foliar application of insecticides and fungicides.

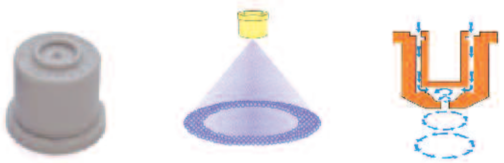

Figure 4

Hollow cone nozzle, spray pattern and liquid flow.

Full (solid) cone

In a full cone the swirl plate has a centrally drilled hole to create the full cone effect. Normally full cone nozzles are fitted to air-assisted crop sprayers. Lurmark has specifically manufactured a new range of full cone nozzles for knapsack sprayers. Full cone nozzles are also fitted as standard equipment on many spot guns. Figure 5 shows a typical full cone nozzle and typical spray pattern.

Figure 5

Full cone nozzle and spray pattern.

Tables 16, 17, 18, 19 refer to hollow cone nozzles and Table 20 refers to full cone nozzles. The list of manufacturers is not exhaustive; blanks in the tables indicate that information was not available from the manufacturer.

Table 16 Hollow cone nozzles: Lurmark Fulco Tip 80.

	Hypro/Lurmark			
Tip reference	**FCX0.2**	**FCX0.2**	**FCX0.3**	**FCX0.3**
Colour	Yellow	Yellow	Blue	Blue
BCPC code	HC80/0.74/1	HC80/1.05/2	HC80/1.12/1	HC80/1.58/2
Spray angle	80	80	80	80
Variables pressure (bar)	1	2	1	2
Flow rate (l/min)	0.74	1.05	1.12	1.58
Height (m)	0.6	0.6	0.6	0.6
Swath width (m)	1	1	1	1
l/ha @ 1 m/s	124	175	187	264
Spray quality (E=estimate)	Fine (E)	Fine (E)	Fine (E)	Fine (E)

Table 17 Hollow cone nozzles: Hardi.

	Hardi								
Tip reference	**371694**	**371694**	**371694**	**371682**	**371682**	**371682**	**371695**	**371695**	**371695**
Colour	Yellow	Yellow	Yellow	Red	Red	Red	Brown	Brown	Brown
BCPC code	HC/0.46/1	HC/0.57/1.5	HC/0.65/2	HC/0.81/1	HC/0.99/1.5	HC/1.14/2	HC/1.04/1	HC/1.27/1.5	HC/1.47/2
Variables pressure (bar)	1	1.5	2	1	1.5	2	1	1.5	2
Flow rate (l/min)	0.46	0.57	0.65	0.81	0.99	1.14	1.04	1.27	1.47
Height (m)									
Swath width (m)									
l/ha @ 1 m/s									
Spray quality (E=estimate)	Fine (E)	Fine (E)	Fine (E)	Fine (E)	Fine (E)	Fine (E)	Fine (E)	Fine (E)	Fine (E)

Information on height, swath width and volume rate was unavailable.

Table 18 Hollow cone nozzles: Teejet Whirljet.

	Teejet								
Tip reference	1/4B-SS2-2W	1/4B-SS2-2W	1/4B-SS2-2W	1/4B-SS2-5W	1/4B-SS2-5W	1/4B-SS2-5W	1/4B-SS3-8W	1/4B-SS3-8W	1/4B-SS3-8W
Colour	Grey	Grey	Grey	Grey	Grey	Grey	Grey	Grey	Grey
BCPC code									
Variables pressure (bar)	1	1.5	2	1	1.5	2	1	1.5	2
Flow rate (l/min)	0.9	1.05	1.2	1.2	1.45	1.65	1.85	2.25	2.25
Height (m)									
Swath width (m)									
l/ha @ 1 m/s									
Spray quality (E=estimate)	Fine (E)	Fine (E)	Fine (E)	Fine (E)	Fine (E)	Fine (E)	Fine (E)	Fine (E)	Fine (E)

Information on BCPC code, height, swath width and volume rate was unavailable.

Table 19 Hollow cone nozzles: Sprays International.

	Sprays International				
Tip reference	HC-01	HC-015	HC-02	HC-035	HC-04
Colour	Orange	Green	Yellow	Black	Red
BCPC code	HC85/0.4/3	HC85/0.6/3	HC85/0.8/3	HC85/1.4/3	HC85/1.6/3
Spray angle	85	85	85	85	85
Variables pressure (bar)	3	3	3	3	3
Flow rate (l/min)	0.4	0.6	0.8	1.4	1.6
Height (m)	60	60	60	60	60
Swath width (m)	1	1	1	1	1
l/ha @ 1m/s	66	100	133	166	190
Spray quality (E=estimate)	Fine (E)	Fine (E)	Fine (E)	Fine (E)	Fine (E)

Table 20 Full cone (solid cone) nozzles: Teejet Fulljet.

	Teejet								
Tip reference	FL-5V	FL-5V	FL-5V	FL-6.5V	FL-6.5V	FL-6.5V	FL-8V	FL-8V	FL-8V
Colour	Brown	Brown	Brown	Grey	Grey	Grey	White	White	White
Variables pressure (bar)	1	1.5	2	1	1.5	2	1	1.5	2
Flow rate (l/min)	1.2	1.45	1.7	1.55	1.9	2.15	1.9	2.3	2.6

Twin-fluid nozzles

Twin-fluid nozzles are so called as two fluids, the liquid containing the pesticides and another fluid usually an airstream, are combined inside the nozzle body. There are two types of nozzle that incorporate an airstream.

- Air-induction nozzles draw air into the nozzle through a side hole.
- Air-inclusion nozzles use pressurised air from a compressor which is actively injected into the nozzle.

Both types produce coarse sprays with reduced drift with droplets containing air bubbles. Air-inclusion nozzles require the air pressure to be altered to change the spray quality whereas air-induction nozzles need only the liquid pressure to be changed. Only the passive type air-induction nozzles are suitable for hand-held applicators.

Air-induction nozzles

Air is drawn into the nozzle through an aperture in the side of the nozzle to create large aerated droplets. These break up when they hit the target and disperse to provide improved coverage and penetration with reduced drift. This may be advantageous when spraying in exposed conditions or alongside highways where wind gust can be a problem. Adjusting the operating pressure of the spray system can change the spray quality.

Many air-induction nozzles (Figure 6) operate at pressures exceeding 2 bar, which may not be suitable for some hand-held applicators. It is important to check that the use of air-induction nozzles is suitable for the product, crop and target.

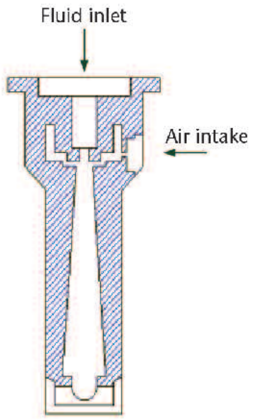

Figure 6

Air-induction nozzle.

CARE AND MAINTENANCE

Nozzles are very critical components in the spraying system chain, and can be the most neglected. Worn or damaged nozzles can lead to misapplication of pesticides, crop damage and environmental contamination. Abrasive spray formulations (some wettable powders) and/or careless handling can damage nozzles. They must be regularly inspected to ensure they are providing the specified spray pattern. The slightest damage to the orifice of the nozzle will affect the flow rate and spray pattern.

Regular examination

Nozzles should be examined and checked at frequent regular intervals in the following way:

1. Using water, check the flow rate by timing the discharge at the specific pressure into a calibrated measuring jug over a 1 minute interval, comparing the result with the flow rate specified on the data sheet. If the value is 10% or more above that specified, replace the nozzle. Always keep a quantity of spare nozzles with the applicator for immediate replacement in the field when necessary.

2. Nozzle spray patterns should be visually inspected to assess damage, which can be seen as streaking in the spray pattern. If there is any doubt, compare the current nozzle with a new nozzle to assess the spray pattern.

Blockages

Blocked nozzles should be soaked in clean, warm water and carefully cleaned using only a special tool (Figure 7), soft brush or an airline. No attempt should be made to clear a nozzle by the operator physically blowing or by trying to remove stubborn deposits with pins, wire or other sharp implements.

Figure 7

Nozzle cleaning tool.

Replacement

It is strongly recommended that nozzles are replaced at least once a year or sooner if deterioration is seen or suspected. The cost of renewing a complete set is minimal compared to the potential costs caused by chemical wastage and crop damage due to worn/damaged nozzles.

CALIBRATION

Calibration is the process of manipulating the variables of pesticide delivery, to ensure the right amount of product and diluent is applied to the target area. The variables can be any of the following:

- **Applicator pressure** Knapsack applicators may be fitted with some form of pressure control, which can use a number of fixed settings or a stepless adjustment range. This form of pressure regulation reduces the monitoring input required from the operator. A less reliable alternative is to use a pressure gauge and an adjustable pumping rate to maintain a defined pressure, which can be difficult on rough sites.

- **Nozzle size** A range of nozzles is available which allow different amounts of fluid to flow through at a given pressure.

- **Ground speed** For all techniques (apart from static spot spraying via a cone nozzle), the faster a given nozzle passes over the target the smaller the amount of pesticide that will be applied. Therefore, ground or walking speed is a critical variable to measure and control. Ground speed can vary across a site depending on slope and changes in vegetation. Operator fatigue throughout the day also has to be considered.

- **Nozzle height** Increasing the height at which the nozzle is held above the target also increases the application area, which can lead to under-application. Conversely, reduced nozzle height can lead to over-application of pesticide. Another source of error occurs when the nozzle height is calibrated on a uniform surface and the pesticide is applied over uneven, e.g. ploughed, ground. If the operator walks in the bottom of a plough furrow, the nozzle could then be held too close to the plough ridge, resulting in over-application, especially critical with overspraying.
- **Pesticide volume rate** Some pesticides are only approved for one dilution rate, while others are approved for a range of dilution rates. Where a range can be used, the water quantity used for dilution should be matched to the applicator capacity.

Calculations

Nozzle output can be calculated using the following equation:

$$\frac{\text{walking speed (m/min)} \times \text{volume rate(l/ha)} \times \text{swath width (m)}}{10} = \text{nozzle output (ml/min)}$$

Example

$$\frac{45 \text{ m/min} \times 200 \text{ l/ha} \times 1.5\text{m}}{10} = 1350 \text{ ml/min}$$

This equation can be applied to any type of swath-based sprayer, such as a knapsack. The quantity of pesticide with dilutant that flows through the nozzle in 1 minute can be calculated for combinations of nozzle height (via swath width), speed of travel and specified volume rate. Within specified parameters (volume rate) and physical constraints, variables can be adjusted and measured to determine the effect on nozzle output. Where the variables can be accepted, and the nozzle rate achieved, the operation can achieve safe and legal working constraints.

It is worth noting that:

- Swath width tends to be dictated by operator physique and comfort, vegetation height and ground conditions, which may be modified by ground preparation.
- Walking speed is affected by ground conditions, vegetation types, operator physique and fatigue. Fatigue rates are affected by time of day, site and weather conditions, operator health and personal protective equipment requirements.
- Pesticide volume rate is related to product rate and label requirements for dilution.

Assuming that walking speed and nozzle height are set at ergonomic and achievable values, then the most practical variable to alter is nozzle output via pressure control and/or use of alternative nozzles. Using this process, the nozzle output can be determined and set at achievable rates using calibration

In addition, the amount of pesticide (per sprayer tank) with given water quantities has to be calculated. This is achieved by using the following equation:

$$\frac{\text{Tank capacity (l)} \times \text{Product rate (l/ha)} \times 1000}{\text{Volume rate (l/ha)}} = \text{quantity of herbicide (ml) per applicator}$$

Example

$$\frac{10 \text{ l} \times 5 \text{ l/ha} \times 1000}{200 \text{ l/ha}} = 250 \text{ ml herbicide (9750 ml water per tank)}$$

Equipment

The following equipment is required for calibration.

Stopwatch

A stopwatch is needed to time nozzle flow rate and walking speed.

Metronome

A common error associated with calibrating spraying operations is measuring and monitoring walking speed. As mentioned previously, walking or ground speed can vary due to terrain, vegetation and fatigue. Most operators slow down as the day progresses and will not re-calibrate their walking speed to compensate. A metronome to monitor walking rate is therefore recommended. Many types are available and the simplest is often best. Figure 8 shows a simple clip-on metronome that allows the operator to maintain a steady walking rate during operations; speed can still be altered if longer or shorter steps are taken than those used in the calibration run.

Figure 8

Typical metronome.

Measuring cylinder or jug

The mixing and filling of applicators is considered to be the point at which the operator is most exposed to contamination from the concentrate. Greater levels of measuring accuracy can be achieved with measuring cylinders rather than jugs because the intervals on the former are usually calibrated to measure to the nearest millilitre. However, the neck of a cylinder is much narrower than a jug and spillage can occur when pouring concentrated pesticide from cylinder into container. Using a small funnel usually solves this problem. Further investigation is under way on closed transfer systems which reduce operator exposure to pesticide concentrates.

Tape measure

A tape measure is used to measure swath width and the distance walked in 1 minute. Alternatively, a measuring wheel can be used.

PRESSURE REGULATION

A reliable and consistent flow rate through the nozzle at the manufacturer's specified pressure is essential for calibration and accurate pesticide delivery. Variations can lead to uneven distribution in pesticide application and fluctuations in pesticide drift. Variation in operating pressure can be attributed to a number of factors including the frequency and force at which the pressurising lever is pumped. To maintain a consistent pressure at the nozzle, many applicators can be fitted with a constant flow valve (CFV) like the one shown in Figure 9.

Formerly known as a spray management valve, the CFV works to maintain a constant operating pressure and acts as a check valve. If the pressure drops below a specified level, the valve shuts off flow to the nozzle. The CFV is usually fitted after the trigger mechanism and before the nozzle. CFVs are available in 1.0, 2.0 and 3.0 bar pressure and colour-coded according to pressure value. It is important to match the CFV thread type with the applicator thread type.

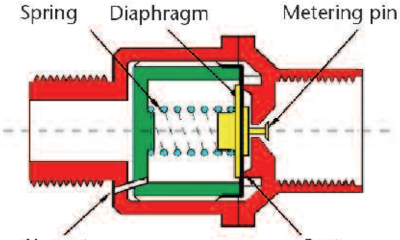

Figure 9

Constant flow valve.

NOZZLE MANUFACTURERS

The nozzles used during this evaluation are available from the manufacturers listed below. As indicated on page 4, this list of manufacturers is not comprehensive; similar products may be available from other manufacturers.

Hardi Ltd
www.hardi.co.uk

Hypro EU Ltd
www.hypro-eu.com

Sprays International
www.sprays.co.uk

TeeJet-LH Agro North Europe
www.mid-tech.com

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