Pesticide Application

Compiled by

S.K. Pal and S.K. Das Gupta

Skill Development Series no. 17

ICRISAT

Training and Fellowships Program

International Crops Research Institute for the Semi-Arid Tropics
Patancheru 502 324, Andhra Pradesh, India

1996

Pesticide Application

Compiled by

S.K. Pal and S.K. Das Gupta

Skill Development Series no. 17

ICRISAT

Training and Fellowships Program

International Crops Research Institute for the Semi-Arid Tropics
Patancheru, Andhra Pradesh 502 324, India

1996

Training and Fellowships Program

Publications in this Skill Development Series (SDS) are issued semiformally for limited distribution to program participants, colleagues, and collaborators. Copies may be requested by the SDS number. Constructive criticism from readers is welcomed by: Program Leader, Training and Fellowships Program, ICRISAT. Contributors for this issue are Mr. S.K. Pal, Manager, Plant Protection, Farm Engineering and Services Program, and Dr. S.K. Das Gupta, Senior Training Officer, Training and Fellowships Program.

Acknowledgments

Information presented in this document has been taken from published and unpublished reports. Efforts have been made to indicate trade names (®) where available. Omissions or inclusions of a trade name does not constitute endorsement or discrimination of a product by ICRISAT or the compilers. This publication should not be cited as a reference.

Comments and suggestions from Mr D.S. Bisht and Mr C. Ram Reddy, and Mr V.S.R. Das for compiling this document are gratefully acknowledged. Thanks to Ms Smitha Sitaraman, Mr S.V. Prasad Rao and Mr A. Vasanth Reddy for editing and processing this publication.

Contents

Plant Protection Equipment 1

Different Types of Plant Protection Equipment Generally Used 1
Selection and Use of Spraying Equipment 1

Pesticide Application Techniques 3

Commonly Used Spraying Equipment 5

1. Hand-operated Hydraulic Sprayers 5
2. Power-operated Hydraulic Sprayers 7
3. Air Carrier Sprayers (Mist Blowers) 9
4. Electrodyne Sprayer (Electrostatic Sprays) 9
5. The Birky Sprayer 10
6. Controlled-droplet Application (CDA) Sprayers 10
7. Dusters 12

Different Types of Nozzles and their Main Uses 13

Maintenance and Safe Handling of Equipment 19

Storage of Equipment 20

Hints for Trouble-shooting 21

Safety Precautions 25

Suggested Books for Reading 30

Plant Protection Equipment

Selecting the right equipment for pesticide application is important for successful pest control. The correct usage of equipment and its proper maintenance are important factors which affect the ability to place pesticides on target more economically and effectively. The choice of equipment depends on its specific use and the need of a particular pest control measure.

Different Types of Plant Protection Equipment Generally Used

- Hand sprayers and atomizers
- Hand compressed sprayers
- Knapsack sprayers
- Tractor-mounted sprayer
- Motorized knapsack mist blowers
- Ultra low volume or controlled-droplet applicators (ULV/CDA)
- Fogging machines/fogair sprayers
- Hand-carried dusters
- Hand-carried granule applicators
- Power dusters
- Aerial application (Aircraft sprayers)
- Injectors and fumigation equipment.

Selection and Use of Spraying Equipment

Spraying equipment (Fig. 1) should be selected on the basis of:

- frequency of pesticide application,
- availability of diluent (water, oil, kerosene, etc.),
- availability of labor (human or animal power),
- area requiring treatment,
- characteristics of area (machine equipment for large areas, hand-operated equipment for smaller areas),
- durability of equipment,
- cost of equipment,
- availability of after sales service,
- operating cost, and
- speed required to treat an area (this will depend on type of crop, stage of crop growth, and volume of spray solution to be applied).

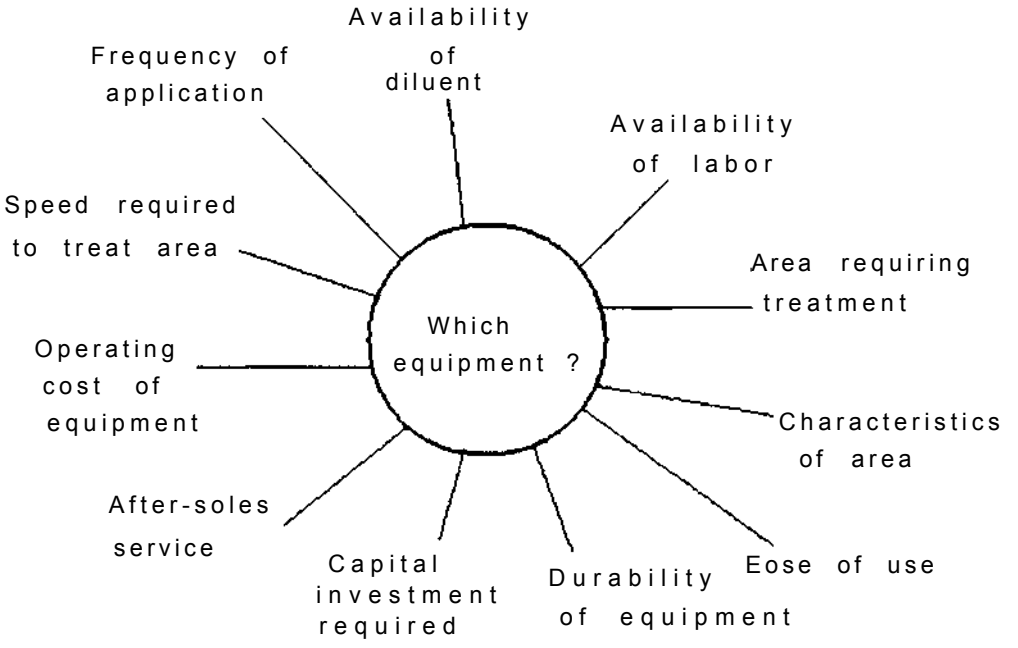


Figure 1. Factors governing the selection of spraying equipment.

Pesticide Application Techniques

The methods used to apply agricultural chemicals on crops and herbicides on weeds or on soil, are known as application techniques (Fig. 2). Appropriate dosage and even distribution of spray droplets on a target area are of paramount importance (Fig. 3 and 4). Chemicals are used in doses ranging from 100 g or less to as high as a few L and kg ha^{-1}. Carriers or diluents are mixed with chemicals to ensure even distribution. The most important diluent-carrier is water. When used as a pesticide carrier, its volume should be varied with the method of application (Table 1).

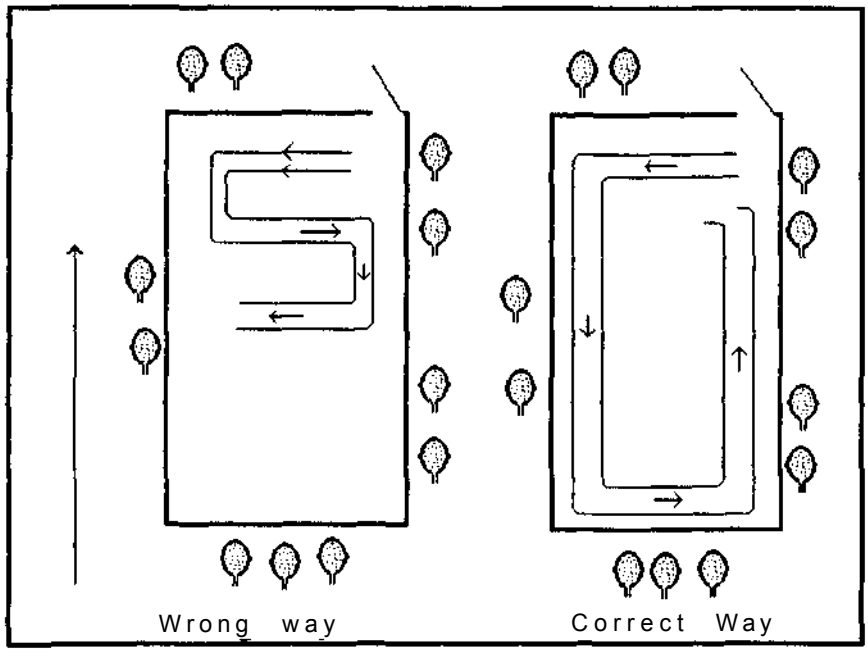


Figure 2. The correct and wrong ways of spraying.

Table 1. Volume of water or any diluent carrier at flowering stage.

Volume	Field crops (L ha^{-1})	Trees and bushes (L ha^{-1})
High volume (HV)	>600	>1000
Medium volume (MV)	200-600	500-1000
Low volume (LV)	50-200	200-500
Very low volume (VLV)	5-50	50-200
Ultra low volume (ULV)	<5	<50

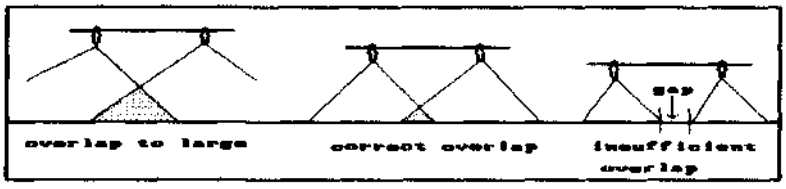


Figure 3. Overlap of spray swath.

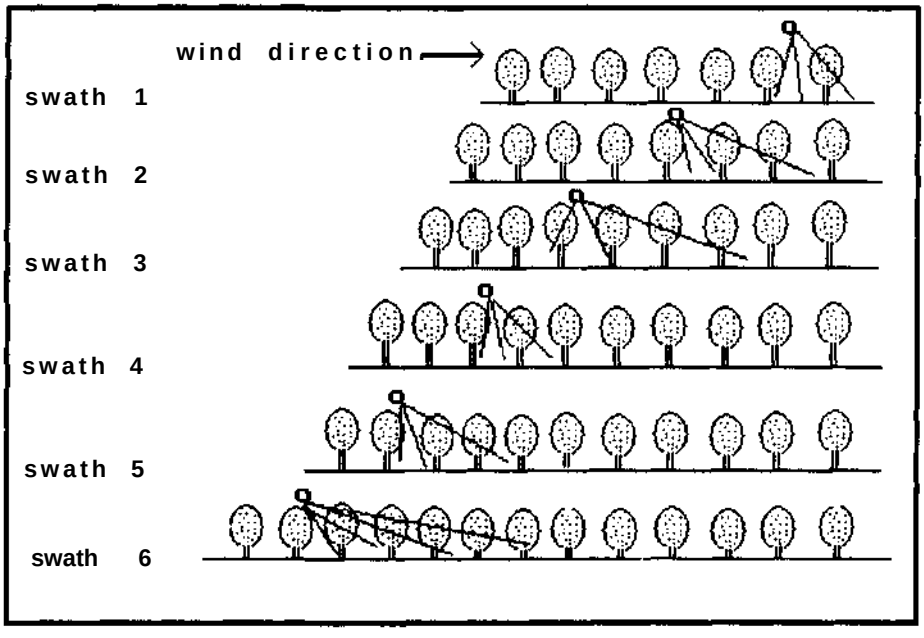


Figure 4. Overlapping of swaths as the operator moves upwind across a field.

The efficacy of a pesticide in any application technique is mainly influenced by the following three factors:

- Mean level of deposit (dosage): This refers to the total amount of toxicant (active ingredient) used in treating a unit of the target area;

- Distribution of deposit: The surface of the leaf may be completely covered by a chemical (active ingredient) deposit in the case of runoff (high volume) spray, but the deposit may be unevenly distributed; and

- Wetting agents tend to decrease droplet size and increase spreads, and low-volatility carriers help prevent the evaporation of small droplets (low and ultra low volumes) and ensure better distribution.

Importance of Droplet Size

Droplet size plays a very important role in pesticide application by minimizing environmental contamination. Pesticide sprays are generally classified according to droplet size. When drift is to be minimized, a medium or coarse spray is required irrespective of the volume applied (Table 2).

Table 2. Classification of sprays according to droplet size.

Volume medium diameter of droplet (µm)[1]	Classification of droplet size
<50	Aerosol
51 - 100	Mist
101 - 200	Fine spray
201 - 400	Medium spray
>400	Coarse spray

1. The most widely used parameter of droplet size is volume medium diameter (Vmd) which is measured in micrometers (µm). 1 mic = 1/1000 mm.

Commonly Used Spraying Equipment

1. Hand-operated hydraulic sprayers (knapsack sprayers)
2. Power-operated hydraulic sprayers (tractor-mounted sprayers)
3. Air carrier sprayers (mist blowers)
4. Electrodyne sprayers (electrostatic sprayers)
5. Birky sprayers (Birky knapsack sprayers)
6. Controlled-droplet application sprayers
7. Dusters

1. Hand-operated Hydraulic Sprayers

These sprayers are the most widely used. They are small and compact e.g., knapsack and hand compressed sprayers.

Knapsack sprayers (lever operated)

The lever-operated (piston/diaphragm type) knapsack sprayer is one of the most commonly used sprayers. In this equipment, liquid is drawn through a valve into a pump chamber with the first stroke. When the lever returns to its original position, the liquid in the pump chamber is forced past another valve into a pressure chamber. The valve between the pump and the tank is closed during this operation to prevent the return of the liquid into the tank. A good seal between the pump and cylinder is obtained by a 'cup washer' or 'O' ring. As liquid is forced into the chamber, air is trapped in a part of the pressure chamber and compressed. This forces the liquid from the pressure chamber through a hose into the nozzle. Compression sprayers, hand sprayers, and shoulder-slug compression sprayers fall under this category.

Calibration of spraying equipment

To achieve good results from spraying, the sprayer must be clean and in working condition. It must be calibrated before every major spraying operation so that the exact quantity of spray is delivered on the target, which may be plants in the case of insecticide application or soil in the case of herbicides.

The volume of application depends on the:

- droplet size the sprayer can deliver (depending on the size of the orifice of the nozzle tip),
- surface area to be sprayed/applied,
- weather conditions,
- pesticide formulations (EC, WP)
- availability of diluent,
- spraying pressure (maintain uniform pressure throughout the operation),
- uniform spray swath, and
- speed of an operator/tractor: maintaining a tractor's or operator's (in the case of manual operation) constant forward speed is essential.

Calibration of knapsack sprayers (refer to SDS no. 15 - Pest Control)

a. Rinse and clean the sprayer.
b. Determine nozzle discharge (by selecting a nozzle) in L min^{-1} at known pressure (V).
c. Calculate the walking speed of the operator (starting point, end point) in M min^{-1} (L).
d. Determine the width of the spray swath in meters (W).
e. Calculate the area sprayed in one minute (W x L) M^2 min^{-1}

Area sprayed min^{-1} = Swath width of spray x Forward speed min^{-1}.

f. The application rate for any given area:

$$\text{Volume of spray in L unit}^{-1}\text{ area} = \frac{\text{Nozzle discharge (L min}^{-1}\text{) x Area}}{\text{Area sprayed min}^{-1}}$$

or

$$\text{L ha}^{-1} = \frac{\text{V x 10000}}{\text{L x W}}$$

g. Calculate the number of spray loads ha^{-1}

$$\text{Loads } ha^{-1} = \frac{\text{Rate of application } ha^{-1}}{\text{Tank capacity of sprayer}}$$

Example: How many liters of the commercial formulation Rogor® 30 EC (dimethoate) is required to treat an area of 0.5 ha, if the recommended dose is 0.1%?

a. Compute the total volume of spray (in L) needed to treat the area

Volume of spray after sprayer calibration:	320 L ha^{-1}
EC form:	Rogor® 30 EC
Recommended dose:	0.1%
Area to be treated:	0.5 ha

320 L x 0.5 ha = 160 L

Formula: $$\frac{\text{Amount of spray required} \times \text{\% of spray concentrate}}{\text{\% of ai (EC)}}$$

$$\frac{160 \text{ L} \times 0.1}{45} = 0.533 \text{ or } 533 \text{ mL.}$$

Therefore, 533 mL of Rogor® 30 EC must be mixed in 160 L of water to spray 0.5 ha.

2. Power-operated Hydraulic Sprayers

Tractor-mounted sprayers

The tractor-mounted boom sprayer with a pump driven from the power take off (PTO), is used to apply 50-500 L ha^{-1} on field crops over a large area. Tanks with a large capacity may be mounted on trailers or as saddle tanks along side the tractor engine to spread the load more evenly. Some large sprayers are self propelled. However, these are used only where sufficient flat land allows the use of booms up to 27 m wide.

The important components of power-operated sprayers are:

a. Tank mounted on a sprayer
b. Pumps: piston, centrifugal, gear, roller-vane, and diaphragm pumps.

c. Pressure controlling devices: Pressure gauge and Pressure Relief Valves (PRV).
d. Nozzles: hydraulic nozzles; impact nozzles: cone nozzles and fan nozzles.
e. Agitators.

Calibration of tractor-mounted sprayer

This sprayer is calibrated by allowing it to travel over a known distance and then measuring the volume of chemical applied (in liters). The width of the swath must be measured (in meters) while keeping the distance between the nozzle and ground level constant. The pump pressure and travelling speed must be constant. The following parameters are important for calibration:

- pressure in tank,
- nozzle size (tip),
- forward speed of tractor, and
- swath width of spray.

Example: Calibration of a tractor-mounted sprayer (Allman) for spraying 300 L ha^{-1}.

Number of nozzles: 28 (fitted 50 cm apart)
Swath width of boom: 14 m (50 cm x 28 nozzles)
Area to be sprayed: 1 ha

Distance travelled (forward speed) by tractor: 100 m min^{-1} (6 km h^{-1})
Area covered by tractor in one pass: 100 m x 14 m (swath) = 1400 m^2
Nozzle discharge min^{-1}: 1.5 L min^{-1} (one nozzle)
Discharge from 28 nozzles: 1.5 L x 28 = 42 L
Discharge of spray solution over an area of 1400 m^2: 42 L

Discharge of spray solution over 1 ha (10000 m^2): $\frac{10000 \times 42}{1400}$ = **300** L

Therefore, 300 L ha^{-1} can be obtained with these parameters.

Calibration of a tractor-mounted sprayer with various settings.

Calibration	Tractor gear	Throttle setting	Ground speed km h^{-1} (discharge L min^{-1})	Nozzle tip size	Pressure PSi	Output (L ha'^{1})
1	1st high	4th notch	7 km	1.0 LM^{-1}	28	265
2	4th low	3rd notch	6.5 km	1.25 LM^{-1}	32	290
3	4th low	2nd notch	6 km	1.5 LM^{-1}	35	300

300 L ha^{-1}

Sprayer calibration aims at obtaining a spray pattern and droplet size that will ensure optimum coverage of a target area with uniform sized droplets without causing runoff. Calibration should, therefore, take into account:

- Target area: canopy area to be sprayed (a large leaf area requires a large volume of water).
- Droplet size: fine droplets cover a large area with less volume and reduce runoff, but can cause more drift and evaporation losses under warm and windy conditions.
- Once the volume of spray and droplet size are determined, the nozzle size and their spacing on the boom should be decided keeping in view the height between the boom and the crop canopy.

- All hydraulic nozzles work effectively only within a given pressure range. The sprayer pump should, therefore, deliver the required volume with the correct pressure. To do so, the tractor must be driven at an optimum speed (engine rpm) in order to deliver power through PTO or hydrostatic drives to the pump input.

- Given that the type of nozzles, pressure obtained, tractor rpm, spray swath, etc., remain constant, the only variable that can be adjusted is the volume of spray/unit area with the speed of the tractor. This can be done by gear selection (if the engine speed is fixed).

- The volume ha^{-1} can be regulated by slightly adjusting the pressure regulator or engine speed with little effect on pump output.

3. Air Carrier Sprayers (Mist Blowers)

The use of portable air carrier sprayers, known as motorized knapsack mist blowers, follows the development of light weight, two-stroke engine aeroplanes suitable for aerial spraying over large areas.

The fan in these sprayers produces a high velocity air stream which is diverted through a 90° elbow to a flexible discharge hose. The most common nozzle fitted in these sprayers is the shear nozzle (gaseous energy nozzle). Air is drawn into the fan at a high speed and discharged through a flexible tube in which a liquid flow nozzle is mounted. As the high velocity air stream passes over the nozzle, it makes the emerging liquid break into droplets which then enter the air stream and are sprayed.

Calibration of knapsack motorized mist blower

a. Check all the components of the sprayer to see if they are in working condition.
b. Fill the sprayer with water sufficient for at least 1 minute of spraying.
c. Record the time taken to spray the measured volume with a stop watch.

4. Electrodyne Sprayer (Electrostatic Sprays)

The functioning of the electrodyne sprayer is based on a system which atomizes and propels charged droplets of chemical spray by electrical forces set up between a nozzle with a positive high voltage charge. Since the charged droplets are readily deposited on an 'earthed' object, e.g., a plant, the total deposit on the foliage can be significantly increased compared to uncharged sprays.

The liquid pesticide is poured into a bottle and fed by gravity to the nozzle, where it picks up charged droplets (positive charges) generated by batteries. The liquid leaves the nozzle in a number of uniform ligaments which break up into electrically-charged droplets. The positively-charged droplets move along curved electrical field lines towards and around the plants, covering the visible as well as hidden surfaces. The size of the droplets range between 20 and 200 microns.

A special feature of this type of sprayer is that the formulations used in it come in a special bottle fitted with the particular nozzle required.

5. The Birky Sprayer

The Birky knapsack sprayer is the first low volume (LV) spinning disc sprayer which does not require batteries. The need to apply herbicides at very low volumes gave rise to this sprayer.

The spinning disc of the Birky sprayer is driven by air supplied by a pneumatic pump to a turbine. Since it has no batteries, it reduces spraying cost. The spray swath can be increased to about 1.6 m.

Some of the advantages of a Birky sprayer are:

- A low water requirement that makes it ideal where water is not readily available.
- Its one spray-load covers 1/4 of an hectare (20 L ha^{-1}).
- A working output of 3-4 ha day'[1], compared to one hectare by the knapsack sprayer.
- Requires less physical effort to operate and is less tiring for the operator.
- A pneumatically-driven disc.
- Easy to maintain and has a wider spray swath.
- Droplet size ranges between 250 and 300 microns.

Operation of a Birky sprayer:

- Calibrate the sprayer before spraying in the same way as is done in the case of a knapsack sprayer.
- Start operating the handle to obtain the correct speed of the spray disc (a whistling sound will be heard).
- Open the tap. Swing the spray tube sideways to check the proper flow and atomization of the spray solution.
- Start spraying and maintain a proper ground speed.
- Swing the spray tube sideways from time to time to check whether the sprayer is working properly.

6. Controlled-droplet Application (CDA) Sprayers

These sprayers (Fig. 5) apply the correct size and uniform droplets on a given target area so that optimimum use is made of the spray volume and dosage. It is a logical extension of the ultra low volume (ULV) concept.

The most promising method of controlling droplet size within fairly narrow limits is by using centrifugal energy nozzles (spinning discs or cups) which adjust droplet size by varying their rotational speed. A suitable formulation and flow rate are selected so that at a given rotational speed, droplet formation is from ligaments with a minimum number of satellite droplets.

The volume of spray depends not only on the droplet size selected but also on droplet density. Uniform droplet density can be obtained by using as little as 500 mL ha^{-1} of the formulation with a droplet size of 46 m or 1-8 L ha^{-1} at 70 µm or 200 L ha^{-1} at 340 µm droplets.

Spraying procedure

To avoid contact with the spray, the drift operator must walk progressively up-wind across the field through nontreated crops. The sprayer is held either with the handle across the front of the operator's body or over his shoulder, with the disc above the crop pointing downwind. The

Figure 5. Controlled-droplet application sprayer.

spinning disc is normally held 1 m above the crop. It may be necessary to hold it lower while spraying the first swath along the leeward side of a field in order to reduce the chemical's drift outside the treated area.

7. Dusters

Appliances that are used for distributing dust formulations are called dusters. Dusters may be manually or power operated. Machines used for applying dusts mainly consist of a hopper (dust chamber) with an agitator, an adjustable orifice or other metering mechanism, and delivery tubes. Some dusters are power operated, e.g., motorized mist blower-cum-dusters, tractor-mounted dusters, and rotary dusters.

The following types of power dusters are generally in use:

Tree duster

This duster has an upright metallic discharge tube varying in length from 1 to 4 feet, which helps carry the dust upwards to the trees. The height upto which the dust can be carried depends on the length of the tube and the engine's horsepower. Generally a long hose (10 feet) is used to dust tall trees.

Row crop duster

This duster has 4-8 outlets in the fan chamber. Each outlet is connected by flexible pipes meant to spread the dust, and arranged on an iron rod in the rear of the tractor for delivering the dust right on the crop. Crops grown in a row are most suitable for treating with these dusters. Row crop dusters can be fitted on to any vehicle or animal-drawn trolley and can dust vast areas.

All-purpose dusters

These range from the small knapsack and wheel barrow or skid type dusters to the large tractor or vehicle-mounted power dusters. They usually have a single delivery outlet connected to a 4-6 foot multidirectional flexible delivery pipe. They are used for all kinds of crops except tall trees, and can dust 20-30 acres day^{-1} depending on crop height and formulation dosage.

Self-propelled dusters

Power dusters of this type are mounted on a frame carried by 3 or 4 wheels driven by an engine.

Motorized knapsack sprayer-cum-dusters

These dusters are light in weight, generally powered by 0.5 -1.0 hp engines, and can be carried on an operator's back. The frame has a shock proof cushion with shoulder straps.

The hopper and delivery hose pipes are small and the tank can hold upto 8-10 kg of dust. The machine's total weight with the dust can be around 20 kg.

These dusters can be converted into a sprayer (mist blower) by removing the agitating tube from the tank and fixing the hose in the outlet of the chemical tank.

The advantages and disadvantages of dusting over spraying.

Advantages	Disadvantages
Treatment costs less	Higher cost of active ingredient
Covers a larger target area than spraying	Uneven deposition and poor adherence to the canopy
Equipment is light in weight and easy to handle	Limited choice of dust formulations
Dust formulations have a greater shelf life than EC and deteriorate less rapidly	Dusting cannot be done when very windy
	Weather condition is a constraint (dust washes off after rain)

Different Types of Nozzles and their Main Uses

Nozzles are an important part of spraying equipment. They vary in their delivery system.

Hydraulic Energy Nozzles

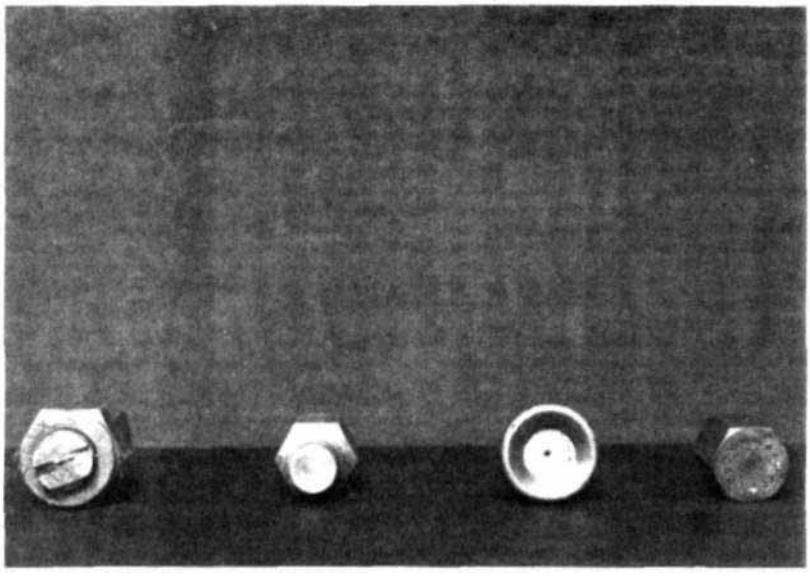
In this type of nozzle, liquid under pressure is forced through a small opening. The velocity of the liquid breaks it into droplets. Properties of the liquid, such as surface tension, specific gravity, and volatility influence the delivery of the spray mix.

The various types of hydraulic energy nozzles are:

- Cone jet nozzles: Hollow cone jet and solid cone jet which are used for foliage sprays (Fig. 6).
- Flat fan: This is used for spraying on flat surfaces and in aerial spraying.
- Impact nozzle or flood jet: This is a low pressure nozzle with coarse spray, mainly used for herbicide application (Fig. 7).
- Other types: The adjustable nozzle (Fig. 8) and the swirl nozzles (Fig. 9) for spraying in two different directions.

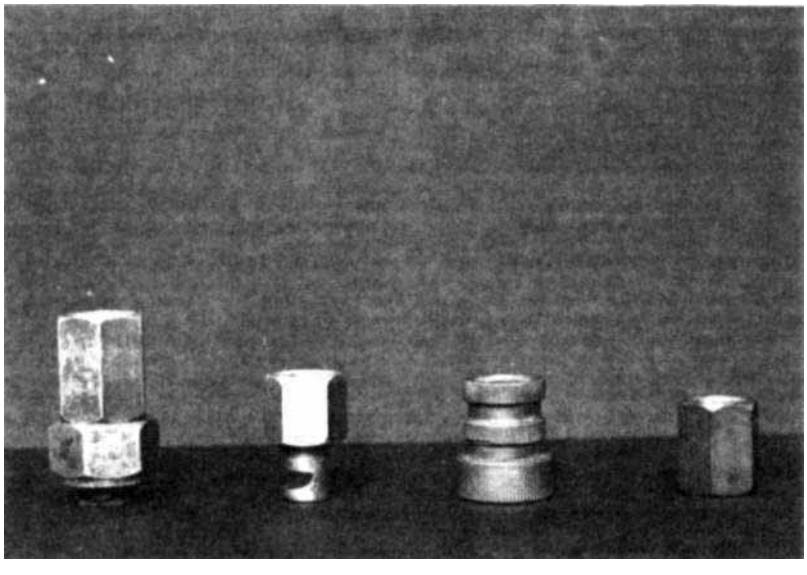
The main components of a hydraulic spray nozzle are:

- Body
- Cap
- Strainer-sieve
- Tip



Front view

(Types from left)
Flat fan
Flood jet
Hollow cone
Hollow cone



Side view

(Types from left)
Flat fan
Flood jet
Hallow cone
Hallow cone

Figure 6. Different types of nozzles.

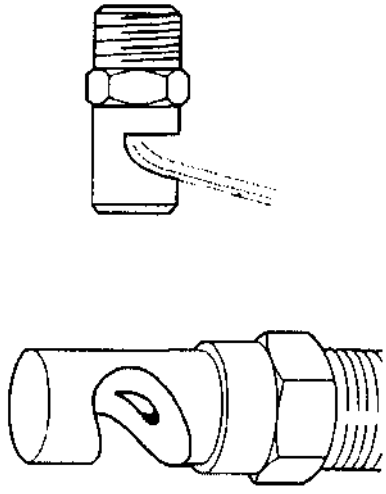


Figure 7. An impact nozzle.

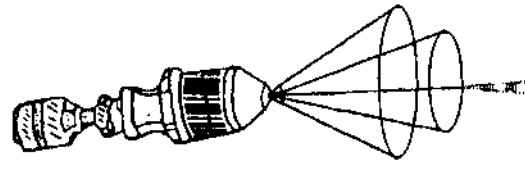


Figure 8. An adjustable nozzle for distant target.

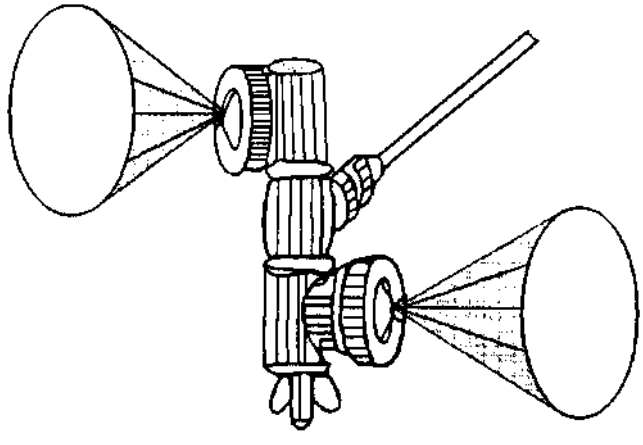


Figure 9. A swirl nozzle used for spraying in two different directions.

The pattern of droplet distribution and the amount of liquid sprayed (Fig. 10) depend on:

- type and design of nozzle,
- diameter of nozzle orifice,
- discharge angle of spray,
- operating pressure (P),
- fluid sprayed, and
- weather conditions.

Gaseous Energy Spray Nozzles ('Twin-fluid')

In this kind of nozzle, the liquid disintegrates into droplets by the impact of a high speed air stream on the spray liquid. Droplets are formed at a relatively low air pressure (less than 0.3 bar). However, when fine (aerosol) droplets are required, the volume of air must be increased. The rate at which the liquid flows into the nozzle depends on its viscosity. An increased flow of liquid and lower air speed result in large droplets which are mainly used for spraying on trees and bushes.

Centrifugal Energy Nozzles

The spray liquid is fed near the center of a rotating disc in these nozzles. The liquid is uniformly distributed to the serrated periphery of the disc by centrifugal force. It is propelled from the edge of the disc in the form of ligaments, and breaks down into droplets. A lower rotational speed and higher flow rate result in larger droplets. This nozzle is mainly used to apply low volumes with controlled droplet size and also in air-carrier sprayers.

The diameter of a single droplet (d) produced by a rotary nozzle can be calculated approximately thus:

$$d = \frac{\text{constant}}{\text{rpm}}$$

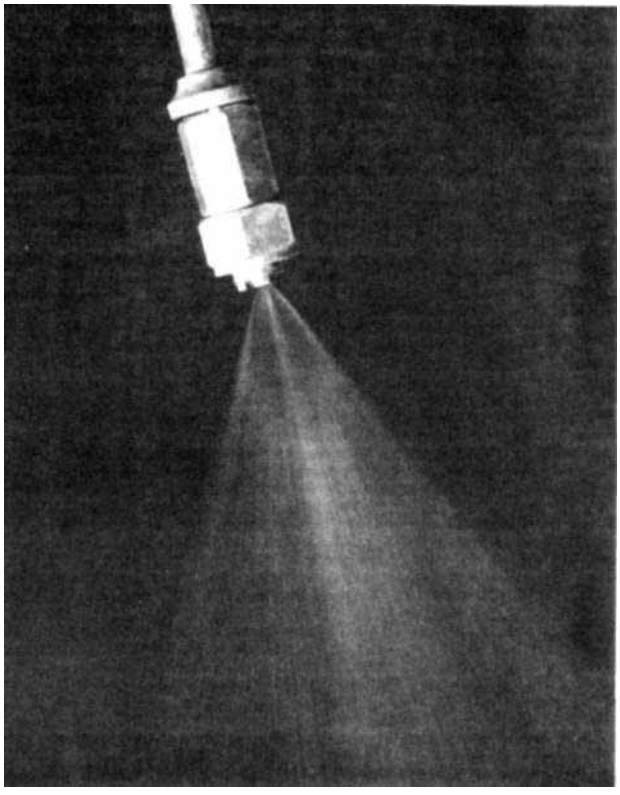
where d = droplet diameter (µm).

Effect of Droplet Size and Spray Coverage

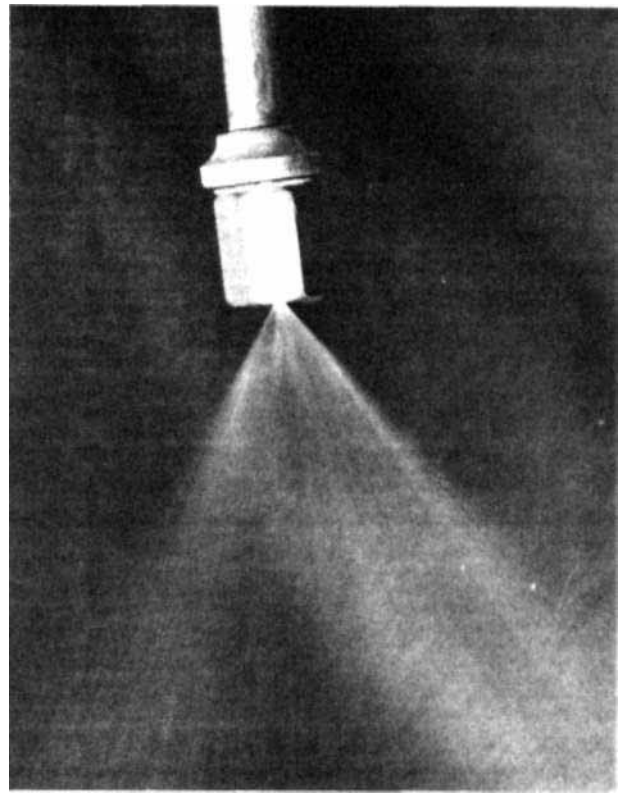
Distribution of spray. Droplet size, density, and penetration can be visible on water-sensitive papers tagged on to a plant at different heights. Droplets deposited on the plant surface spread and increase up to 3 times in size. The smaller the droplet, the greater the spread factor.

Nozzle Erosion and Spray Pattern

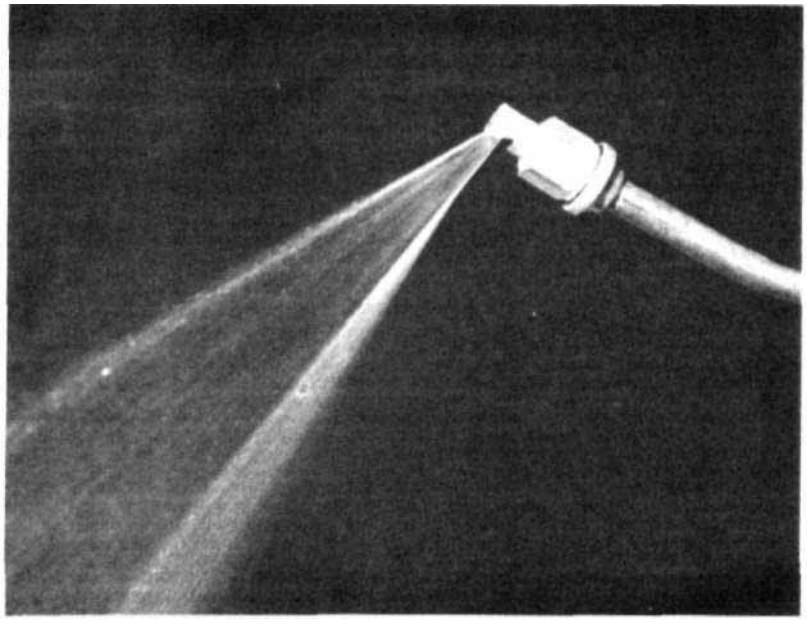
The accuracy of the deposition of spray droplets depends on the nozzle. The orifice of the nozzle tip gets enlarged over a period of time by the combined effects of the chemical action and the abrasive effect of the particles. These may be in the 'filler' portion of wettable powder formulations, where foreign particles are frequently suspended in the spray. This is referred to as nozzle-tip erosion and results in an increase in liquid flow rate, droplet size, and an alteration in spray pattern. An increased flow rate can lead to an overdose of pesticides. The discharge from a nozzle or group of nozzles can be measured with a patternator (Fig. 11), which monitors the liquid discharged through a flow meter. Water is sprayed into one, two or three nozzles on to a channelled table and collected in a sloping section which drains into calibrated collecting



Flat fan



Hollow cone



Flat jet

Figure 10. Nozzles and their spray pattern

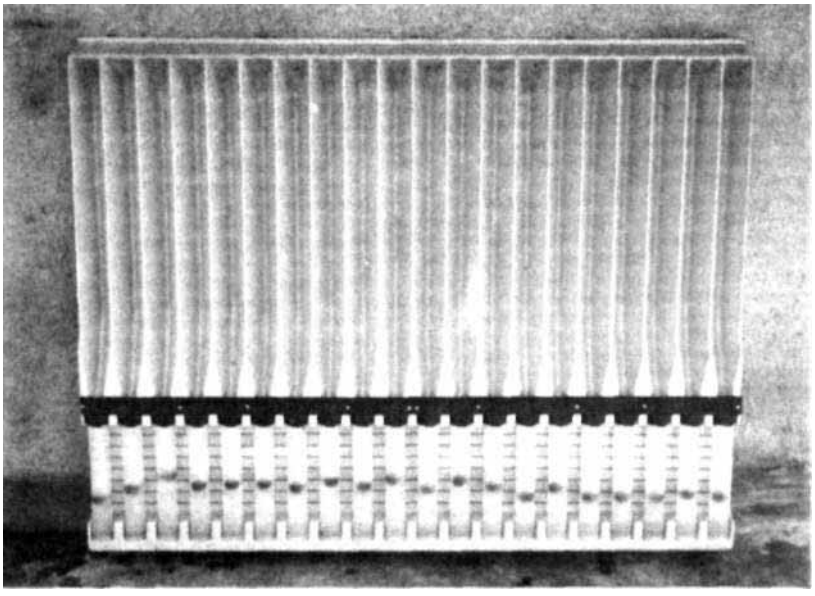


Figure 11. A patternator

tubes at the end of the channels. The nozzle is usually mounted 45 cm above the tray andconnected to a similar spray line. The patternator can be placed under a tractor boom to find out the variation in spray distribution along its length. The coefficient of variation of a boom pattern can be obtained when limits for individual nozzle patterns have been defined using a fluorescent tracer technique to determine liquid distribution.

Advantages and disadvantages of CDA over conventional spray applications.

Advantages	Disadvantages
Produces smaller and uniform size droplets	The smaller droplets tend to evaporate easily and drift from the target area
The smaller the droplet, the greater the spread factor and the better the coverage	Application has to be under ideal weather conditions
No diluent is required	Selective in use of formulations
Easy to carry, use, and maintain	Hazardous to operator and surroundings because of the use of high concentration of chemicals
Covers large areas in less time and with less inputs	Losses due to wind
Wider swaths and no runoff	Strict adherence to weather conditions

Calibration of Equipment

The spray volume can be calculated theoretically by the following formula:

$$\text{Application rate in L ha}^{-1} = \frac{600 \text{ L} \times \text{L min}^{-1} \text{ (nozzle discharge)}}{\text{Swath width (m)} \times \text{Speed m min}^{-1}}$$

Maintenance and Safe Handling of Equipment

Regular preventive maintenance of equipment is required so that the components which are subject to wear and tear are replaced before they wear out. Proper maintenance of equipment is, therefore, essential.

Problems Associated with Spraying Equipment

Nozzle blockages

If a nozzle blockage occurs while spraying, the nozzle tip and filter should be replaced with clean points. The blocked nozzle should be cleaned and spares should be taken to the field. When spares are not available, water or a solvent should be taken to the site of operation to clean the blockage. The occurrence of blockages can be reduced by filtering the spray liquid while filling the chamber.

Inefficient pumps

Pumps are fitted with 'O' ring seals or leather or synthetic cup washers. As the seals can get damaged due to suspended spray particles, they should be checked regularly. Apart from cleaning and replacing damaged parts, it may be necessary to change the formulations used or to improve the filtration of water before use.

Leakage

'O' ring washers and other types of seals are liable to wear and tear or damage when hose connections, trigger valves, and other components are unscrewed. Compression spray equipment and certain motorized knapsack mist blowers function properly provided they are airtight.

Maintenance and safe handling

a. Daily maintenance

- Clean after use.
- Check pump, nozzles, etc., before operation with water.
- Inspect mobile parts.

b. Periodic preventive maintenance of the following is important:

- Pumps
- Pipes and connections
- Pressure gauges and pressure regulators
- Agitator
- Nozzles and booms
- Tank components
- Engine

c. Off-season maintenance and storage. All plant protection equipment must be stored in a cool and dry place and in the shade.

- Equipment should be washed thoroughly with plain water before storage.
- Grease and lubricants should be applied to joints and surfaces wherever required to protect from rust.

Storage of Equipment

After each day's field work and at the end of the season, the sprayer's pump, control units, booms, hoses, and engine should be checked thoroughly before storing in a dry place. All spraying equipment should be kept locked and away from children, food, and farm animals, and measures taken to prevent rats from nibbling at hoses and other parts. Many small hydraulic sprayers are preferably stored upside down with the lid removed to allow complete drainage of formulation. If engines are to be stored for a prolonged period, the spark plug should be removed and a little oil, preferably formulated with anti-rust additives, poured into the crank case. The engine should be turned over a couple of times to enable the oil to spread evenly. At the end of each day, it is advisable to add some oil to any type of sprayer pump. This is not necessary if the sprayer is to be used again the following day.

Hints for Trouble-shooting

Two-stroke Engines

Problem	Remedies
Engine does not start	
Fault in fuel system	
Fuel cock has not been opened or is blocked	Ensure there is sufficient fuel in the tank. Open the fuel cock. If the fuel flow is not smooth, remove cock, clean, and replace.
Air vent in fuel tank filter is blocked	Clean vent.
Thimble filter in carburetor is blocked	Remove filter, clean, and replace.
Main jet in carburetor is blocked	Remove, clean, and replace.
Water in carburetor float bowl	Remove and clean. Check whether fuel in tank is contaminated with water.
Float needle sticking and stopping petrol supply	Remove needle. Check for burrs or rough surface. Remove rough surface. If not possible, replace with a new needle.
Too much fuel in engine (flooding)	Close fuel cock, and remove spark plug. Open throttle and pull recoil starter rope to turn engine over a few times. Clean and replace.
Fault in ignition system	
High-tension lead to spark plug is loose or disconnected or insulation is broken or burned	Fasten lead securely to plug. If badly damaged, replace.
Dirty spark plug; carbon or oil deposits on electrodes	Remove plug and clean. Set gap between points as recommended by manufacturer. If porcelain insulation is damaged, replace with a new plug.
Contact breaker points dirty or pitted	Clean and adjust to correct clearance when points are open. If honing fails to remove pitting, replace with a new set.
Exhaust blocked	Remove exhaust and clean or replace with a new one.

Engine runs erratically or stops

Dirt or floating debris in fuel system	Clean all fuel lines, filters, and carburetor bowl, and ensure there is no air in fuel line.
Main jet blocked	Remove, clean, and replace. Do not use nail, pin or wire to clear obstruction.
High-tension ignition lead is loose or 'shorting' on metal parts of the engine	Check that the lead is firmly affixed to the spark plug. Where it has been chafing on bare metal, either cover the bare wire with insulation tape or replace with a new lead.
Fuel running low in tank. Engine vibration or operator's irregular movement leaves outlet pipe uncovered, resulting in fuel starvation	Refill tank with correct fuel mix.

Engine lacks power

Choke is closed	Open choke.
Fuel starvation	Partially blocked pipes or filter should be removed and cleared.
Air cleaner blocked	Remove and clean by washing in petrol, and squirt a little light oil on the cleaner element. Conform to manufacturer's recommendations.
Dirty carburetor	Remove from engine. Dismantle carefully, clean, and examine all parts. Worn-out parts such as the float needle valve must be replaced.
Loose or leaking joint at carburetor flange to cylinder	Check gasket. Replace if worn-out or damaged and tighten nuts or studs.
If whistling noise is heard from the cylinder when the engine is running, there is a possibility of the cylinder head gasket being worn-out or damaged	Check carefully when the engine is running. If gases are escaping, remove head, fit new gasket, and tighten nuts evenly. On a new machine, it may be necessary to tighten the nuts evenly without fitting a new gasket. If heavy carbon deposits are seen on the piston crown or cylinder head when the head is removed, these should be scraped away carefully. The ring of hard carbon in the cylinder should not be disturbed.
Dirty exhaust	Remove exhaust. Clean carbon deposits if possible or replace with new part.

Engine backfires

Ignition may be badly retarded	Should only be attempted by trained or qualified workshop personnel. Magneto should be checked and reset to manufacturer's specification.
Carbon whisker bridging gap in spark plug	Remove plug, clean, adjust gap to correct clearance, and replace.

Overheating of engine

Incorrect mixture of petrol and oil in fuel tank	Drain tank. Refill with fuel and oil in the correct ratio (see handbook or markings on tank).
Incorrect size of main jet	Remove and refit one that complies with the manufacturer's specifica-tion.
Ignition retarded too far	To be checked and reset by a competent person.
Exhaust and silencer choked with carbon	Remove, dismantle, clean, and reassemble.

Faults with knapsack, lever-operated (piston or diaphragm) pumps.

Fault	Remedies
No spray	If resistance is felt on downward movement of lever when the cut-off valve is open, check nozzle for blockage, and clean if necessary. Check and clean filter or strainer in the handle of the cut-off valve. If there is no resistance, check tank contents and fill if necessary. Ensure that the operating lever as well as all the connections to the pump are tight. Check that when the lever is operated, the shaft or connecting mechanism and the piston or diaphragm all move together. Pump-valves and valve-seat should be checked. If worn-out or damaged these should be replaced. Dirt and debris should be removed.
No suction	Ensure that liquid is present in the container. Check whether the suction and discharge valves are not sticking and that the liquid ports that allow the flow from the tank to the pump are not blocked. If a piston-type pump is used, check whether the piston seal is not excessively worn-out or damaged, as this will allow the liquid to pass between the piston and cylinder wall.
No pressure	Check liquid contents of the container. Fill if necessary. After several strokes of the operating lever, check if air bubbles are rising to the tank's surface. If so, this could mean a leak in the pressure

	chamber. Where the pressure chamber is screwed onto the pump body, check that the seal is not damaged. Replace if necessary. Check both suction and discharge valves. Remove any accumulated dirt or debris from discs, balls, and valve seats. If discs are worn-out or damaged or the rubber is damaged, replace. If ball valves and seats are pitted or balls are no longer spherical, replace. If resistance is felt while pumping and no reading is seen on the pressure gauge, replace gauge. In a diaphragm-type pump, check whether it is seating correctly, is not damaged or split and that the rubber is not porous. Where a pressure-relief valve is embodied in the pressure chamber, check whether it is adjusted correctly and make sure that the spring-loaded valve is seating properly. Ensure that the openings between the pump inlet and outlet ports and the liquid container are not blocked. Check that the air vent in the filler cap is not blocked, as this could be the means of a vacuum forming in the container.
Abrupt fall in pressure	Check pressure chamber for leaks. Air bubbles seen rising to the liquid surface are a good indication. Check valves for discharge. The discharge rate may be higher than the pump capacity.
Liquid leaks on to operator	Where the pump is mounted on the base of the sprayer, a ruptured diaphragm, or one incorrectly assembled, will permit liquid under pressure to leak. In a piston-type pump, a worn-out piston seal or deep scratches in the cylinder wall will allow the liquid to escape and wet the operator. Check the container for cracks or leaking joints. Metal tanks can be soldered or brazed. Make sure that the lid of the container fits tightly.

Faults with compression sprayers (any tractor-mounted sprayer).

Fault	Remedies
No spray	Ensure the container has liquid. If the pressure gauge shows a reading and there is no spray when the cut-off valve is opened, close the valve and check the nozzle. If the nozzle is blocked, follow the procedure for clearing blocked nozzles. Check strainer in cut-off valve. Clean and replace. Check hose connections and tighten. If no reading is displayed on the pressure gauge, ensure that the gasket between the pump body and the liquid container is not leaking. Replace if leaking. Remove pump from container and check by giving a few strokes on the pump handle to test the valve. On each pressure stroke, the valve should 'grunt' or make a noise of escaping air. If the valve disc or ball is malfunctioning, it should be replaced. Where a dip-tube is part of the assembly, check that it is not blocked.
Leaks from pump	After the container has been filled with liquid spray to the required level, if on the first or second downward stroke of the pump handle

the liquid is forced up past the shaft and out through the guide, it is a sign that the valve requires attention. If strong resistance is felt on the downward stroke, it means the valve is faulty and that it has permitted liquid to enter the pump barrel and, as the liquid cannot be compressed, resistance is encountered.

Abrupt drop in pressure

Check that the filler cap or lid gaskets are serviceable and that the cap is properly secured. Also check that the safety valve is not leaking and is in working condition. Some compression sprayers have a constant-pressure valve fitted. Check that this is adjusted correctly and that there are no leaks from the point of entry to the tank. Ensure that all connections to the tank are tight and that all gaskets and washers are serviceable. Check the tank for leaking seams by pressurizing and immersing completely in water.

Air bubbles rising to the surface indicate a leak. Leaking tanks cannot be repaired in the field. All repaired compression sprayers must be pressure-tested to at least twice the working pressure before being used.

Other faults

If the nozzle dribbles with the cut-off valve closed, it indicates that the '0' ring seal or the valve seat is damaged. Dismantle and check. Replace with new parts if unserviceable. In some plastic-type pressure gauges, the indicator sometimes becomes loose on its pivot, thereby giving a false pressure reading. By tapping the gauge against the hand, it can be seen whether or not it is loose. If it is, remove the protective glass front, replace the needle on the pivot loosely and, with it pointing to zero, press it firmly on to its mounting. Replace the glass and check with a master gauge.

Safety Precautions

The importance of taking safety precautions while handling and applying pesticides is often underestimated. An effort must be made to give a comprehensive account of the various aspects of the safe use of pesticides, especially for staff operating spraying equipment and handling chemicals.

Pesticide Selection

The most important step in pesticide safety is its proper selection. First of all, the pest problem must be correctly identified. Control measures need not be taken if the pest is not of economic importance. Once economic damage due to a pest has been established, the appropriate pesticide and method of treatment can be chosen. Buying an excess of pesticide should be avoided.

Handling and Mixing

The following safety guidelines should be followed while handling pesticides:

- Read the label on the pesticide container and leaflet carefully and follow the instructions therein.
- Make the calculations required for dilution.
- Obtain the application equipment required, including personal protective devices.
- Never work alone when handling highly toxic pesticides.
- Never leave pesticides unattended; children or animals may be affected.
- Mix chemicals in the open or in a well ventilated area.
- Measure and mix quantities accurately.
- Never eat, drink, smoke, rub eyes or face while working with pesticides.
- Do not use the mouth to siphon a pesticide from the container.

Disposal of Empty Containers and Unwanted Pesticides

- Empty the spray tank completely during spraying.
- Never empty the spray tank into irrigation canals, waterways, ponds or a well.
- Decontaminate and destroy devices such as empty containers, buckets, and measuring cups after use.
- Decontaminate all protective clothing and footwear.
- After handling pesticides, take a bath with plenty of water, detergent or soap.

All pesticides and pesticide containers must be disposed of carefully, failing which animal poisoning or environmental contamination can occur. Pesticide wastes should be buried. The site must be chosen carefully to prevent contamination of surface water runoff or groundwater. Pesticide wastes should be buried under at least 1/2 a m of soil mixed with lime to enhance degradation. Initially the pit should be lined with 5-10 cm of clay and coated with 2-3 cm of lime. Wastes should be added to the pit in layers not more than 10-15 cm deep and inter mixed with lime and bio degradable household waste, to assist in biological degradation.

Recognizing Pesticide Poisoning

The fundamental principle of safety in the use of pesticides is to prevent poisoning by exercising care. It is easier to prevent poisoning than to treat it. Different pesticides act differently on the human body, and the mechanism and mode of action varies for different insecticides. Some general symptoms however apply. They are listed below.

Symptoms of Organophosphorous poisoning

Headache, giddiness, nervousness, blurred vision, weakness, nausea, cramps, diarrhoea and discomfort in chest are some symptoms of poisoning. Other symptoms are sweating, excess salivation, rapid heart beat, and vomiting. Advanced stages of poisoning usually results in convulsions, loss of bowel control, loss of reflexes, and unconsciousness.

Symptoms of Carbamate poisoning

The symptoms of Carbamate poisoning are essentially the same as those caused by Organophosphorous pesticides.

Symptoms and signs of Organochlorine pesticide poisoning

Nervousness, nausea, diarrhoea, and convulsions may result from an exposure to a large dose. Liver and kidney damage have been observed in laboratory animals when administered repeated large doses.

First aid

Immediate medical attention can prevent pesticide exposure from turning into pesticide poisoning. All pesticides have recommended antidotes. Antidotes are drugs and chemicals which counteract the effect of pesticides. Though they do not prevent poisoning, once symptoms of poisoning develop, they counteract that action. Therefore, antidotes are not prophylactic and shouldn't be used routinely prior to handling pesticides.

In the event of pesticide exposure:

- remove patient from the source of contamination,
- remove contaminated clothing and give patient a bath,
- keep the patient calm, comfortable, and warm,
- give the patient immediate medical attention,
- identify the pesticide as accurately as possible, and
- if breathing has stopped, initiate artificial resuscitation.

Antidotes

Antidotes should be administered only under the supervision of a registered medical practitioner. Following are the antidotes generally used:

- Atropine: This antidote for Organophosphates or Carbamate poisoning is administered orally and in severe cases injected. In case of Organochlorine poisoning, this drug can become a lethal poison.

- Vitamin-K (Phytonadione): This is the prefered antidote for anticoagulant poisoning such as that caused by warfarin (Corax®).

- Calcium gluconate: This is administered intravenously and is effective against some Organochlorine insecticides.

- Amyl nitrate: Inhalation is effective against poisoning of hydrogen, cyanide, and calcium cyanide. Sodium nitrate and sodium thiosulphate may be given intravenously.

Personal Protective Equipment

Personal protective equipment (Fig. 12) prevents pesticides from coming in contact with the body or clothing. These also protect the eyes and prevent the inhalation of toxic chemicals. Personal safety gear includes clothing that covers the arms, legs, nose, and head. Gloves and boots are used to protect the hand and feet, and hats, helmets, goggles, and face masks to protect the hair, eyes, and nose. Respirators are used to avoid breathing dust, mist or vapour.

Different types of safety masks.

Spraying with a face mask on.

A Catridges face mask.

Figure 12. Safety in operation.

Body wear

Overall: Overalls made of cotton are the best but should not be worn without additional protective clothing. When there is a chance of contacting wet spray, large sleeves with cuff-buttons, and pants with buttons at the bottom offer good protection.

Aprons: Waterproof rubber or plastic aprons are effective. They should be long enough to protect the general clothing.

Head protection

Dust and mist settle easily on hair. Hats that are water resistant, wide brimmed with sweatbands are effective in protecting it. Many helmets provide attachments for face shields and goggles.

Goggles: These are used to protect the eyes from splashes, spills, mist, and droplets. Goggles with plain lenses and full side shields are preferable. The lenses may become coated with pesticide droplets during spraying; hence cleaning tissues or an extra pair of goggles are a must.

Face shield: A face shield is a transparent acetate or acrylic sheet which covers the face and prevents it from splashes or dust. Face shields allow better air circulation and provide a greater range of vision than goggles.

Hand and feet protection

Gloves: Dermal exposure occurs the most in the hand region. The use of gloves reduces this risk. Gloves should be up to 2 to 3" long below the elbow i.e., they should extend to the mid forearm. Waterproof gloves, such as those made of rubber, latex or PVC are preferable. After use, they should be discarded away from ponds, wells, and animals or even incinerated.

Footwear: Shoes made of rubber or synthetic materials like PVC and nitrite can be used to prevent dermal exposure of feet. Protective footwear should be calf-high and worn with the legs of the protective pants on the outside to prevent spray from getting in. Leather or fabric shoes should never be worn as they absorb pesticides. Shoes should be checked for any leakage or damage before use.

Respiratory equipment

A respirator is a device that offers protection to the lungs and respiratory tract. Different kinds of respiratory equipment are used based on the type and toxicity of pesticides. They include nose filters/disposable masks, cartridge respirators, canister-type respirators/gas masks, positive pressure breathing apparatus, self-contained breathing apparatus, and powered air cartridge respirator.

Safety in Application of Pesticides

Misuse of pesticides can be extremely dangerous. Apart from polluting the environment, they may prove fatal to human beings, animals, birds, and fish. Phytotoxicity often results when used in excess in plants. Judicious use, and careful and safe handling may prevent hazards. Safe handling of pesticides involves their proper selection and careful handling during mixing and application.

Safety During Application

This reduces risk and prevents pollution. It also ensures safety to animals, which may be nearby. The following precautions may be taken while applying pesticides.

- Wear clothing and use equipment that are protective.
- Spraying should be done in the windward direction, taking care to see that there are no animals, people, or animal feed nearby.
- Apply the correct dosage. Do not use higher dosages than recommended.
- Do not blow, suck or apply the mouth to any sprayer nozzle or other spraying equipment.
- Check the sprayer and spraying equipment for leaks before use. Use properly maintained and functioning equipment.
- If any irregular symptoms are noticed during application, medical attention should be sought immediately.

Suggested Books for Reading

Bindra, O.S., and Singh, H. 1971. Pesticide application equipment. New Delhi, India: Oxford and IBH.

David, B.V. 1992. Pest management and pesticides. Indian Scenario (Edi.) Namrutha Publications, Madras. 384 pp.

Anonymous 1983. Manual for pesticides users. New Delhi, India: Pesticides Association of India. 191 pp.

Matthews, G.A. 1979. Pesticide application methods. Longman, London. 334 pp.

Mehta, P.R., and Varma, B.K. 1968. Plant protection. New Delhi, India: Directorate of Extension, Ministry of Food, Agriculture, Community Development and Cooperation. 587 pp.