6

Manually-operated hydraulic sprayers

Hydraulic-energy nozzles continue to be more widely used than the other types described in Chapters 8–11. Several new designs are now commercially available and add to the considerable flexibility which can be achieved by interchanging the tips in a standard nozzle body to provide a wide range of outputs and spray patterns at low cost. Hydraulic nozzles are used on a wide range of sprayers from a simple hand-syringe type to equipment mounted on aircraft. Hand-operated equipment is described in this chapter, power-operated equipment in Chapters 7 and 10, while aerial equipment is discussed in Chapter 13.

Sprayers with hydraulic pumps

Syringes

There are various types of simple syringe-type sprayers in which liquid is drawn from a reservoir into a pump cylinder by pulling out the plunger; the liquid is then forced out through a nozzle on the compression stroke. This type of sprayer has been replaced either by the double-acting slide pump or hand compression sprayer. A small syringe-type sprayer is useful for spot treatment, for example individual *Striga* plants can be killed in maize if there is a low infestation; a volume of 1 ml can be applied as a coarse spray to an area of 25 cm diameter. Some of these syringes have a simple means of adjusting the volume dispensed (Fig. 6.1). A syringe-type sprayer is also used to inject systemic insecticides into holes previously bored into trees.

The double-acting slide pump consists of a piston pump in which one valve is mounted at the inlet end of the cylinder, and a second valve is in a tube which is used as a piston. A handle grip is positioned on both the pump cylinder and piston. Holding the piston handle-grip firmly and moving the cylinder in and out continuously, while directing the nozzle, operates the pump. On the first

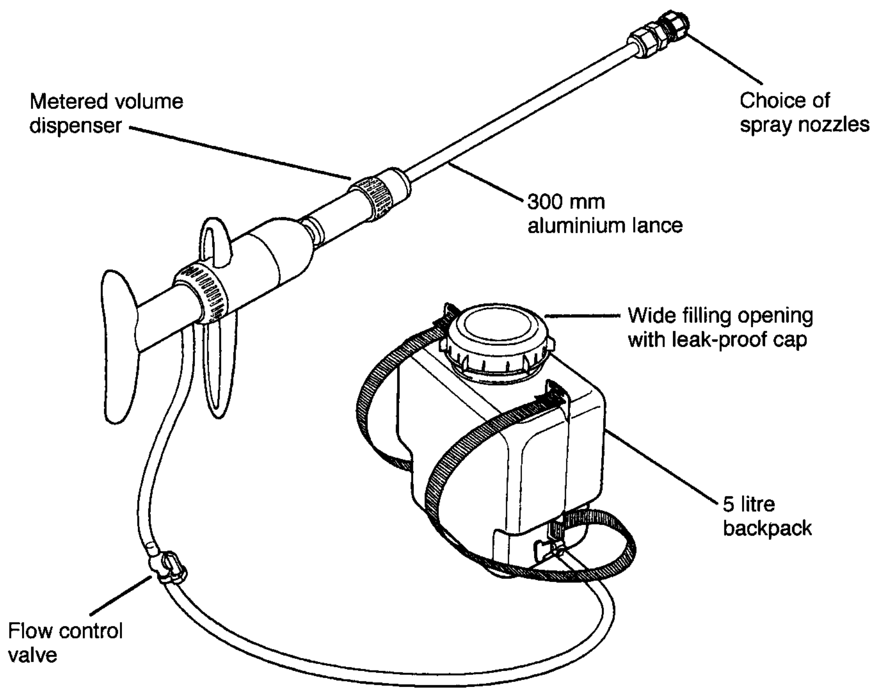

Fig. 6.1 Variable dose spot sprayer.

stroke, liquid from a separate container is drawn into the cylinder past the inlet valve, and on the return stroke, the inlet valve is closed and the liquid is forced past the second valve into the piston tube. The piston seal is usually a thick washer. If this is too tight in the cylinder, pumping effort will be excessive, and conversely, if too loose, pumping will be inefficient. An effective seal is also needed between the piston rod and end of the cylinder, otherwise spray liquid will leak over the operator's hands. A rubber stop between the cylinder and the piston handle-grip cushions the end of the pump stroke. The piston handle grip is usually enlarged to contain a small pressure chamber to even out the variation in pressure between strokes of the pump. A knapsack container or ordinary bucket can be used to contain the liquid, which must be kept stirred, especially if wettable powder suspensions are being applied. The delivery tube to the pump usually has a filter fitted at the inlet end.

Because of the narrow diameter of the pump cylinder (15–20 mm) and long stroke (25–40 cm), quite high pressures can be obtained with small nozzles. Output varies with the length of pump stroke, so syringes are not suitable for precise application of pesticide. Various types of hydraulic nozzles can be used, but these sprayers are often fitted with an adjustable cone nozzle. Both hands are required for operation, so the pump is very tiring to use, even when spraying is over a short period.

For small-scale home garden use, a 1 or 0.5 litre container with a trigger-operated pump is often suitable for intermittent operation. Continuous use is tiring.

Stirrup pump

This version of the double-acting pump requires two operators – one to work the pump while the other directs the nozzles. The lower end of the pump is immersed in the spray liquid in a bucket. The user needs to keep one foot on a footrest or stirrup on the ground next to the bucket while pumping. Ideally, the position of the stirrup can be adjusted to allow buckets of different depths to be used. Agitation is seldom provided, but on some sprayers there is a paddle agitator in the bucket which may cause splashing when the bucket is nearly empty. Agitation is also possible by recycling some of the liquid through a nozzle mounted at the lower end of the pump. The outlet of the pump is near the top and is connected to a hose, usually 6 m in length, with a lance, at the end of which any type of hydraulic nozzle may be fitted. Longer hoses are difficult to handle. Spraying is continuous because an air chamber is incorporated in the spray line, and on some models pressures up to 10 bar can be obtained fairly easily.

With stirrup pumps, great care has to be taken to avoid spillage of toxic chemicals as the liquid is in an open container. These pumps are strongly constructed and should withstand considerable wear in the field if properly cleaned after use. The pump may be a simple plunger type or a piston with a cup washer or gasket gland, which should be smeared with grease, especially if it is made of leather. Stirrup pumps have been used to treat apple orchards in India, but preference is now given to motorised portable line systems. In vector control, larvicides can be applied to the surface of water and to spray a residual insecticide on the wall surface of dwellings, but compression sprayers are now preferred. Specifications for a stirrup pump have been published by the World Health Organisation (WHO/EQP/3.R3). They have been used to apply molluscicides to water and, by removing the nozzle, can also be used to transfer liquids from a container to a sprayer.

Knapsack sprayers – lever-operated

The lever-operated knapsack sprayer (LOK) continues to be the most widely used small sprayer (Fig. 6.2). They were initially developed to treat vines with fungicides in the late nineteenth century (Lodeman, 1896; Galloway, 1891). A lever-operated sprayer consists of a tank which will stand erect on the ground and fit comfortably on the operator's back like a knapsack when in use, a hand-operated pump, a pressure chamber, and a lance with an on/off tap or trigger valve and one or more nozzles. FAO and some national Standards organisations have published specifications for this type of sprayer (FAO, 1998). Some aspects of these specifications are aimed at improving operator safety.

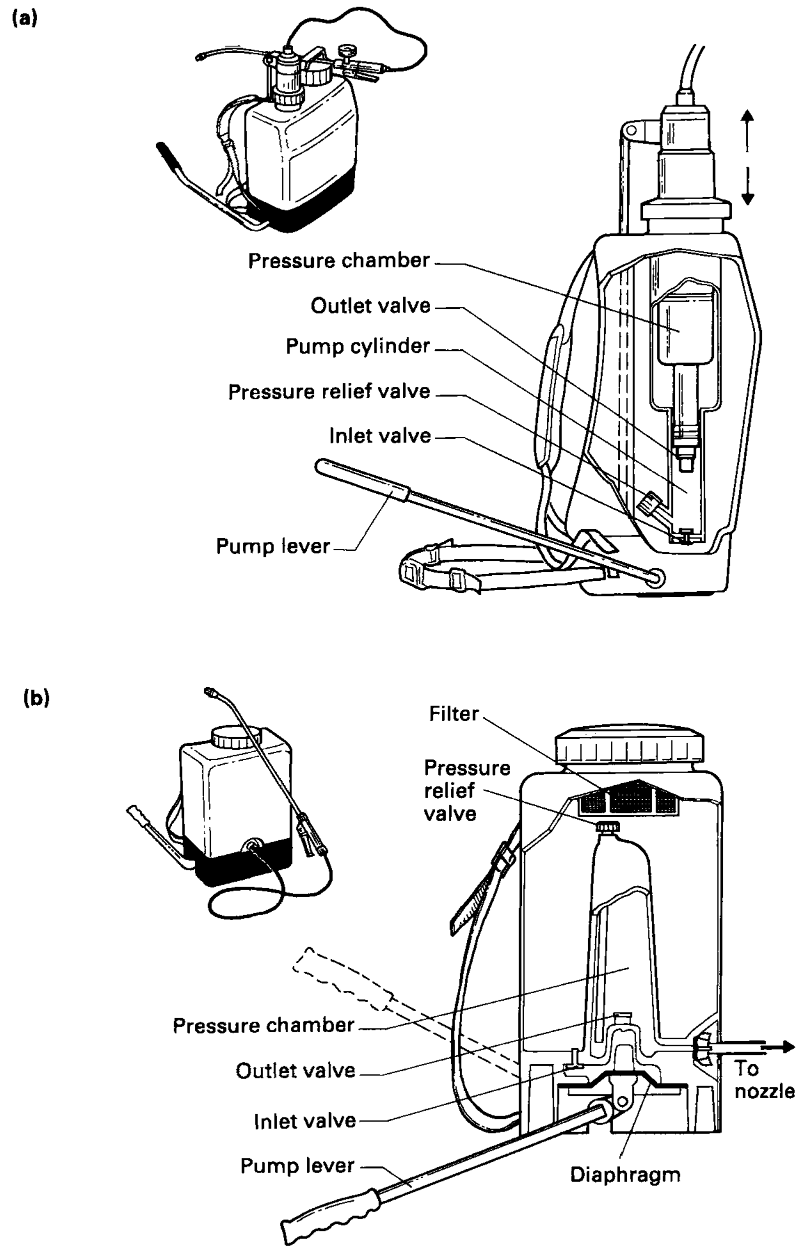

Fig. 6.2 Lever-operated knapsack sprayers: (a) piston type; (b) diaphragm pump type (courtesy: British Crop Protection Council).

The tank is now usually moulded from polypropylene or an alternative plastic that is extremely resistant to most of the agrochemicals used. To reduce the effect of sunlight on the plastic, a UV-light inhibitor is incorporated into the plastic. A few manufacturers can supply a tank made from brass or stainless steel. In Europe, regulations concerning the weight that can be lifted by a person limit the capacity of the tank; thus most tanks carry about 15 litres. Smaller 10 litre sprayers are also available. Plastic tanks can be moulded to fit the operator's back more comfortably than was possible with metal tanks. The design of the tank must avoid any outer surfaces that might collect spray liquid to which the user will be exposed. The volume of spray in the tank is usually indicated by graduated marks, moulded into the tank. To facilitate filling, the tank should have a large opening not less than 95 mm in diameter at the top. This large opening permits operators to put their gloved hands inside the tank if necessary for cleaning. The lid covering this opening must fit tightly. An air vent in the lid must have a valve to prevent any spray liquid splashing out and down the operator's back. When filling the tank, there should be a filter in the opening to remove particles that might damage the pump or block nozzles. The filter should be positioned deep inside the tank, so that liquid will not splash back on the spray operator. As some pesticides are now available in a water-soluble sachet or are formulated in a tablet, the filter should be designed to hold the pesticide while water is poured into the tank. The filter can have a mark to indicate the capacity of the tank to avoid the risk of over-filling. Some filters have a 50 mesh strainer, but most have a coarser mesh at this stage to allow rapid filling.

Lever-operated knapsack sprayers usually have an underarm lever, but some farmers prefer sprayers with an over-arm lever as this keeps the hand away from crop foliage; however, operating this lever for any length of time causes blood to drain from the arm and fatigue occurs very easily. There is either a piston or diaphragm pump (Fig. 6.2), which has to be continually operated at a steady rate. The piston pump is more common as higher pressures at the nozzle can be obtained, but some users prefer the diaphragm pump, especially when applying suspensions that may cause erosion of the piston chamber. The pump is operated by movement of a lever, which is pivoted at some point on the side of the tank. Many sprayers have the facility to change the lever from left- to right-arm operation.

To use the lever efficiently, the sprayer must fit comfortably on the operator's back so that the straps can be adequately tightened. Easily adjustable straps made of suitable rot-proof, non-absorbent material should be wide enough (40–50 mm) to fit comfortably over the shoulder without cutting into the neck. A waist strap is essential to reduce movement of the tank on the operator's back while pumping, and enable the load to be taken on the hips. Straps fitted with a hook to clip under the edge of the protective skirt of the tank tend to slide out of position easily, especially when the sprayer is not full, and are not recommended.

When using the sprayer, liquid is drawn through a valve into the pump chamber with the first stroke. With the return of the lever to the original position, liquid in the pump chamber is forced past another valve into a pressure chamber. The first valve between the pump and the tank is closed during this operation to prevent the return of liquid to the tank. A good seal between the pump piston and cylinder is obtained by a cup washer or 'O' ring. Abrasive materials suspended in the spray will cause excessive wear of the pump, also the chemicals in some formulations cause the seal to swell and prevent efficient operation of the pump. Air is trapped in part of the pressure chamber and compressed as liquid is forced into the chamber. This compressed air forces liquid from the pressure chamber through a hose to the nozzle. The size of the pressure chamber varies considerably on different types of knapsack sprayers (160–1300 ml), but should be as large as possible and at least ten times the pump capacity. Considerable variations in pressure will occur with each stroke if the capacity of the pressure chamber is inadequate, but even with a pressure chamber strongly constructed to withstand these fluctuations in pressure, a small variation in pressure occurs while spraying unless a pressure regulating valve is fitted to the lance.

The valves on each side of the pump can be either of a diaphragm type or a ball valve. Some operators prefer the ball valve, which is usually made of polypropylene. Pitting of the side of the ball valve or collection of debris in the ball-valve chamber may cause the liquid to leak past the valve. Also, the ball valve is easily lost when repairs are carried out in the field. The alternative is a diaphragm valve, made of various materials such as synthetic rubber (e.g. Viton) or certain plastics. The chemicals, or more often the solvents, used in some formulations can affect the material and cause the valve to swell up. This causes the valve to stick and block the passage of liquid through the pump unless there is adequate space for the diaphragm valve to move. With many knapsack sprayers an agitator or paddle is fitted to the lever mechanism, or directly to the pressure chamber, to agitate the spray liquid in the tank. On a few sprayers, part of the pump's output is recirculated into the tank to provide agitation. Agitation has been essential when spraying certain pesticides to reduce settling of particles inside the tank, which can occur rapidly with some wettable powder formulations. The pressure chamber and pump are fitted outside the tank of some sprayers to facilitate maintenance, but they are more vulnerable to damage if the sprayer is dropped. The pressure chamber may be fitted with a relief valve so that the operator cannot over-pressurise it. This should not be used as a pressure control valve and should be touched only when the tank is empty and clean.

To start spraying with a lever-operated knapsack, the lever is moved up and down several times with the trigger valve closed, so that pressure is built up in the pressure chamber. The trigger valve is opened and the operator continues to pump steadily with one hand while spraying. Inevitably there are variations in pressure at the nozzle unless a regulating valve is fitted adjacent to the nozzle or trigger valve. Several designs of regulator are available and of these the constant flow valve is the lightest (Fig. 6.3) (McAuliffe, 1999; Eng *et al.*, 1999). It operates at a set pressure so that the user cannot adjust the output in the field. Different versions are available to provide 1, 1.5, 2 and 3 bar

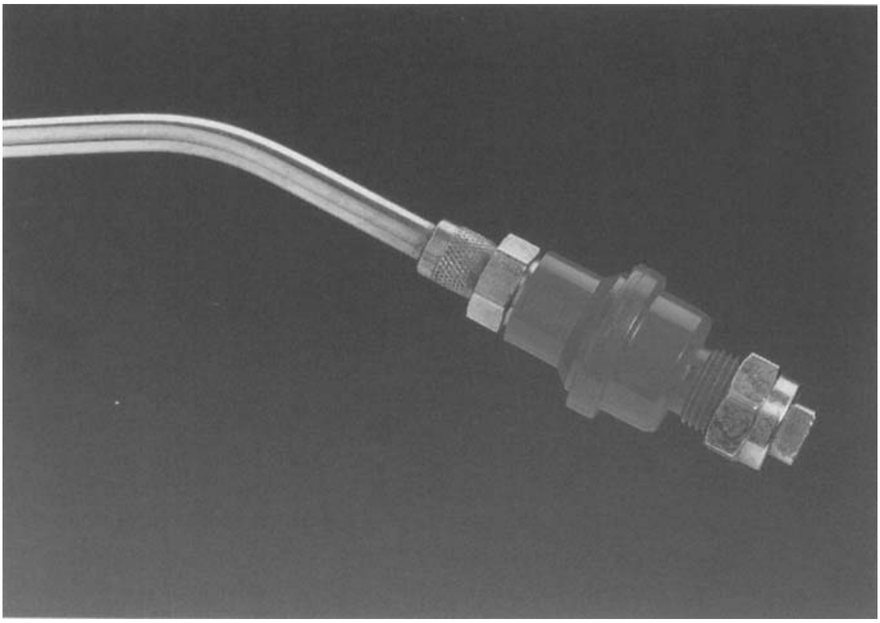

Fig. 6.3 Control flow valve (Global Agricultural Technology Engineering).

operating pressures. The lowest pressure is required where spray drift must be avoided, whereas the 3 bar version is intended for applications where a higher pressure is recommended. The 1.5 and 2 bar control flow valves provide a compromise suitable in many circumstances for either herbicide, fungicide or insecticide application. On some vertical spray booms it may be useful to fit a low pressure control flow valve near the top of the crop to minimise drift, yet have a higher pressure valve close to the bottom of a crop canopy to obtain better coverage.

Most lever-operated knapsack sprayers are fitted with a simple lance with usually one, but sometimes two, nozzles at the end. Continuous operation of the lever makes it difficult to direct the lance precisely at a target, so in certain circumstances the compression sprayer is preferred. A major problem is that the operator tends to walk towards where he is directing his spray and then through foliage which has been treated, thus becoming contaminated with pesticide, particularly on the legs (Tunstall and Matthews, 1965; Sutherland *et al.*, 1990; Thornhill *et al.*, 1996; Machado-Neto *et al.*, 1998). On various occasions, therefore, adaptations on the knapsack sprayer have been developed either to improve safety, obtain a better distribution of spray droplets or to increase the speed of spraying.

An example of this is the fitting of wide-angle nozzles onto the back of the spray tank for treating rice crops so that the operator walks away from the spray (Fernando, 1956). Pairs of nozzles are used on the tailboom (Fig. 6.4) as the plants increase in size, so that good distribution is achieved throughout the

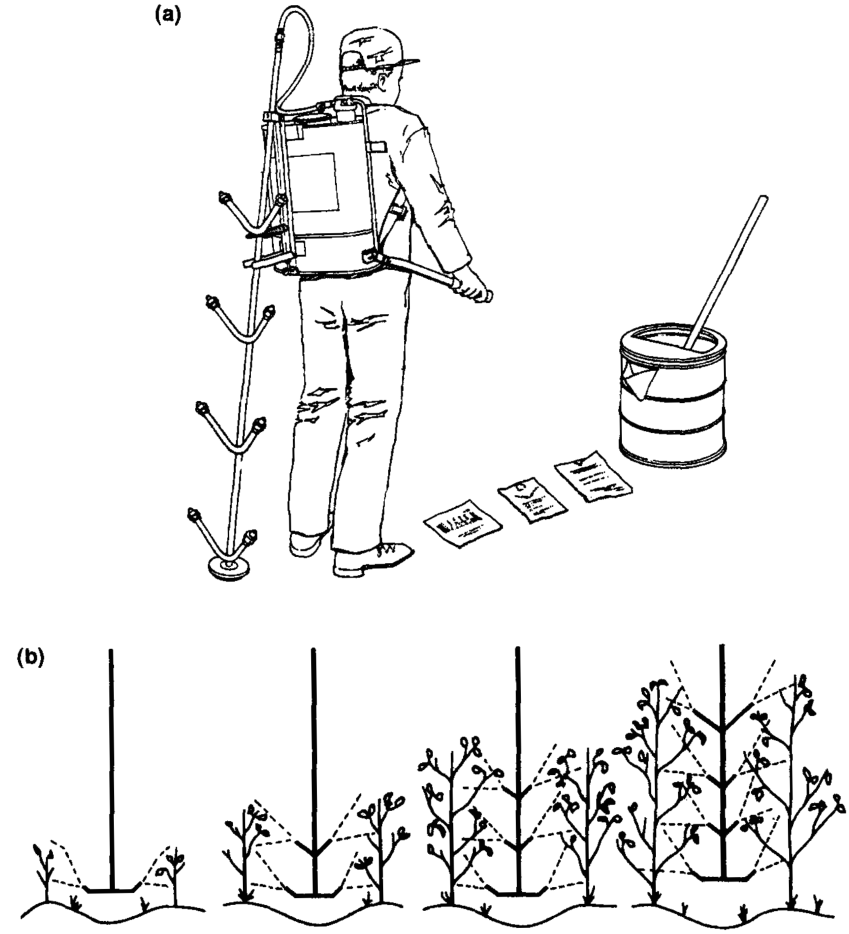

Fig. 6.4 (a) Knapsack sprayer with tailboom for spraying cotton. (b) Variation in the number of nozzles with plant height.

crop canopy (Tunstall *et al.*, 1961, 1965). By angling the nozzles upwards, underleaf coverage is increased, thus improving control of insects and pathogens located there, including whiteflies. A tailboom has also been used to spray coffee. To improve the speed of spraying, a horizontal boom has been developed for spraying more than one row of cotton at a time (Cadou, 1959), and for applying fungicides to groundnuts (Johnstone *et al.*, 1975).

In addition to the conventional lance, some sprayers have a short boom with two or three nozzles fitted to the end of the lance. Extendable lances made of bamboo, glass-reinforced plastic (GRP), carbon fibre or aluminium may be used to spray trees up to about 6 m in height. A gooseneck at the end of a lance is useful for spraying some inaccessible sites; similarly, other specialised nozzle arrangements have been used to spray special targets such as pods resting on stems of cacao trees. The nozzles may be shielded so that herbicide sprays can be applied close to a susceptible plant or tree.

The design and efficiency of operation of trigger valves on lances vary considerably. The handle should fit comfortably in the operator's hand, so that the valve is easy to operate. A clip mechanism to hold the valve open for prolonged spraying is useful, provided it can be released easily. Ideally there should be a clip to hold the valve closed when not in use. Unfortunately, many valves leak, particularly after abrasive particles have been sprayed, so that regular maintenance of the valve seating is needed with replacement springs. Hall (1955) has described a test procedure for trigger valves (WHO, 1990).

Some commercially available lever-operated sprayers are strong enough only if used for short periods and frequently leak. In an assessment of sprayers in Malaysia, nearly half the knapsack sprayers leaked (Cornwall *et al.*, 1995). When crops require several treatments, a farmer requires a robust sprayer. Mechanised durability tests can be carried out to assess whether the pump mechanism will operate without any problem for at least 250 hours (Matthews *et al.*, 1969; Thornhill, 1982). The main faults have been poor linkage, inadequate strength of the lever, poor design or strength of certain components such as strap hangers, and the poor capacity and design of the pumps.

The performance of lever-operated sprayers has been recorded in the field by using a small portable recording pressure gauge. Comparison of number of strokes required to maintain various outputs and pressures can be a useful guide to the efficiency of the different sprayers commercially available (Matthews, 1969; Thornhill, 1985). To avoid the drudgery of manual pumping, there are now motorised versions, and some have an electrically operated pump powered by a rechargeable battery. Field workers preferred the latter in trials in plantations in Malaysia (Fee *et al.*, 1999).

Stretcher and other sprayers

Stretcher sprayers are seldom used now. They have rather heavy piston pumps, which are operated by hand by a rocking motion of a long handle or by a foot pedal. A very strong pressure chamber with the pump allows pressures up to 10 bar or more to be obtained. They are normally operated in one position with one or more hoses up to about 14 m in length to supply lances to which various hydraulic nozzles are fitted. A separate spray container is needed and has to be carried separately from the pump. Two people are needed to carry the pump and operate it, while two or more others are needed to handle the lances. Stretcher sprayers have been most useful for spraying large or tall trees or widely spaced bush crops. Similar sprayers are sometimes mounted on a wheelbarrow frame, together with a spray tank.

Compression sprayers

Compression sprayers have an air pump to pressurise the spray tank, which is never completely filled with liquid. Space is needed above the liquid so that air can be pumped in to create pressure to maintain the flow of liquid to the nozzle. Usually, a mark on the side of the tank indicates the maximum capacity of liquid at about two-thirds of total capacity. These sprayers vary in size from the small hand sprayers, suitable for limited use by gardeners, to large shoulder mounted sprayers usually of 10 litre capacity. Some may be carried as a knapsack. As no agitation is provided, these sprayers need to be shaken occasionally if using wettable powder formulations to prevent the suspension settling out.

Hand sprayers

A small tank usually made of plastic and of 0.5–3 litres capacity is pressurised by a plunger-type pump to a pressure of up to 1 bar (Fig. 6.5). Often a cone nozzle, the pattern of which can sometimes be adjusted, is fitted to a short delivery tube. The on/off valve is sometimes a trigger incorporated into the handle. Hand sprayers are useful for spraying very small areas where it is inconvenient to pump continuously.

Fig. 6.5 Hand-carried compression sprayer.

Shoulder-slung and knapsack compression sprayers

There were two types – the ordinary and pressure-retaining types – but use of the latter has been discontinued due to their weight and necessity for routine testing of the strength of the tank. There are a large number of non-pressure retaining compression sprayers with which the air pressure is released before refilling the tank with liquid.

The compression sprayers (Fig. 6.6) are pressurised by pumping before spraying commences, in contrast to the continuous pumping needed with

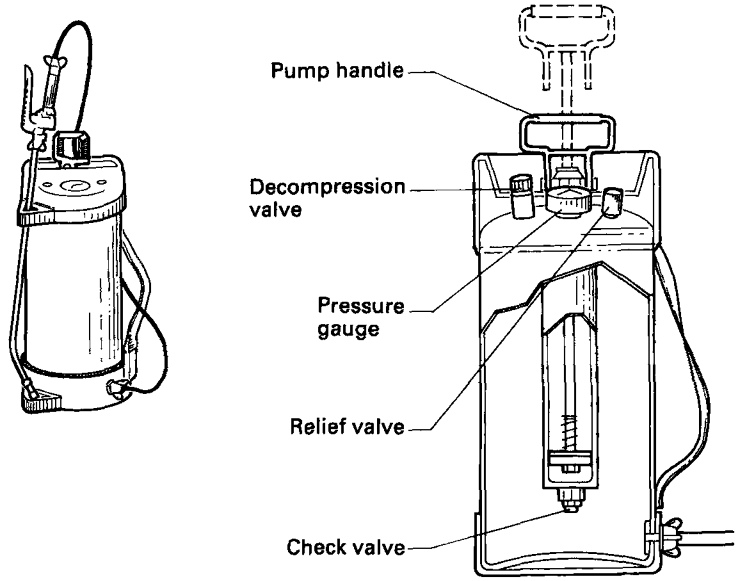

Fig. 6.6 Compression sprayer (courtesy: British Crop Protection Council).

lever-operated sprayers. This allows the operator to give more attention to directing the nozzle at the correct target. The pump is screwed in as part of the lid of the tank on the simpler and cheaper compression sprayers. The action of screwing the pump into the tank before each pressurisation can damage the threads, so limiting the life of the sprayer. Another problem with this design is that when the pump is removed to refill the tank, it can contaminate the surface on which it is placed and may transfer dirt into the tank when it is replaced. The tank lid and pump are separate on the more durable designs of compression sprayer. Ideally, this type of sprayer should be fitted with a pressure gauge so that the operator knows what pressure is in the tank. A pressure gauge may not be provided, in which case the operator is instructed to pump a given number of strokes to achieve the working pressure. Some sprayers have a safety valve which releases excess pressure if the operator pumps too much.

When using a compression sprayer, the tank pressure decreases very rapidly as soon as the operator starts spraying. Operators may have to stop and repressurise the tank before they can discharge the total contents from it. With the decrease in pressure at the nozzle while spraying, the output will decrease (Fig. 6.7) and droplet size will increase. To apply a pesticide more uniformly, it is essential to fit a pressure-regulator or constant flow valve to the tank outlet or lance. After use, the whole sprayer must be cleaned with water and the pump used to flush liquid through the valve and nozzle, so that any particulate formulation does not dry out inside and cause a potential blockage when the sprayer is used again.

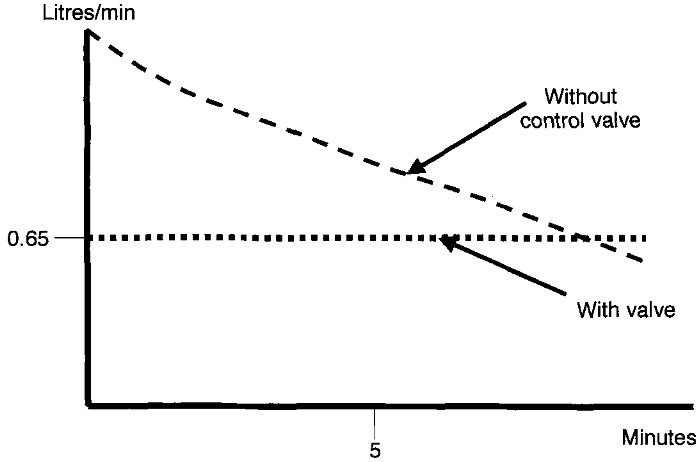

Fig. 6.7 Compression of nozzle flow rate from a compression sprayer with a control flow vale and without a valve.

On some occasions, some pressure may still be inside the tank when the operator has discharged the spray liquid and needs to refill the tank. This is released on the first quarter turn of the lid or pump, when a hissing sound indicates the escape of air. On some sprayers, the lid cannot be moved until a valve is activated to release the pressure. The valve is either in the lid or on the top of the tank. The tank expands and contracts slightly during normal operation. To assess the durability of the tank, this is simulated by pressurising the tank to 4.5 bar for 11 seconds, releasing the pressure and then repeating this for 12 000 cycles. The sprayer must be completely filled with water during this test. Further tests at 7 bar are usually carried out after dropping the sprayer in set positions to detect any weakness caused by the drop tests (Hall, 1955). Manufacturers should not use rivets in metal tanks used as compression sprayers, although one particular version has a strengthening bar that is held in place by two rivets. Some people may feel that plastic tanks will not be as strong as metal tanks but, in general, blow-moulded plastic tanks so far tested can stand pressures in excess of 7 bar, which is usually far above that obtained with the hand pumps provided with the equipment. Degradation of the plastic in sunlight (or UV light) has occurred, possibly by interaction with pesticides impregnated on the tank wall. The strength of these tanks is thus impaired. The base of the tank is usually provided with a skirt for protection against wear and also to enable the sprayer to stand firmly on the ground. On some sprayers, a footrest is attached to the skirt to assist pumping. The skirt serves as a backrest on some sprayers and is the lower fixing point for straps.

As with the lever-operated sprayers, the sprayer should have as large a tank opening as possible to facilitate filling. This has become more important where a pesticide is provided in a water-soluble sachet, so that the sachet can be put easily into the tank. A wide lid also allows operators to put their gloved hands through the opening and clean the inside of the tank. Unfortunately, very few of the sprayers of this type have an adequately wide tank opening.

The hose outlet is often at the base of the tank to avoid leaving any liquid inside and to eliminate a dip tube inside the tank, but this hose nipple is often broken when the sprayer is accidentally dropped. The better types of compression sprayers have the hose opening at the top of the tank and a clamp is also provided to hold the lance when not in use. When the lance is left to trail in the mud while the sprayer is being refilled, the possibility of nozzle blockages is increased. Thornhill (1974a) has described the adaptation of a container used for dispensing soft drinks as a compression sprayer.

Compression sprayers (Fig. 6.8) have been widely used on farms and also in vector-control programmes. WHO specification WHO/EQP/l.R4 was developed to ensure that reliable equipment was used to spray a residual deposit of insecticide on walls to control mosquitoes (Fig. 6.9). The standard technique recommended by WHO for indoor residual spraying was to apply 757 ml/min through an 8002 fan nozzle when operated at 2.8 bar. Unless a pressure regulator is fitted, the working pressure decreases from 3.8 to 1.7 bar (Brown *et al.*, 1997). Normally, the sprayer is charged initially to at least 3.8 bar with about fourteen pump strokes per bar (one stroke for each p.s.i.) and usually needs repressurisation once during a 10 min period to discharge 7.5 litres. The lance is held 45 cm from the wall and moved at a steady speed of 0.64 m/s up and down the walls, covering a 75 cm swath (with 5 cm overlap) each time. The same technique has been used for a number of different insecticides. If a constant flow valve at 2 bar is used, apart from more uniform spraying, the decrease in output from 757 to 650 ml/min allows a longer time for spraying per sprayer load (Fig. 6.7).

The same type of sprayer has been used to apply larvicides, but a solid stream or cone nozzle is used instead of a fan nozzle. An experienced sprayman using a solid-stream nozzle with a 'swinging wand' pattern can treat an 8–10 metre swath when walking at a steady 2 m/s. The nozzle is pointed above the horizontal so that the liquid trajectory reaches a maximum distance. If it is pointed down at the water surface there will be localised overdosing. The jet from the nozzle breaks up into a band of droplets, which overlap with each swing of the lance. The solid-stream nozzle is also useful when directing spray into cracks and crevices in houses so that an insecticide is deposited in the resting sites of cockroaches and other household pests. A cone nozzle is used if a wider band of spray is needed on irregularly shaped objects in areas such as at the backs of sinks and boilers.

Pressure-regulating valve

Apart from the control flow valves referred to above, there are adjustable pressure-regulating valves suitable for use on knapsack compression sprayers; they differ from that used on powered equipment in that there is no by-pass

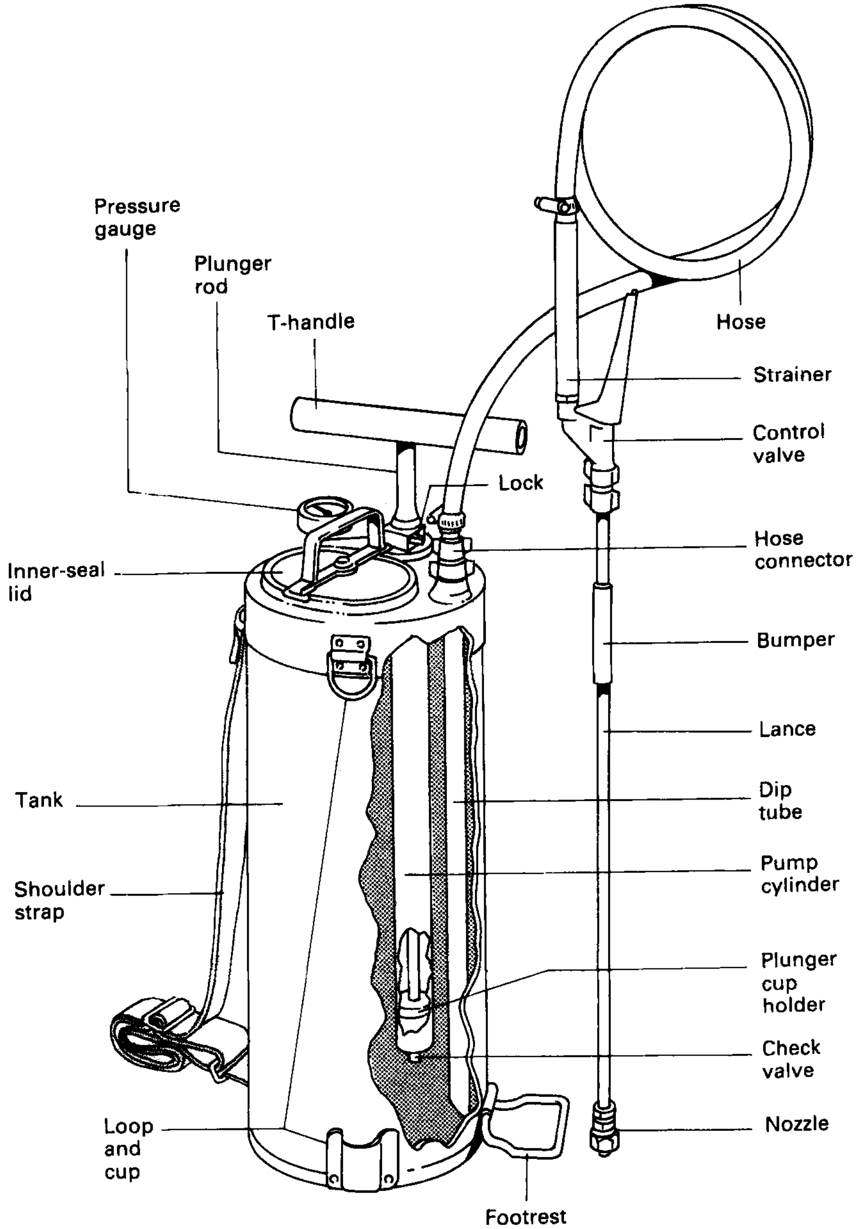

Fig. 6.8 Compression sprayer to meet WHO specification (courtesy: H.D. Hudson Manufacturing Co.).

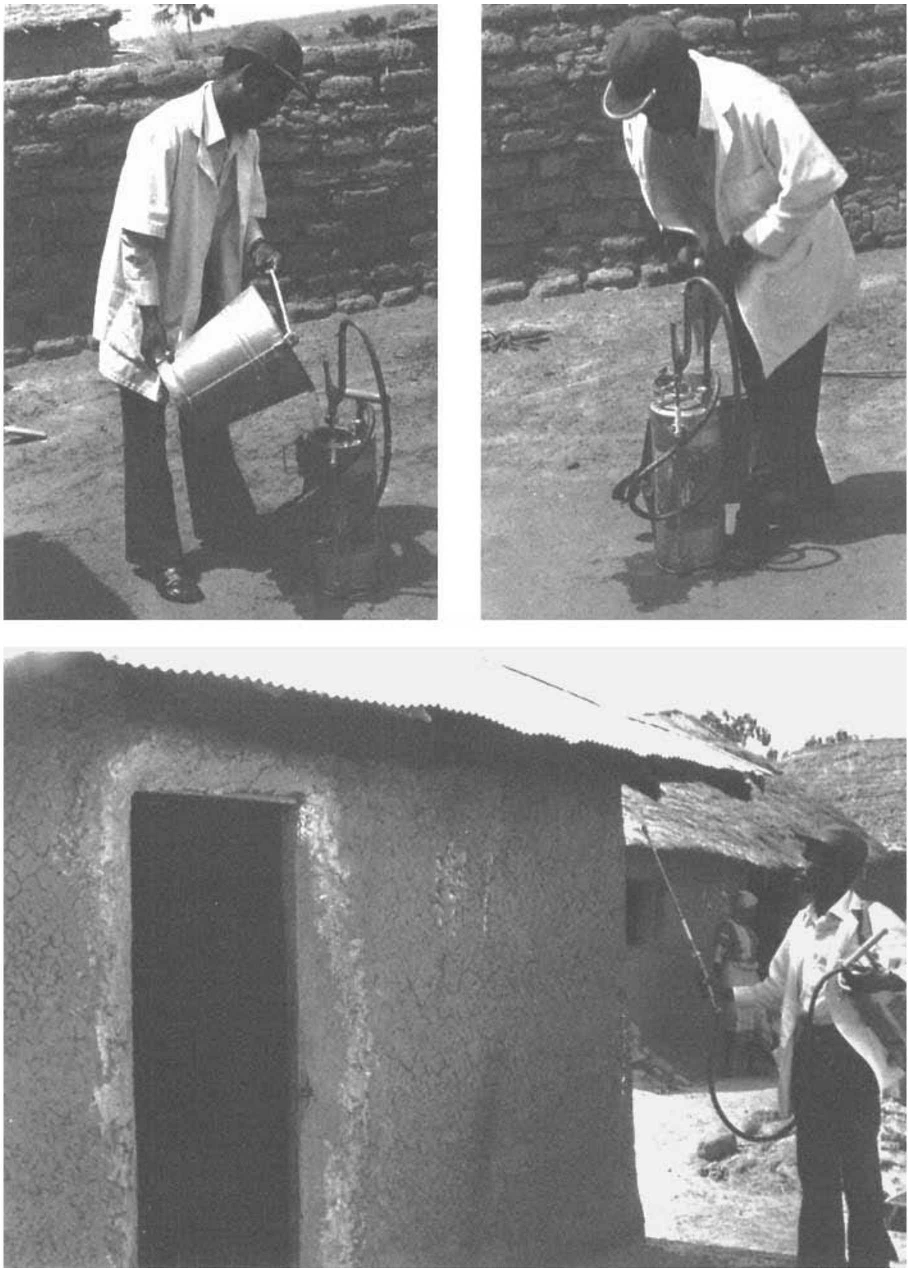

Fig. 6.9 Residual spraying against mosquitoes in dwellings (photos: R. DaSilva, WHO).

return to the spray tank. The valve consists of a diaphragm, the movement of which is effected by a spring. The tension of the spring can be adjusted by means of a screw so that output pressure can be varied from 0.71 to 4 bar, irrespective of the input pressure, which can be up to 18 bar. The main problem with an adjustable valve is that the user is never sure what the output pressure is unless there is also a reliable accurate pressure gauge on the lance.

Calibration of knapsack sprayers

The label of the pesticide should be examined to see if a volume application rate, spray quality, nozzle or spray concentration is recommended. The desired nozzle is selected and its output measured during 1 minute. When using lever-operated sprayers, a control flow valve, or alternatively a 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 practise before achieving an even pumping rate. Having determined the output from the nozzle in litres/min, the rate per unit area treated can be calculated, knowing the swath width and walking speed.

$$\frac{\text{Output (litres/min)}}{\text{Swath (m)} \times \text{Speed (m/min)}} = \text{Volume application rate (litres/m}^2\text{)}$$

Thus with a swath of 1 m, walking at 60 m/min and a flow rate of 0.6 litres/min, the volume of spray per square metre is

$$\frac{0.6 \text{ litres/min}}{1\,\text{m} \times 60\,\text{m/min}} = 0.01 \text{ litres/m}^2 \quad \text{or} \quad \times\, 10\,000 = 100 \text{ litres/ha}$$

Alternatively, if you measure speed in km/h, then

$$\frac{600 \times \text{Output (l/min)}}{\text{Swath (m)} \times \text{Speed (km/h)}} = \text{Volume application rate (litres/ha)}$$

Thus if your flow rate is 2.2 litres/min over a 1.7 m swath and your speed is 3.8 km/h, then your application rate is 204 litres/ha.

If the application rate is incorrect, other nozzles should be tried. When the most suitable nozzle has been selected, the volume applied can be rechecked by measuring the distance walked and time taken to spray a known quantity. For example if a full tank load of 15 litres is applied in 25 minutes, the output is 0.6 litre/min which checks against the earlier calibration, the volume per hectare being given by

$$\frac{15 \times 10\,000\,\text{m}^2 \text{ (i.e. 1 ha)}}{\text{Distance travelled (m)} \times \text{Swath width (m)}} \times \text{Application rate (litres/ha)}$$

If the distance travelled was 1.5 km with a swath of 1 m, the application rate was 100 litres/ha. When the output is low, the sprayer can be calibrated more quickly by using a smaller volume in the tank.

Some manufacturers supply a calibrated container (Fig. 6.10) which can be fitted to the nozzle so that the spray is collected while treating a known area

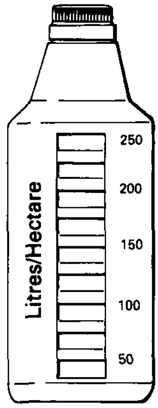

Fig. 6.10 A calibrated bottle to assist calibration of knapsack sprayers.

($25\,m^2$). This method is particularly useful when training teams of spray operators, because individuals can see their own output and adjust their speed of walking or rate of pumping to get the required output.

Another method is to measure the time to walk 100 metres and the swath width, then measure the output of the sprayer for the same time that it took to walk 100 metres. Then the volume per hectare is the output in millilitres divided by the swath width (m); then divide answer by ten.

Handymist sprayer

In China, Tu (1990) designed a lever-operated sprayer with an air pump. The sprayer is essentially a compression sprayer but, in addition to pressurising the liquid, some of the air is fed to a single twin fluid nozzle. The manually operated sprayer provides an inexpensive means of applying a very low volume mist sprayer and has been used to spray insecticides on rice and cotton. The sprayer has not been widely used.

Disposable container dispenser

A disposable container dispenser (DCD) was designed to fit manually operated sprayers, so that only water is put in the lever-operated knapsack or compression sprayer container (Craig *et al.*, 1993). When the water passes through a specially designed trigger valve that incorporates a flow control, pesticide is metered into it at a set dilution rate. The aim was to reduce exposure of the operator to the pesticide as there was no longer a need to measure out small quantities of pesticide product to put in the sprayer. However, the design was not suitable for all pesticide formulations and the container could not be rinsed after use. The intention was to return the container for refilling, but this has not been adopted by the chemical industry.

Peristaltic pump

Liquid is forced through a piece of rubber of plastic tubing by progressive squeezing along the wall of the tube. A peristaltic pump, operated by rotating cams, attached to the wheel of a small sprayer can be used to deliver small volumes to individual nozzles.