INTRODUCTION

PESTICIDE APPLICATION TECHNIQUES

Pesticide application plays an important role in pest management. Proper technique of application of pesticide and the equipment used for applying pesticide are vital to the success of pest control operations. The application of pesticide is not merely the operation of sprayer or duster. It has to be coupled with a thorough knowledge of the pest problem. The use of pesticides involves knowledge not only of application equipment, but of pest management as well.

The main purpose of pesticide application technique is to cover the target with maximum efficiency and minimum efforts to keep the pest under control as well as minimum contamination of non-targets. All pesticides are poisonous substances and they can cause harm to all living things. Therefore their use must be very judicious. The application techniques ideally should be target oriented so that safety to the non-targets and the environment is ensured. Therefore, proper selection of application equipment, knowledge of pest behaviour and skillful dispersal methods are vital. The complete knowledge of pest problem is important to define the target i.e., location of the pest (on foliage, under the leaves, at root zone etc). The most susceptible stage of the pest for control measures will help to decide the time of application. The requirement of coverage and spray droplet size depends upon the mobility and size of the pest. The mode of action of pesticide, its relative toxicity and other physicochemical properties, help to decide the handling precautions, agitation requirement etc. Further the complete knowledge of the equipment is necessary to develop desired skill of operation, to select and to estimate the number and type of equipments needed to treat the crop in minimum time and to optimize use of the equipment.

Thus the following aspects must be considered for a successful pest control programme.

A. <u>Knowledge of pest problem:</u>

- Where is the pest location? : To define the target.
- What is the most susceptible stage for control? : To decide the time of application.
- What is the mobility of the pest? : To define the coverage requirements and droplet size.

B. <u>Knowledge of pesticides:</u>

- What is the mode of action? : To define the application technique.
- What is the phytotoxicity? : To define the calibration requirement
- What is mammalian toxicity? : To take up necessary precautions in handling.

C. Knowledge of formulations:

- What is the solubility?	:	To define the agitation requirements.
- How should it be mixed with water?	:	To collect suitable measure and water buckets and tools etc.

D. Knowledge of techniques & equipments:

- How should it be operated and maintained?	:	To operate the equipment without field troubles.
- What are the capabilities?	:	To estimate sufficient number of equipment needed.
- What adjustments are necessary?	:	To get an optimum use of the equipment.
- What technique is to be adopted?	:	To select suitable equipment.

OBJECTIVE OF PESTICIDE APPLICATION

The objective of the application of pesticide is to keep the pest under check. The pest population has to be kept suppressed to minimum biological activities to avoid economic loss of crop yields. Thorough killing of pest or eradication of pest is neither practical nor necessary. The objective of pesticide application besides keeping the pest population under check should also be to avoid pollution and damage to the non targets.

The success of pest control operations by pesticide application greatly depends on the following factors:-

1. Quality of pesticide
2. Timing of application
3. Quality of application and coverage

Different types of pesticides are used for controlling various pests. For example Insecticides are applied against insect pests, Fungicides against crop diseases, Herbicides against weeds etc. in order to protect the crop losses. But it is essential that besides choosing an appropriate pesticide for application it has to be a quality product i.e., proper quantity of pesticide active ingredient *(a.i)* must be ensure that the quantity is maintained in production and marketing of pesticide formulations.

The application of pesticide is very successful when applied at the most susceptible stage of the pest. If the timing of pesticide application is carefully considered and followed, the results will be good pest control and economy. Therefore for large area treatment careful selection of equipment becomes necessary so that within the available 'Time' the area could be treated.

Even though good quality pesticide is used and optimum timing for the application of pesticide is also adopted; unless the pesticide is applied properly it will not yield good results. Therefore, the quality of application of pesticides is very important in pest control operations. Adherence to the following points can ensure it:

1. Proper dosage should be applied evenly
2. The toxicant should reach the target
3. Proper droplet size
4. Proper density of droplet on the target

The dosage recommendation are generally indicated for acre or hectare e.g. kg/ha or lit/ha or gm *ai*/ha. It should be properly understood and the exact quantities of the formulated pesticide should be applied.

Pesticides are dispersed by different methods like spraying, dusting etc. For spraying of pesticides different types of nozzles such as hydraulic, air blast, centrifugal and heat energy type are used. Water is a common carrier of pesticides but air or oils are also used as carriers. Selection of proper droplet is an important consideration. The shape, size and surface of the target vary greatly. For spraying against flying insects, the hydraulic nozzles will not be effective. Here we need fine size spray particles to remain airborne for longer time. However, for weed control operation usually the requirement is drift free application or coarse spray droplets. Adequate number of spray droplets should be deposited necessarily. For fungicide application the number of droplets deposited per unit area should be more and may be for translocated herbicide application it can be less in number. It may need fewer numbers of droplets to be deposited in case of highly mobile (crawling) insect pest.

The pesticides are formulated in liquid form, dust powder or granule forms such that it makes possible to apply small quantities of pesticides over large area. Some of the pesticides are applied as low as few gram *a.i.* per hectare. Therefore adoption of proper Application Technique is vital for uniform depositing of pesticide. The method of setting the pesticide application equipment to ensure even distribution of certain quantity of pesticide over the desired area is called Calibration.

SPRAYING TECHNIQUES

Most of the pesticides are applied as sprays.

The liquid formulations of pesticide either diluted (with water, oil) or directly are applied in small drops to the crop by different types of sprayers. Usually the EC formulations, wettable powder formulations are diluted suitably with water which is a common carrier of pesticides. In some cases however, oil is used as diluent or carrier of pesticides.

The important factors for spray volume consideration are:

The volume of spray liquid required for certain area depends upon the spray type and coverage, total target area, size of spray droplet and number of spray droplets. It is obvious that if the spray droplets are coarse-size then the spray volume required will be larger than the small size spray droplets. Also if the thorough coverage (eg. both the sides of leaves) is necessary then the spray volume requirement has to be more.

On the basis of volume of spray-mix the technique of spraying is classified as:

1. High volume spraying
2. Low volume spraying
3. Ultra low volume spraying

The range of volume of spray mix in each of the above case is arbitrary. Usually for field crop spraying the following spray volume ranges are taken as guide.

High Volume Spraying	300 - 500 L/ha
Low Volume Spraying	50 - 150 L/ha
Ultra Low Volume Spraying	< 5 L/ha

There is distinct advantage in the case of lower volume of application over the high volume application. The higher the volume to be applied the more the time, the more the labour and the more the cost of application due to labour cost. However the lower volume applications are concentrated spraying of pesticide which should also be considered properly.

CLASSIFICATION OF PLANT PROTECTION EQUIPMENTS

SPRAYERS (Hydraulic energy)

Manually operated	*Powered operated*
1. Syringes, slide pump	1. High pressure sprayer (hand carried type)
2. Stirrup pumps	2. High pressure trolley/ Barrow mounted
3. Knap sack or shoulder-slung: • Lever operated K.S. sprayer • Piston pump type • Diaphragm pump type	3. Tractor mounted/ trailed sprayer
4. Compression sprayer • Hand compression sprayer • Conventional type • Pressure retaining type	4. High pressure knap sack sprayer
5. Stationary type • Foot operated sprayer • Rocker sprayer	5. Air craft, aerial spraying (Fixed wing, helicopter)

SPRAYERS (Gaseous energy)

Manually operated	*Powered operated*
1. Hand held type	1. Knap sack, motorized type 2. Hand/ Stretcher carried type 3. Tractor mounted

SPRAYERS (Centrifugal energy)

1. Hand held battery operated ULV sprayer.
2. Knapsack motorized type
3. Tractor/ vehicle mounted ULV sprayer
4. Aircraft ULV sprayer

OTHER SPRAYERS

1. Aerosol sprayers
2. Liquefied-gas type dispensers
3. Fogging machines
4. Exhaust Nozzle Sprayer

DUSTING EQUIPMENT

Manually operated

1. Plunger duster
2. Bellow duster
3. Rotary duster:
   - Belly mounted model
   - Shoulder-slung model

Powered operated

1. Knapsack motorized duster
2. High pressure trolley/ Barrow mounted
3. Tractor mounted/trailed duster
4. Aircraft

GRANULE APPLICATOR

Manually operated

1. Broad-casting tins
2. Knapsack Rotary granule

Powered operated

1. Knapsack motorized type
2. Tractor mounted/ trailed duster
3. Aircraft

SPRAY NOZZLES AND THEIR CLASSIFICATION

All types of sprayers generally speaking emit pesticide solution in very fine spray form. Spraying nozzle thus is a device for emitting spray liquid, breaking it up into small droplets and throwing the droplets away from the nozzle orifice. Different designs of nozzle are used to produce appropriate droplet size spectrum. In order to break the liquid into droplets energy is needed. The spray nozzles therefore are classified as:

Hydraulic energy nozzles
Gaseous energy nozzles
Centrifugal energy nozzles
Thermal energy nozzles

Almost all sprayers used for high volume spraying methods are fitted with hydraulic nozzles. The knapsack type low volume sprayers are genrally worked with air blast nozzle or gaseous energy nozzle. The hand held battery oprated sprayers also called CDA sprayers are fitted with spinning disc type nozzle which works on centrifugal energy. Thermal energy nozzle also called hot tube nozzles are used with fogging machines for ULV applications. Recently electrical energy has also been used to produce charged spray droplets for ULV application of pesticides.

HYDRAULIC ENERGY NOZZLES

The hydraulic nozzles are most commonly used spray nozzles for pesticides application. Almost all the hydraulic sprayers use this type of nozzle. The following types of hydraulic nozzles are used for spraying pesticides:

1. Hollow cone type
2. Fan type
3. Impact type

Hollow cone nozzles:

This is a very popular type of hydraulic snozzle for spraying insecticides and fungicide. It produces a hollow cone pattern of spray consisting of mixture of different sizes droplets. In its simplest design this type of nozzle is made of brass metal having orifice hole drilled in it and a rotral with tangential cut grooves provides swrill motion to spray liquid which breaks down into droplet when emerging from the nozzle under pressure. This simple brass nozzle is screwed onto a hand lance/ boom. There are different designs of hollow cone nozzle. Other designs of nozzles consist of a stainless steel disc with a central circular hole through which the spray emerges from a swirl chamber behind it. The disc and the swirl plate (core) are suitably fitted in the body of the nozzle which has threads for screwing (fitting) it to the lance/ boom. The normal working pressure of hollow cone nozzle is about 40 psi.

Hollow cone nozzles are good for treating complex targets because spray particles move in infinite angles and various planes providing better penetration of spray. These nozzles are generally not recommended for herbicide application due to possible drift of fine spray particles and difficulty in obtaining an even distribution of spray across the swath. The variation of liquid pressure can vary discharge rate, spray angle and also droplet size. The nozzles are made from brass, stainless steel and plastic materials. The nozzles tips wear due to chemical corrosion and abrasive action. The stainless steel tips or plastic tips are better wear resistant and help consistant spraying.

Fan nozzle:

They are also called flat fan nozzles. The spray liquid is thrown from an orifice which is elliptical to give a flat shaped sheet of spray. These are used for band spraying. These nozzles are generally used on booms with propor distance in between and overlapping to give even distribution. The normal working pressure is about 40 psi. However these fan nozzles can also be used for herbicide application but the application is done at low pressure like 15 - 20 psi to avoid drift of fine droplets.

Impact nozzle:

These nozzles are also known as deflector nozzles or floodjet nozzles. In these nozzles, the spray liquid emerging from a circular hole strikes an inclined smooth face and is deflected at an angle. The liquid thus spreads as a sheet in a wide angled fan pattern. These nozzles are used for herbicide spraying and are low pressure (15 - 25 psi). The spray pattern essentially consists of coarse droplets.

Adjustable nozzle:

These are also called as tripple action nozzle. They are so called because of varying patterns of sprays that can be obtained by manipulating the swirl velocity of spray liquid in the eddy chamber. The hollow cone spray pattern consisting of fine spray particles, or a jet spray for orchard/ tree spraying and a medium coarse spray petterns can be obtained by simple adjustments. These nozzles are generally used with foot operated sprayers, rocking sprayers or high pressure hydraulic sprayers for spraying trees.

GASEOUS ENERGY NOZZLES

In this type of nozzle spray liquid is injected into a stream of high velocity air. The force of the air streches the liquid to form ligaments which ultimately break into fine spray droplets. The airstream further transports the droplets to the target. The liquid flow into the airstream is metered. Motorized knapsack sprayer or mist blower is fitted with this type of air blast nozzle. The spray droplet size depends upon the nozzle design. The positioning of liquid flow and air velocity is very important. By increasing the liquid flow rate the droplet size also

increases. In larger models of sprayer's hydraulic nozzle atomise the liquid first and then the droplets are further sheared by the air blast. Vertical nozzles also work on gaseous energy for ULV spraying.

CENTRIFUGAL ENERGY NOZZLES

If liquid is fed on fast rotating disc, then it is carried by centrifugal force to the outermost edges of the disc and spray droplets are issued. Rotating cylindering cage of fine mesh also produce fine spray if liquid is fed into it. The revolving speed of the disc or cage is very important for size of droplets. The disc has serrated teeth on the periphery which make droplet spectrum narrow. The physical properties of the spray liquid are important for droplet size besides the speed of rotation. These types of nozzles are generally used for ULV spraying and for L.V spraying methods.

THERMAL ENERGY NOZZLES

Fogging machines work with thermal energy nozzles, also called hot tube nozzles. Spray liquid is injected into stream of hot gases (exhaust of engine) where it vaporises due to high temperature but then it condenses when issued out of the nozzle due to outside temperature and forms fog of fine droplets. Exhaust nozzle sprayers (vehicle mounted) are used for ULV application in locust control operation. Pulse jet engine models are used for pesticide fogging for public health purposes.

SPRAYING TECHNIQUE – I (HIGH VOLUME SPRAYING)

This is very common and popular method of pesticide spraying. The spray solution is prepared by mixing water with pesticide formulation in appropriate quantities. This diluted mixture is sprayed through hydraulic nozzles. The spraying is usually to the point of drip from foliage. In this method large volume of spray liquid is applied. Usually the spraying volume is 300-500 L/ha. The spray volume is not always rigid. The spray volume requirement depends on many factors eg. Sprayer capability, nozzle charecteristics, stage of growth of crop, type of crop etc.

A variety of high volume sprayers are available in the market. Almost all types of high volume sprayers have some kind of pump to supply pressurised spray liquid to the hydraulic nozzle which breaks the liquid into spray droplets and throws the spray away from it. The high volume sprayers are both manually operated or power operated type.

SLIDE PUMP OR HAND SPRAYERS

This is a simple sprayer. It creates hydraulic pressure by forcing spray solution to a nozzle by the direct action of hand pumping. The spray solution is filled in a plastic can (5-10 L) which is usually shoulder slung. A dip-tube draws liquid from the tank due to hand actuation of the plunger. Held by both the hands the piston pump is worked by sliding action. For want of a pressure chamber it is not possible to retain pressure and therefore the operator has to pump continuously without break. Due to constant engagement of both the hands it is difficult for the operator to ensure thorough coverage. Further due to pressure fluctuation the nozzle performance is not stable. The discharge rate varies, spray angle changes and spray droplets size fluctuates. This sprayer is suitable for small scale application in nursery or kitchen gardens etc. It is not a good sprayer for large area treatment. The capacity of this sprayer is about 0.5 acre per day.

STIRRUP PUMP SPRAYER

This is a simple hydraulic sprayer. It consists of hand operated hydraulic pump. The suction part of the pump is immersed in the spray solution kept on floor in a bucket. The pump is operated by hand by one person while the other person holding the delivery line, tigger cut-off device and lance nozzle sprays pesticide. In few models an air chamber is also provided in the pump system which helps continuous spraying. Also in some models provision of hydraulic agitation is made. This sprayer is used both for public health spraying and agricultural spraying purposes.

COMPRESSION SPRAYER

It comprises of a cylindrical metal tank for holding the spray liquid, a hand operated piston type air pump, a filler hole in the tank out let with delivery pipe, cut-off, lance and

hydraulic nozzle. There is metal or plastic skirit as the base of the tank. A pair of adjustable shoulder straps is provided for mounting the sprayer on the back of the operator.

The sprayers with tanks of different capacities are manufactured, but 18 litre capacity sprayers are commonly used for field spraying. The filtered spray solution is filled to 2/3 of the tank capacity. Then the air pump is operated by hand and air pressure (50-60 psi) is built up. The compressed air exerts pressure to move spray liquid to the nozzle via delivery pipe, cut-off device & lance system.

The spray design is strong and strudy. It is also easy to operate. The operater need not pump continuously so that he can divert his attention to better coverage. However, as the pressure cannot remain constant due to gradual decrease of pressure, the nozzle discharge rate changes so also angle of spray and droplet size. This sprayer is not recommended for herbicide spraying due to high initial pressure. The field capacity is 0.75 - 1.0 acre/day.

FOOT OPERATED SPRAYER

The pump of the sprayer is worked by operating a pedal lever by the foot of the operator. It requires two persons to work. The spray liquid is kept in bucket or container and it is sucked by a suction hose through a filter (strainer) due to piston movement. A suitable ball valve is provided in the piston assembly to serve as suction valve. The liquid from the pump cylinder is then delivered into a pressure chamber where from the pressurized liquid reaches hydraulic nozzle. Minimum two person team is required to work on this machine. Hydraulic pressure of 10 kg/cm^2 can be achieved which is necessary to project the jet of spray to tall trees simultaneously from two spray nozzles.

The foot operated sprayer is basically for orchard and tree spraying. The design is strong and strudy. Hydraulic pressure of 10 kg/cm^2 can be achieved which is necessary to project the jet of spray to tall trees simultaneously from two spray nozzles. An adjustable type hydraulic nozzle (Tripple Action Nozzle) is generally used which can generate different types of spray patterns viz., fine spray (hollow cone), medium spray and coarse spray (jet). The fine and medium spray are suited for low height orchards, jet spray are necessary for tree spraying. The spray jet can reach height of 15 - 20 feet. For spraying taller trees an extra extension like bamboo lance may be used to gain additional height by 8 - 10 feet.

It is diffcult to treat field crops by foot sprayers because the sprayer is kept on ground and pesticide solution tank is also kept on ground separately and so movement of the long delivery hose becomes very diffcult.

ROCKER SPRAYER

It is very much similar to the foot sprayer. The main difference is the operation of pump. The pump actuation is done by hand of the operator. The sprayer pump mounted on wooden platform is kept on ground and the spray solution is kept in a separate tank or container. It can develop high pressure 10 kg/cm^2. For spraying tall trees, an extension bamboo lance can be fitted. The adjustable type hydraulic nozzle (Triple Action Nozzle) is normally used.

LEVER OPERATED KNAPSACK SPRAYER

It is commonly known as knapsack sprayer. The sprayer is mounded on the back of operator with help of a pair of mounting straps. The pump of the sprayer is actuated by working a hand lever up and down by one hand of the operator and the other hand holds the cut off device for spraying purpose. This sprayer consists of liquid tank, hydraulic pump, operating lever, pressure chamber, agitator, delivery hose, spray lance and nozzle. A bean shaped plastic tank of 14-16 liters capacity is commonly used. It is necessary to operate the hand lever continuously at the rate of 15-20 strokes per minute. The normal working pressure is 40 psi.

HIGH PRESSURE POWER SPRAYER

These are high capacity power operated hydraulic sprayers. They are the high volume spraying machines good for large scale application in orchards and tree crops. The source of power is engine or electrical motor. A pressure regulator is used to control the pressure in the discharge lines and bye-pass from the pressure regulator is used for hydraulic agitation in spray tank. High pressure like 400 psi can be built up and large spray discharge rate like 30 L/min. can be obtained. The engine or electrical motors 3 - 5 H.P capacity power the sprayer.

SPRAYING TECHNIQUE – II (LOW VOLUME SPRAYING)

The high volume spraying is labour intensive and time consuming. In water scarcity area it is diffcult to practice high volume spraying. Also in situation where large area treatment in very short time is important, the high volume spraying has limitations. The low volume spraying methods essentially reduce quantity of spray solution. Spraying as against 300 to 500 L/ha in H.V. spraying technique is reduced to 50 to 150 L/ha in L.V. spraying technique.

Motorised knapsack sprayer, also called Mist blower is a L.V. sprayer in which gaseous energy nozzle is used for fine breakup of spray liquid. This type of nozzle is also called Air blast nozzle. The force of escaping air at high velocity is utilised to shear down the spray liquid into fine spray droplets. The size of spray droplets depends upon:

1. Air velocity and volume
2. Liquid flow rate
3. Properties of spray liquid

The spray droplets are then blown away from the nozzle outlet. The blast of air disperses the droplets over wide area and helps penetration of spray into the crop canopy. The gyrating movement of droplets in the canopy improves the underleaf depositing of the spray particles.

A two-stroke petrol engine (35 cc capacity) is used as prime mover to run a fan blower. The engine runs usually at 5000 - 6000 RPM and the blower emits at nozzle outlet about 5 m^3 air per minute and at about 170 km/hr velocity.

The spray droplets are about 150 - 220 micron VMD size. The nozzle flow rate can be adjusted by a regulator provided in the liquid line. The regulator can be a variable restrictor type or different size fixed aperture type. The later type is better because in the variable restrictor type regulator, it is difficult to achieve exact repeat application rates. The flow rate up to 2 L/min can be obtained.

The horizontal reach of spray particles (swath) depends upon the type of crop canopy. Thick and high canopy restricts the droplets filtering down over wide area resulting in smaller swaths. However 2 to 4 meter swaths can be achieved. To help ensure constant rate of flow of liquid from the nozzle the spray tank is pressurised by allowing some air from the blower-case via suitable tubes. This tank pressurisation attachment helps vertical throw of spray to a limited extent only and therefore might not be sufficient to spray high orchards and trees. For trees spraying very large volume of air is necessary to carry spray all through the tree canopy and the two stroke 35 cc engine is not enough for this.

While operating this sprayer the engine should be run at full throttle and the operator should take advantage of prevailing cross-wind for wider dispersal of the spray and also to keep away the spray from himself. The spray nozzle should be held and aimed at rows which are about one meter away from the the nozzle and the operator should try to create a little fluttering of leaves to improve coverage. In a day 2 - 3 hectare area treatment is possible with this machine. Since fine particles in concentrated form are sprayed out, the operator should wear adequate protective clothing and he should especially guard against inhalation hazards.

The motorized knapsack sprayer can be converted into power duster also. Then it is called motorised knapsack sprayer-cum-duster. In most of the machines the spray tank itself is used as dust hopper. In such a tank (dust hopper) suitable dust agitator attachment is fixed inside the hopper and dust-ejector tubes are fitted in the outlet of the discharge pipe. It is necessary to avoid compaction of pesticide dust while filling it in the hopper. The rate of flow of the dust from hopper to the discharge tube is controlled by variable restrictor aperture. In some models this is achieved by placing a butterfly type restrictor.

For improving the dust adhering and retension on foliage a useful modification on motorised knapsack duster is suggested. It is called wet dusting attachment. In this modification one small water container (1-2 L) is fitted additionally and a tube suitably is connected to the spray nozzle. During operation, water is sprayed in a form of mist while the dust is also simultaneously discharged. The mist of water creats moistening of foliage and the wet dust sticks well for prolonged period of time. This saves wastage of pesticide and avoids unnecessary drift.

Another useful attachment is a long dusting hose. About 15 meter long thin polythene pipe with suitable perforations is attached to the dust discharge outlet of the machine and thus the dust is emitted now from many holes (perforations) enabling very wide area treatment by pesticide dust.

Besides usual methods of maintenance of sprayer involving cleaning and lubrication, the engine in this equipment has to be properly looked after. The fuel petrol should be mixed with lubricating oil in correct ratio before filling it in the fuel tank.The air cleaner should be serviced regularly. The spark plug should be cleaned to remove carbon deposition and its electrode-gap should be checked and corrected whenever necessary. The engine must not be operated beyond safe recommended speed. The two stroke engine in this type of sprayer is air cooled; therefore the engine cooling is important. The dust and mud if any on the engine must be removed. If the flow of air from the nozzle is not satisfactory, and then it may be necessary to clean the blower fan where dry leaves, cotton waste like materials cause the choking.

For low volume spraying the aircrafts are also used to spray pesticides at 20 - 25 L/ha. Tractor mounted air carrier sprayers are also used for low volume spraying in orchard and tree spraying. For tall tree spraying like Rubber plantation a mist blower type system run by 3 H.P engine and carried by two persons on stretcher poles is available, called turblow-sprayer.

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SPRAYING TECHNIQUE - III (ULTRA LOW VOLUME SPRAYING TECHIQUE)

The ULV spraying is the method of pesticide application at minimum volume to achieve economic pest control. In this technique of pesticide application the volume applied per hectare is less than 5 liters which is extremely low as compared to the conventional High Volume and Low Volume spraying methods.

The spray droplets in ULV spraying methods are very fine in size. Therefore, the nozzles used in these methods are different. Various designs of rotory atomiser are used to generate droplets of 70 to 100 μ VMD. The vortex nozzles produce droplets in aerosol range i.e. 20 μ VMD. For large area ULV spraying as in the case of locust control exhaust nozzle sprayer which is mounted on a vehicle is used where thermal energy of the engine exhaust gases is used to atomise the pesticide liquid in droplets of 20–50 μ. The thermal foggers using pulse jet engines are used for indoor ULV application. The fogging machines are also used by public health personnels for mosquito control.

The rotary atomiser utilises centrifugal energy to break the pesticide liquid into droplets. The range of spray droplet diameter produced by centrifugal nozzle is generally narrow sprectrum. Therefore, this method of ULV spraying with the help of centrifugal energy nozzle is also called as Controlled Droplet Application (CDA).

The movement of extremely fine spray droplets depends upon natural air movement. These small particles usually take long time to settle and very much influenced due to prevailing wind. The spray therefore is not direct type but it is drift spraying. Obviously for small field treatment the pesticide spray may be drifted to outside the target. Thus the drift hazard is always present in this technique of spraying.

The spray droplets which are fine in size are also subjected to higher rate of evaporation due to increased surface area. Therefore, pesticide spraying diluted with water is not recommended for ULV technique. The rate of evaporation increases if the temperature is more. Also the relative humidity influences evaporation. Due to evaporation the effective aquoes droplet size which actually reaches the target becomes smaller and therefore concentrated pesticide droplets are deposited. The extremely fine size droplets may completely evaporate before landing and can cause pollution. It is, therefore, recommended to apply only special ULV formulation which is basically oil-bound and non-volatile. Some authors have reported use of sugar or mollases solution with the EC formulation to reduce the evaporation losses.

A hand held battery operated model of ULV sprayer is very simple and convenient. This sprayer consists of a spray head which includes an electric motor with a spraying disc and liquid container mounted on the spray head, a holding stick, source of battery power and off-on switch. The electrical motor is a 6 V or 12 V DC motor. The motor drives a directly fitted spinning disc usually plastic 2" to 3" diameter revolving at 6000 - 10000 RPM. The spinning disc is very light weight plastic disc flat or cup shaped having fine serrations cut on

its periphery. In certain designs fine feeder channels are also provided on the disc such that the liquid is fed uniformly through these channels to the disc serrations. The pointed edge at the disc periphery serves as zero issue point so that uniform size spray droplets are released from the disc. The pesticide container is usually one liter capacity plastic bottle which is screwed on the spray head. The flow of pesticide from the cantainer is simply due to gravity and depends upon the size of opening provided in the spray head. However, in certain models the rate of flow of liquid can be changed by replaceable orifice plates of different diameter or by changing liquid flow tubes of different size opening. The dry cells (4 or 8 Numbers) or rechargeble storage battery supply 6 V or 12 V DC power to run the electric motor which rotates the the plastic disc. The chemical moves by gravity to the spinning disc and due to centrifugal energy the liquid is broken into very fine spray droplets.The rate of flow of chemical liquid is from 50 to 100 ml/min.

The transportation of fine droplets to the target is achieved due to prevailing wind. The spray droplets are distributed over wide swaths. The effective swath width depends upon the wind velocity and crop growth. Higher the wind velocity, wider the swath of spray. The swath of 2 m to 10 m is reported at different stages of crop growth. Since the total weight of the machine is very less (about 2 kg) the operator can walk swiftly achieving 1 m/sec speed. Therefore, the time required to treat crop area is very less as compared to high volume or low volume methods. One operator can treat 3-4 hectare area in one day with this type of sprayer.

Due to pesticide drift hazard and concentrated form of spraying the operator must be careful. The operator must always avoid wind moving the pesticide spray on to him. The operator should always walk across the prevailing wind direction so that the the spray is always moving away from his body. He should also wear protective clothing like nose and mouth respirator, hand gloves and full length trousers and shirts. The ULV spraying should be avoided in still-wind conditions as the distribution of pesticide is very much reduced and spray particles might drift on to the operator himself. Similarly application should not be made when the wind velocity is more than 12 km/hr. This spraying is better done in wind velocity between 3-10 km/hr

The ULV spraying is good in dry land areas where water is scare and therefore conventional high volume spraying is not feasible. This technique is also called waterless spraying due to special ULV formulations. But as the ULV formulations are not available, the advantage of this method is not being availed at present.

The speed of rotation of the disc depends upon the battery condition. The run-down or used up battery are of no use as they cannot run the electric motor at proper speed. The spray droplets size tends to become large if the rotational speed of the disc is reduced. The speed should not come below 4000 RPM otherwise the droplet size shall increase drastically which will effect the coverage and swath width. A set of battery can last for 8-10 hours of spraying time. But the life of battery really depends upon the quality of electric motor. Some electric motors consume more power and hence less battery life. Usually these electric motors

consume 3 - 8 W of power. If rechargeble battery is used to run the motors then it should be kept fully charged.

ELECTROSTATIC SPRAYING

The conventional high volume spraying is labour intensive and time consuming process. The hydraulic nozzles produce wide spectrum of spray droplets and more than 40 - 60% of sprayed pesticide does not really deposit on the foliage. Neither the very small drops nor very big drops are useful due to drift and run off problems. The Controlled Droplet Application (CDA) method improves pesticide deposits and lower application volumes of less than 5 L/ha can be achieved. The ULV application method has serious problem of pesticide drift too.

The electrostatic spraying system reduces the application volume substantially and greatly improves pesticide deposites. The liquid atomisation is achieved by utilizing electrostatic forces. The spray particles of about 50 μm size having high electrostatic charge are issued from the nozzle. It is reported that the depositing increases by three times, or more. This system has great potential.

By imparting electrostatic charge to spray droplets of hydraulic nozzles and spinning disc nozzles also depositing improves much. There are following three systems of electrostatic charging of sprays:

1. Corona charging
2. Contact charging
3. Induction charging

A high voltage pointed electrode issues ions of similar polarity to the liquid droplets which become electrically charged. The sprays from hydraulic nozzle and rotary nozzle can be charged by these methods. The electrostatic application of paints industrially is also based on Corona charging.

In Contact charging system the high voltage potential is directly connected to the nozzle or to the spray liquid system. The electrical charge transfer occurs by conduction to spray liquid and finally to the spray droplets during disintegration. This system works well with the conductive liquids. The total system needs very good insulation.

In the Induction charging system the electrical field force is used to charge the spray droplets. This system needs good insulation between the conductive liquid and the charging electrodes.

The Electrodyne sprayer (developed by ICI) is good for electrostatic charged spraying of pesticides. A high potential of 13 to 24 KV is applied to the spray head having pesticide bottle and electrodyn nozzle combination (called BOZZLE) resulting in dis-integration of

spray in very fine charged droplets of 30-50 μm size. The application volume is drastically reduced to 0.5 to 1.0 L/ha besides much improved deposition of pesticide. The charged droplets leaving the nozzle repel each other owing to similar charge and thereby forming spray cloud. These charged droplets are readily deposited to foliage being earthed object.

The power requirement is met by 6 V DC (4 torch cells) sources which are multiplied to 24 KV by a solid state electronic generator. The power consumption is very low. The collection of spray is so efficient that penetration into the canopy can be poor. The nozzle is held 40-50 cm above the crop canopy. Because of good depositing properties, the drift of pesticide is very minimum, so also the wastage.

ADVANTAGES OF ELECTRODYNE SPRAYING

1. Better deposit of pesticide
2. Minimum drift losses/wastage
3. Low power consumption
4. Narrow spectrum of droplet size
5. Labour and time saving
6. Minimum volume per hectare

LIMITATIONS OF ELECTRODYNE SPRAYER

1. Top few leaves are deposited heavily but not the lower leaves.
2. Good for broad leaf crops and not so efficient for narrow-leaf crops like paddy.
3. Special Electrodyne formulations are suitable.
4. Electrodyne formulations of various Pesticides are not available.

DUSTERS AND DUST APPLICATIONS

The dusting powders are low concentration ready to use type, dry formulations containing 2 to 10% pesticide. The inert material or dry diluents is talc, soapstone, attapulgite, etc., and it is non toxic. The sulphur dust is not diluted with inert material.

The advantages of pesticide dusting application are:

1. Ready to use product reduces field tasks concentrate handling and further dilution (as in case of spraying)
2. In dryland agriculture where water is scare.

But the important disadvantage is pesticide drift. The fine dust particle cause serious drift problems and the operator and field labourer are exposed to dermal and inhalation hazards, besides pesticide being carried to neighbouring field/area and causing pollution. This is the main reason why the herbicides are not formulated as Dusting Powders. Precise metering and even distribution of dusting powders in field conditions is very difficult.

The dusts are applied at 20 - 50 kg/ha. It should be noted that the application is done in highly concentrated form, as compared to high volume or low volume spraying technique. Therefore, adequate precautions must be taken in handling the dust and during the application in field. The dusters are available both manually operated and power operated models.

MANUALLY OPERATED DUSTERS

PLUNGER DUSTER:

They are very simple, low cost machines and useful in a limited way. The field application capacity is low. They hold 200 to 400 g of dust in a chamber into which air is pushed by an adjoining piston type air pump operated by hand. The dust cloud is issued from the discharge outlet.

BELLOWS TYPE DUSTER:

This is also a simple design low cost dusting machine. A collapsible bellows pushes air into a dust hopper of 1-2 kg capacity and dust is discharged from the nozzle outlet.

HAND SHAKE DUSTER:

This too is low cost very simple equipment which can be locally made by village artesian. It is particularly good for spot application of dust in rice crop and BPH control. These dusters are good for small scale application and spot treatment and they do not cause much drift problems, metering lacks in these equipment.

HAND ROTARY DUSTER:

This type of duster makes use of a fan or blower to flow large volume of air at high speed. The dust powder is fed into the stream of air and blown from the outlet tube. The fan or blower rotates at high speed by hand cranking handle, which is geared to it. The higher gear-ratio and better blower design provide easy cranking and good volume of air is emitted. The dust hoppers are generally cylindrical and are provided with agitator, feeders and dust metering mechanism.

Such rotary dusters are either shoulder slung type or belley mounted type. The shoulder-slung models are better balanced when the dust hoppers are filled. But it becomes inconvenient to operate in crops like sugarcane and cotton. The belley mounted type can be used in such situations. A hand rotary duster can discharge dust powder from 0 – 150 g/min and displace air about one m^3/min at 35 RPM. Such machine can treat 1 to 1.5 ha /day.

POWER DUSTER

These are bigger machines run with the help of engine or electrical motor. Some power dusters are tractor mounted type and are driven by tractor P.T.O. The equipment is mounted on iron frame (stretcher) and can be carried by 2-3 men. The engine/motor drives a centrifugal fan usually via V-belt drive. The engine is petrol/ diesel run and 3 - 5 H.P. The fan displaces 20 m^3 air/min or more at 100-250 km/hr air velocity. These dusters are good for large area treatment and suitable for application on tall trees. In this type of duster design, usually the dust powder is not rotated in the fan-case but dust powder is aspirated in the delivery channel by air blast. The dust hopper capacity is 10-20 kg and dust can be discharged at a rate of 1 to 8 kg/min. A power duster can cover about 10 ha/day.

KNAPSACK DUSTER

The motorised knapsack sprayer can be converted to a duster by replacing some plastic fittings inside the hopper. Almost all mist blowers have provision of converting them from spraying unit to dusting unit. The two stroke petrol engine runs a blower fan and delivers the air through a hose pipe system. The dust is agitated and lifted by the blast of air in the hopper and it is fed into the main air hose or a long dusting hose (40-50 ft long polythene perforated hose) can also be attached to knapsack duster. Such an attachment is very good for large area treatment in less time. The dust output can be adjusted from 0 to 1.5 kg/min. The motorised knapsack sprayer-cum-duster unit is therefore useful for both low volume spraying and dusting operation.

PRECAUTIONS:

The dusting powers are very finely divided particles which can remain air-borne for long time and can drift far distances. The fine particles can very easily enter into body system by inhalation. Therefore, the operator should wear protective clothing. He must cover his

nose and mouth in order to avoid inhalation of pesticide drift.The operator should never operate against the wind direction. Also if the wind velocity is more or wind turbulance exists, the dusting application should not be done.It is better to apply the dust power in early morning hours and in late evening hours, avoidind the mid-day and afternoons.

MAINTENANCE:

The dry and well sieved dust power should be loose filled in hopper. It should not be hand compacted. The dust powders often absorb atmospheric moisture and clods are formed, such clods should be crushed before filling into the hopper. After the completion of the work the dust powder should be removed from the hopper carefully. The dust materials which still remain in the hopper, feeders, discharge tube should also be removed by briskly cranking and blowing action. Finally, a dry brush should be used to dust off from inside the hopper, etc. The lubricating oil should be applied on moving parts e.g., gearbox, crank handle, agitator, fan bearing, etc.

SOME SIMPLE PLANT PROTECTION EQUIPMENT FOR FARMERS

A few simple plant protection techniques and equipment were developed at the National Institute of Plant Health Management, Rajendranagar, Hyderabad for adoption by small farmers in application of pesticides efficiently in order to protect their crops and stored food grains. The details of their design fabrication and use are explained below.

HAND SHAKE DUSTER:

This is a simple device to apply pesticide dusts. This is useful in pesticide dust application in low height crops. The brown plant hopper is a serious pest in many parts of the paddy growing areas. This equipment is well suited for pesticide application for control of brown plant hopper in paddy crop.

It consists of a metal container cylindrical in shape with 5½" diameter and 7" long. At its bottom, one covergent and divergent cones are fitted. The duster is provided with suitable handle on top with galvanized iron wire. The total length of the duster is 30". Sufficient number of perforations are made alround the container at its lower end and on the bottom case. The divergent cone which is inside the container helps to push quickly the dust through perforations. The bottom cone helps in keeping the duster away from the soil and water in the paddy fields. The dust hopper can contain about 2 kg dust. The dust is emitted by shaking the duster by hand, in twrilling or up down jerk motion.

Brown plant hoppers generally harbour at the lower portion of the paddy crop and hand rotary duster usually fails to apply the dust at the bottom of the crop. Hence, this device is very useful for the farmers. This is cheap and can be fabricated by local tinsmith. It costs about Rs. 100/- or so. A farmer can cover one acre of paddy in a day with the help of this duster. This could be utilised for other crops as well.

WET DUSTING EQUIPMENT FOR DRY LAND CROPS:

A low cost equipment for wet dusting on crops was devised. It is particularly suitable for dryland crops. The losses in dust application due to drift is minimised. Wet dusting is more effective and economical to farmer than mere dusting on crops. A small hand operated sprayer of two litres capacity is amounted on the lid of the shoulder mounted rotary duster. On the top of the duster's outlet, one spray nozzle was provided to issue water spray. The nozzle was connected with a long hose pipe from the outlet of sprayer which is kept on the duster. In this process the dust particles becomes wet when released from the duster and also the leaves and other plant parts become wet and the dust depositing is improved. The operator of the duster carries the duster and sprayer combined. He operates the crank of the duster. The sprayer's trigger is made on with the help of latch and the spraying of water takes place continuously. Four kgs of dust needs two litres of water for the wet dusting operations effectively.

This equipment is more useful for dryland farmer when there is water scarcity always. The cost involved in conversion of the sprayer and duster for wet dusting cost to Rs. 100/- being the cost of plastic pipe and clamps etc. This equipment can be used for simultaneous spraying and dusting of two pesticides if they are compatible.

WICK APPLICATION OF HERBICIDES TO KILL WEEDS IN ROW CROP:

Herbicides are modern tools in Agriculture for the control of weeds in crops. But the application of herbicides needs proper knowledge and skill on the part of farmer. Further the farmers should require a good sprayer, nozzle and understand the pressure, discharge, calibration and proper coverage aspects; otherwise the herbicide application might not be very useful.

In order to make herbicide application easier and less hazardous, one simple equipment was designed. This is called as "Wick Applicator "of herbicides. Herbicides kept in the tank come down through wicks and when the wet wicks touch the weeds, the herbicide acts on weeds with the result weeds are killed.

The equipment consists of one herbicide tank, one wick chamber and wicks. This is mounted on wheel push hoe or sliding push frame. Some portion of the cotton wicks is inside the herbicide tank and a small length is hanging outside. The herbicide solution trickles down through these wicks. This equipment is pushed in between the rows of crops and the wicks wet by herbicide apply it on weeds for control. There is no danger of drift and futher it is cheaper when compared to sprayer.

SWING SACK GRANULAR APPLICATOR:

Many pesticides are now available in granule formulation. These granules are to be applied carefully. Since the cost of granule pesticide is considerable, they have to be applied precisely. There should be even distribution in the cropped area.Generally pesticide granules are brodcasted by hand. However, granules are applied in furrows, on spot and broadcasting methods.

The device namely swing sack applicator has been developed for granule application. It consists of a canvas sack to keep granule (2 – 3 kg). The bag has a strap so that it could be hung to the shoulder. To the end of the bag, one 2 feet long conduit pipe is attached. The pipe has an issue head with a hole at its end. The hole determines the discharge. Two or three kg granules are loaded in the bag and bag is held in position with the strap on the shoulder. The operator holds the conduit pipe and begins to swing it. The granules are issued forcibly from the head and distributed over the area. A metal needle (4" long) is provided inside the bag at conduit pipe junction to cause agitation of granules and allow easy flow.

This equipment is very simple and low cost. It can be made locally. This is very handy for the farmers to apply granular pesticides on crops uniformly.

SPRAY DROPLETS, SAMPLING AND MEASUREMENT

The proper application of pesticides is essential for the control of the crop pest. Besides, the correct and quality pesticide and timely application, the quality of the application has main role in the success of pest control. The even distribution of the pesticide in appropriate dosage and its correct placement on the target is essential.

Any sprayer nozzle essentially breaks the liquid into small droplets and throws them. All nozzles in the field produce ranges of droplets of different size called spray spectrum. The hydraulic nozzles have wide range of size of droplets whereas the rotary nozzles have narrow range.

A droplet of 400 µm diameter is 1000 times bigger in volume than a droplet of 40 µm. The volume of spherical droplets can be worked out as $4/3\ \Pi\ r^3$. So if the droplet size of a spraying system could be reduced to half, then there will be 8 fold increases in the number of droplets and the coverage will also increase.

Theoritical number of droplets per cm^2 area at one lit/ha:

Droplet diameter (µm)	**No. of drops/cm^2**
35	512
70	64
140	8
280	1

It is very difficult to define the optimum size for field application due to diversity of targets. But on an average the smaller droplets are more effective.

Different target and optimum droplet size

Flying insects	1 - 50 µm
Insects on foliage	30 - 50 µm
Foliage soil (and avoidance of drift)	250 - 500µm

The droplets collection efficiency of surface is indicated as:

$$E = d^2v/s$$

The droplet diameter (d) and the velocity (v) have direct effect on the deposit efficiency, whereas the size of the objects has inverse effect. Smaller objects e.g. legs and antenna of insects receive heavier deposit of smaller droplets.

The small droplets mostly deposit by impaction and the large droplets by sedimentation. The transport of very small drops is subjected to interaction between cross wind and gravity. So very small drops follow long trajectary than do the large drops. The small drops unable to settle on the target drift down the wind and cause pollution. The bigger drops fall down rapidly and small drops fall down slowly. In other words, small droplets remain airborn longer and therefore fall trajectory is affected by air movement. The cross wind influences the distance travelled by droplets before depositing.

$$S = \frac{HU}{Vt}$$

Where S, the distance travelled (drifted), is directly proportional to H - Height of release and wind velocity U and inversely proportional to Vt - terminal velocity of droplet. The terminal velocity of droplets is the respective constant rate of free fall attained after initial travel of small distance. Accordingly, a 10 µm droplet can travel 2 km distance when the wind velocity is 2 m/sec and the height of release is 3 m.

The air born water droplets are subjected to evaporation. The small droplets have overall increased surface area helping the rate of evaporation. Besides, higher temperature and low humidity also increases the rate of evaporation of very small droplets. Therefore, the ULV spraying needs special oil formulation to avoid evaporation and subsequent drift.

All spray nozzles in the field produce admixture of droplets, always too many small droplets than bigger droplets. But the volume of all the small droplets put together is less than the volume of few large droplets. Therefore, the bigger droplets assume importance when defining the effective diameter of droplets as far as pesticide distribution is concerned.

The median size of droplet spectrum is commonly called Volume Mean Diameter (VMD). VMD of a spray sample is that which divides the spray sample into two equal volumes one containing droplets bigger than the VMD and the other containing droplets smaller than the VMD.

To find out the VMD, the spray sample is collected and minimum 200 droplets are actually measured and counted size wise. A curve line of commulative volume is plotted on graph against the droplet diameter. The droplet diameter corresponding to 50% volume point is VMD.

The pesticide distribution of any spraying system can be assessed as:

1. Quantitative assessment
2. Qualitative assessment

For most field work the qualitative assessment is enough which can indicate the droplet reach, penetration in canopy and droplet deposit density. But for accurate study of pesticide quantity deposit ($\mu gm/cm^2$) the quantitative assessment is needed.

The spray droplets can be collected on natural surfaces and other artificial surfaces too. But collecting droplets on natural surface is obviously difficult as leaves are usually water repellant and the droplets coalition takes places. So there are special papers available for this purpose. Water sensitive paper has a yellow coating which turns blue whenever water droplets deposit. The blue stain size corresponds to droplet diameter. This is good for qualitative assessment, but has limited use for VMD measurements. Kromekote paper is another specially coated paper collecting coloured droplet stains. The soluble dye is added to spray mix suitably and sprayed on the Kromekote paper which leaves measurable stains. This too is good for qualitative assessment and as well for quantitative assessment if the spread factor is correctly worked out.

The droplet samples can be collected on microscopic glass slides. The droplets can be collected on slides coated with oil or grease which help droplets maintain their convexity. The magnesium oxide (MgO) coated glass slides if exposed to spray droplets retain circular craters on the MgO surface, which can be observed and measured by microscope.

The droplets collected on any surface are not spherical but often circular stains/craters which are bigger than the original droplet diameter. The ratio between the true diameters of the drop to the stain diameter is called spread factor (SF). The SF is different for different surfaces. The SF for MgO coated slides is 1.2 and it varies from 2 to 6 in the case of Kromekote paper. The white glossy photographic paper after developing is also a good substitute for Kromekote paper.

The spherical droplets for direct true diameter measurement can be collected in grease matrix. The grease matrix can be prepared by mixing Petroleum Jelly with liquid paraffin. The droplets after depositing on the matrix should be covered by thin layer of paraffin to avoid evaporation.

A compound microscope is used for observing the droplets or stains/craters and a stag micrometer is necessary for linear measurement. An occular grid in the eye piece helps the measurement. A mechanical stage is also necessary. The linear measurement has got to be corrected with the spread factor to arrive at the true diameter of the droplets.

The Laser Beam Particle size Analyser is modern equipment for droplet analysis. This method is the quickest and reliable. The spray from the nozzle is realeased to pass through a laser beam which when cut by the spray droplets of different sizes is difracted and a particular image is formed on the sensitized surface. The difracted images formed on the sensitized surface relay signals to a computer programmed for analysis. The VMD and various other information can be computed in this way. This is very sophisticated and expensive equipment.

CALIBRATION OF SPRAYER

The rate of application of pesticide should be uniform over the whole of the field area. Too much application as well as too less application of pesticide dose is both undesirable.

Too much application - Wastage, crop injury, uneconomical
Too less application - Poor pest control, wastage of pesticide, time and money

The pesticide distribution by any sprayer is regulated by:

1. Nozzle spray discharge rate
2. Swath width
3. Walking speed of operator

Some equipment manufacturers provide tables about use and capacity of their equipment. But it is difficult to always fully relay on such tables. As the sprayer gets old the pump and the nozzle also wearout. The performance of sprayer then changes and rate of application becomes different. The calibration of sprayer, therefore, is essential to make sure that the pesticide is applied correctly and evenly. The sprayer should be checked and calibrated frequently.

There are many methods described for calibration of sprayer. The sprayer can be calibrated theoretically and practically in the field. It is good to frequently verify the correctness of theoretical calibration with field practical calibration.

A very simple and easy to remember formula is

$$F = \frac{SDA}{10000}$$

Where F - flow rate in L/min (This represents flow rate from all the nozzles of sprayer if they are more than one. But if there is only one nozzle, then flow rate from one nozzle only)

S - Swath width in meter
D - Operator's walking speed in m/min
A - Application rate in L/ha

The above formula is useful for calibration of any type of field spraying system ie. high volume, low volume, ultra low volume, tractor mounted sprayer or aerial spraying. If any three variables in this formula are known, the value of the remaining fourth variable can be found out.

SOME WORKED EXAMPLES

I. A knapsack sprayer discharges 600ml liquid every minute and sprays one meter swath. If the operator walking speed is 30 m/min., what is the rate of application in L/ha?

F = 0.6 L/min; S = 1 meter; D = 30 m/min A = ?

$$A = \frac{Fx10000}{S\ D}$$

$$= \frac{0.6 \times 10000}{1 \times 30}$$

= 200 L/ha

II. A motorized knapsack sprayer is to be used for spraying at 100 L/ha. The discharge rate from the nozzle is 1.2 L/min and the operator walking speed is 30 m/min. Find out the swath width.

F = 1.2 L/min; S = meters?; D = 30 m/min; A = 100 L/min.

$$S = \frac{Fx10000}{A\ D}$$

$$= \frac{1.2 \times 10000}{100 \times 30}$$

= 4 meters

III. A battery operated ULV sprayer has to spray at 10 L/ha. If the operator walks 1 m/sec and the swath width assessed is 3 meters, find out the flow rate of the sprayer?

F = ? L/min; S = 3 meters; D = 60 m/min; A = 10 L/ha

$$F = \frac{SDA}{10000}$$

$$= \frac{3 \text{ X } 60 \text{ x } 10}{10000}$$

= 0.18 L/min or 180 ml/min

The nozzle discharge rate, swath width and the walking speed of the operator can be found out without much difficulty and thus the application rate in L/ha can also be theoretically calculated. This way of calibration will help in planning for quantity of water required, mixing tank/buckets, time required, etc. But it is futher necessary to let the operator actually spray a part of the field and calculate the rate of application. This will be more realistic as the operator will have to work in the field conditions.

For this practical field calibration a small area is demarked, say 100 m^2 (10 x 10 m). The sprayer is filled with a known volume of water, say 5 liters. Then the operator sprays this area uniformly and evenly. Afterwards the quantity of water still remaining in the sprayer is measured by a jar, say it is 2 litres. The quantity of water sprayed can be found out. In this case 5-2 = 3 liters sprayed in 100 sq meters. For one hectare or 10,000 sq meters, volume needed is 300 liters. This is the practical way of calibration and is very reliable. Before taking up spraying this procedure should be followed.

For very large area spraying the theoretical calibration and practical spraying calibration both should be done, as in the case of tractor mounted sprayer or aerial sprayer. But for small area treatment the field practical calibration method is enough and satisfactory.

The pesticides are generally diluted before field application. For high volume spraying or low volume spraying the pesticide formulation is diluted with water. The pesticide dust formulations are ready to use type as they are already diluted with inert material like talc to a low concentration eg. 2D, 5D, 10D. Similarly pesticide granule formulations are also 5G, 10G concentrations.

The pesticide application recommentations are usually in terms of active ingredient (a.i) or % concentration (0.1%, 0.05% concentration) and sometimes in parts per million (100 ppm, 200 ppm). It is essential that the pesticide is applied in exact quantity as per recommendation.

After calibration of the sprayer the next stage is making spray mix. How much quantity of the formulation should be mixed with water? There are different formulae for this calculation. However it is calculated very easily by simple steps.

FEW EXAMPLES

1) 25 EC, xyz herbicide is recommended to spray at 1.5 kg a.i/ ha. Find out quantity of formulation and water required to spray 2 ha area at 500 L/ha?

Spray solution volume required for 2 ha area = 2 x 500 = 1000 liters
a.i. required for 2 ha = 1.5 x 2 = 3.00 kg. a.i.

xyz herbicide is 25 EC which means there is 250 gm a.i in 1000 gm of the formulation. That is,

250 gm a.i in 1000 gm formulation

$$3000 \text{ gm (3 kg)} = \frac{1000 \times 3000}{250}$$

= 12000 gm or 12 kg

Assuming the specific gravity as one, formulated herbicide 12 liters is needed be sprayed.

Volume of solution needed = 1000 liters
Volume of pesticide to be mixed = 12 liters
Volume of water needed = 988 liters

2) Insecticide ABC 35 Ec is recommended for spraying at 0.07% concentration solution. How much formulation is required to be added to water to spray one hectare area with 100 liters water?

1% is 1 part in 100 parts
0.1% is 1 part in 1000 parts
0.01% is 1 part in 10000 parts
0.07% is 7 parts in 10000 parts, or 7ml in 10000 ml (10 L)
So 70 ml (a.i) in 100 L
As 35 EC is 35 ml a.i in 100 ml formulations

So, 70 ml a.i will be in $\frac{100 \times 70}{35}$ = 200 ml formulation.

3) A fungicide xy 50 WP is recommended for spraying at 200 ppm. How much of WP formulation is required to mix to treat 1.5 ha area at 400 L/ha?

Quantity of solution required for treating 1.5 ha @ 400 L/ha = 400 x 1.5= 600 L

In terms of ppm means parts per million,

200 ppm means

1000000 parts of solution contain 200 parts (a.i)
So, 600000 ml (600lits.) should contain 200 x 6 = 120 ml a.i

50 W.P is 50 gm a.i in a 100 gm formulation
So, 120 gm a.i will be available in 240 g formulation.

4) 2D abc dust formulation has to be applied to 0.75 ha at 300 g a.i per ha. How much of dust formulation should be applied?

a.i. to be applied in 0.75 ha. = 300 x 0.75 gm. = 225 g
2D formulation has 2 parts a.i in 100 parts of formulation

So 225 g a.i will be there in $\frac{100 \times 225 \text{ g}}{2}$ Formulation = 11.250kg

The mixing of pesticide should be done very carefully. It involves handling of concentrated formulations. It is good to wear hand gloves while opening pesticide container, pouring/measuring the formulation and stirring the solution. If the concentrated formulation spills on hand or other body parts, it should be washed off throughly with water immediately. The measurement of small quantity of formulation should be done with the help of measuring cylinder. The mixture should be stirred with a long stick and never by hand.

For preparing spray mix with wettable powder, first prepare a paste of required quantity of wettable powder with small quantity of water and subsequently add this paste to the desired quantity of water and stirr well. To help uninterrupted spraying always use clean water and use filter when filling solution into spray tank.

The spray solution should not be prepared more than what can be sprayed during the day. The pesticide effect of dilute solutions becomes less if solution is left overnight.

CARE AND MAINTENANCE OF PLANT PROTECTION (PP) EQUIPMENT

I. GENERAL MAINTENANCE:

1) Clean outer surface with brush or cotton waste by using kerosene oil or plenty of water.
2) Oil the moving or rubbing surfaces of parts with lubricating oil (SAE 30) or grease, if needed.
3) Filter or strain the chemical solution/ fuel oil mixture while pouring into the tanks. Make the caps or lids leak-proof with gaskets.
4) Flush the equipment with clean water to wash inside parts of containers, tubes and nozzles to be free from chemicals.

II. CARE AND UPKEEP OF HAND SPRAYER & DUSTER:

1. Dry and sieved dust should be used for dusters.
2. Grease the duster gear box once in a month.
3. Clean the duster after the work by removing all dust from the hopper.
4. Oil the cup washers and bucket washers of sprayer frequently.
5. Spray tank discharge lines and nozzles should be flushed with clean water after the day's work.
6. Lances and nozzles should not keep on the ground. Nozzle parts should be cleaned with a brush.

III. CARE AND UPKEEP OF POWER SPRAYERS AND DUSTERS:

1. Lubricating oil level should be checked and maintained in four stroke engines daily.
2. Mixture of engine oil and petrol in correct proportions should be used for two stroke engines, duly stirred and strained.
3. Clean the Air and Fuel filters with petrol frequently.
4. All the nuts and bolts should be tightened once in a week.
5. Check up the pressure gauges and safety valves frequently.
6. Drain the fuel tank after the day's work.
7. Stop two stroke engines by closing the petrol cock.
8. Belts should be kept tightened always, to be free from slip and slackness.
9. Keep proper inflated pressure in the tyred wheels of power sprayers.
10. Rubber tyre equipment should be rested on steel props when stationed.
11. Rubber hoses should not be bent at angles and dragged on the ground.
12. Equipment should be stored in clean, dry, cool store room.

IV. CARE AND UPKEEP OF PP EQUIPMENT WHEN NOT IN USE :

1. Plant Protection Equipments should be arranged properly in a store house. They should be protected from sunlight.
2. Equipment of one category should be kept at one place and not in a mixed up fashion i.e., do not dump the equipment.
3. Attachment like discharge lines, lances, and nozzles should not be kept attached to the equipment.
4. The equipment should be cleaned with cotton waste every day and polished once in a month.
5. The rubber/ plastic delivery hose should be coiled forming a big circle instead of small spool. Otherwise the hose pipes break or crack when they are straightened.
6. All nozzles should be kept neat and clean separately.
7. The moving parts and washers are to be oiled or greased well once in a week.
8. The equipment should be tested for its normal performance once a week. Even the engines should be run for a short while.
9. The equipment in store should be classified and labeled to indicate its conditions as:
    i) Working condition
    ii) Needs servicing & repairs
    iii) Needs parts & repairs
    iv) Not serviceable
10. Rubber tires should be inflated regularly or they should be jacked and propped.

V. CARE AND UPKEEP OF PP EQUIPMENT WHEN TAKEN TO FIELD :

1. Always carry tools required for attending to field troubles.
2. Carry some spares like washers, filters, gaskets & pins to the field.
3. Carry small quantity of kerosene, petrol, engine oil, grease, cotton waste, and containers.
4. Carry the Plant Protection Equipment properly and carefully.
5. Do not drop the equipment or attachments on the ground.
6. Clean the equipment before and after work is over.
7. Flush the equipment with clean water, after work is over.
8. Oil the moving parts and apply grease on gears and in grease cups.
9. Filter the chemical liquids and fuel oil mixtures before filling.

VI. CARE AND UPKEEP OF PP EQUIPMENT IN TRANSPORTATION :

1. All knapsack equipment should be carried on operator's back, for short distances.
2. All the rubber tiered equipments should be pulled on roads with full inflation in the tier.
3. For longer distances, the equipment should be packed in a crate or box. The accessories should be dismantled and packed separately before placing in the box/ crate.
4. Secure literature like parts catalogue, servicing manuals and special tools etc., for the equipment and keep them handy for ready reference.

TOOLS AND MATERIALS FOR FIELD STAFF

TOOLS:

Minimum tools to be provided for the field operating staff (Field man, Masteries, Village Level Workers, etc.,) for servicing and maintenance of Plant Protection Appliances are:

1.	Double end spanners (7 Nos.)	1 set
2.	Adjustable wrench 9"	1 no.
3.	Screw driver (small) 4"	1 no.
4.	Screw driver (big) 8"	1 no.
5.	Cutting plier 6"	1 no.
6.	Nose plier 6"	1 no.
7.	Feeler gauge	1 no.
8.	Hammer 1/2 lb.	1 no.
9.	Spark plug spanner with rod	1 no.
10.	Servicing brush 1"	1 no.
11.	File 8"	1 no.
12.	Trays 2 sizes	2 nos.
13.	Oil can	1 no.
14.	Measuring can 25 ml.	1 no.
15.	Measuring can 50ml.	1 no.
16.	Funnel with strainer	1 no.
17.	Canvas tool bag	1 no.

OTHER ESSENTIAL MATERIALS (approximate quantities)

1.	S.A.E. 30 oil	100ml.
2.	Emery paper rough/fine	1 piece each
3.	Cotton waste	100 g
4.	Packing rope (Asbestos)	50 cm (200 g)
5.	Winding/ locking wire	Some loose
6.	Sharp Needle	1 no.

STANDARDISATION AND TESTING METHODS OF PLANT PROTECTION EQUIPMENT

The object of proper pesticide application cannot be achieved without good quality Plant Protection Equipment. A well designed machine shall be efficient as far as pesticide distribution and delivery to the target in minimum time with minimum wastages is concerned. Therefore, the machines should be tested to ascertain that they are:

- Efficient
- Reliable
- Long lasting
- Comfortable to operate
- Minimum field problems

The machines should meet certain minimum requirements of performance, efficiency and reliability. For this it is essential that standard specifications are laid down so that it will have the above said qualities. The equipment standard specification parameters are:

Material of construction
Dimensions
Ergonomics
Stability
Safety
Interchangeability
Performance
Strength, Reliability
Workmanship, Finishing

Besides the equipment, the components of the system should be standardized and tested such as:

Nozzles, Cut- off devices, Lances etc.

The Bureau of Indian Standards (BIS) has prepared standard specifications in respect of compression sprayers, knapsack sprayers, foot sprayers, rocking sprayers, motorized sprayers, hydraulic nozzles, cut-off devices and spray lances. Also the BIS have prepared standard specifications on Calibration methods, Handling of pesticides, and Methods of Testing.

Some important aspects of the specifications and testing methods are as under:

1. Compression sprayer:

The routine specifications of material of construction, dimensions, workmanship are included. As the tank of the sprayers is subjected to high pressure, a tank fatigue test is recommended. The spray tank is pressurized by hydraulic force and depressurized. Such 1200 cycles of pressurization are imposed on the tank during which it should not leak. Similarly the impact strength of the sprayer is tested by dropping the filled and pressurized sprayer from a given height in different positions. Also the straps are tested for supporting the weight of the sprayer when it falls from a certain height.

2. Knapsack sprayer:

Besides the material of construction, dimensions, capacity, other aspects of performance are specified. The volumetric efficiency of the pump should be above 80%, the ratio between the pump volume per stroke and the pressure chamber volume should be minimum 1:8. The operating lever movement for full pump stroke should not be more than 35^0 for each movement i.e. upward and downward. The pump discharge rate at 16±1 stroke per minute at 40 psi pressure should be minimum 500 ml/min. The reliability test for 48 hrs continuous working of the sprayer is also recommended.

3. Foot sprayer & Rocking sprayer:

The specifications in respect of material of construction, dimension, workmanship and finishing are standardized. The volumetric efficiency of the pump should be minimum 80%. Other parameters like discharge rate test, ratio of volume and pressure chamber volume, leakage test etc., are considered. The reliability test of 48 hrs of continuous working of the sprayer is recommended.

4. Motorized sprayer:

The spraying systems except the engines are covered in the specifications. The usual specification of material, dimension, capacity, discharge rate is standardized. The air delivery volume and velocity of air at nozzle are also specified. The reliability test and fuel consumption test are recommended.

5. Hydraulic nozzle & Spray lance:

The spray discharge rate and other physical parameters viz. spray angle and spray distribution pattern are specified. The nozzle tip abrasion test is also recommended to ascertain the reliability of performance of hydraulic nozzles.

6. Cut -off device:

The reliability test of cut-off device for 5000 cycles of operation spraying with fine silica powder (abrasive) is recommended. The test for measurement of effort to actuate the lever of the trigger is also specified.

For the above described testing of the Plant Protection Equipment and components the following test rigs are used:

1. Tank fatigue strength test-rig
2. Knapsack sprayer test-rig
3. Spray pattern test-rig
4. Nozzle abrasion test-rig
5. Cut-off device test-rig
6. Impact strength test-rig

PROBLEMS OF MAINTENANCE AND REPAIRS OF PLANT PROTECTION EQUIPMENT

Plant protection machines in general are not well maintained regularly either in godowns/ depots where they are stored or in the field where they are used. Life of a machine depends entirely on its care and maintenance. Even though machines are made with high standards of skill and workmanship, they can easily be ruined due to improper care and maintenance. Good and constant performance from machines can be obtained only when they are used and serviced periodically. The purpose of maintaining a machine is for increasing the useful life of the machine and to be available in working order whenever put to use. The maintenance of a machine involves proper care, operation, servicing, repair and keeping it in good working order.

MAINTENANCE:

Normal maintenance jobs include cleaning the equipment and applying necessary lubricating oils and greases to the rubbing and moving parts. If this normal maintenance is neglected the machine gets rusted and moving parts wear out quickly resulting in loss of efficiency, frequent replacement of spare parts and finally uneconomical working.

Besides the normal maintenance as above, special care has to be taken for maintaining the plant protection equipment. The pesticide formulations are chemically aggressive on metals, etc. The cleaning and washing of the chemical tank, discharge lines, nozzles, etc., are to be done regularly after the day's spraying work is completed otherwise the residues of chemicals used for spraying acts on the parts and causes corrosion and deterioration of materials.

If this aspect of thorough cleaning is not done on the plant protection machine, even though it is made of with high standard materials, it will not serve its normal life and would lead to premature condemnation.

MAINTENANCE JOB FOR HAND OPERATED EQUIPMENT:

1. Cleaning the chemical tanks, hoses, valves and nozzles etc. and flushing sufficiently to avoid pesticide residue which is corrosive.
2. Cleaning the machine equally well from outside also as it is contaminated due to leakage, spilling of pesticide.
3. Lubricating suitably the pump parts like piston, cylinder, valves and other rotating, sliding, moving parts.
4. Store the machine in dry place duly protected from sun and rain.

MAINTENANCE JOB FOR POWER OPERATED EQUIPMENT:

All the above maintenance jobs apply to power equipment also. But the engines have to be taken care of specially. The life and efficiency of the engine mostly depends upon

proper maintenance. For their running all engines need fuel, air and proper system of ignition. Thus in petrol engine, clean petrol, clean air and healthy ignition (spark plug & magnets) are essential. Besides those, the engine need perfect lubrication, too. In two stroke petrol engine, care must be taken to mix lubricating oil and petrol in exact ratio as recommended by engine manufacturer. Similarly in four stroke petrol engine the lubricating oil should be kept in sufficient quantity by observing the level gauge. The air cleaner should be cleaned occasionally. The spark plugs should be also cleaned, carbon removed and proper electrode gap should be maintained. The 2-stroke petrol engines used in low volume spraying should invariably be in good order otherwise the pesticide spraying will not be efficient.

Sufficient care should be taken at the depots to clean, oil and check equipment periodically when they are stored, and whenever machines are sent out to work, and when returned from field work. This minimum care to inspect the equipment, clean and flush and keep it duly oiled, would go along way in improving the availability of good working sprayers and dusters and also prolonging their useful life.

REPAIRS AND REPLACEMENTS:

The plant protection equipment is often found requiring frequent repairs and replacements which are both minor and major in nature. Due to this, a good number are found sick in the depots.

Hand operated equipment generally need minor repairs such as replacement of plunger washers, springs, nozzle etc., and these repair could as well be attended to by the operators themselves with little training and experience. It is essential to supply them necessary spare parts and tools well in time for repairing. In the case of power operated sprayers the engine repairs are classified into minor and major ones.

1) ***Minor repairs :***

   Spark plug cleaning and adjustment, air cleaner, carburetor cleaning, fuel cock and lines cleaning and starter repairs, etc. These can be attended to by the operators themselves with little experience and training.

2) ***Major repairs:***

   These repairs include replacement of parts like piston, rings, liners, crankshaft, bearings, valves, etc. These repairs have to be carried out systematically in well equipped workshops by the competent and trained mechanics. Untrained personnel should not be allowed to handle such major repairs.

SUGGESTIONS ON MAINTENANCE

In order to improve the present situation the following suggestions are made:

1. Plant protection equipment manufacturers, their dealers, State agril. Engineering workshops and extension officers need better coordination & cooperation to reduce the number of sick equipment.
2. The field operating staff needs orientation training to be given on maintenance, repairs, operations and calibration of equipments on periodic basis.
3. Adequate number of mechanics and supervisory staffs has to be posted for maintenance and repairs of the equipment.
4. A district-wise service station, properly equipped, could cater to major repairs on power operated equipment within its zone.