Guidelines on

GOOD PRACTICE FOR GROUND APPLICATION OF PESTICIDES

Guidelines on Good Practice for Ground Application of Pesticides

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BACKGROUND

Since 1995, FAO AGSE has worked to improve the safety and efficiency of pesticides within systems of sustainable agriculture and integrated pest management (IPM). This began with the publication of guidelines to assist member states to control the quality of the most commonly used types of application equipment. The first versions of the FAO guidelines on pesticide application equipment were approved for publication in May 1997 by; the FAO Panel of Experts on Pesticide Specifications, Registration Requirements, Application Standards and Prior Informed Consent; and the FAO Panel of Experts on Agricultural Engineering.

In 2001, FAO AGSE produced a new, revised and expanded series of pesticide application equipment-related guidelines. The guidelines in this document cover the application of pesticides using any ground based field crop sprayers, including operator carried and tree and bush crop sprayers. A similar guideline covers the use of spray aircraft:

Guidelines on good practice for aerial application of pesticides;
These guidelines have been prepared to offer practical help and guidance to all those involved in using pesticides for food and fibre production as well as in Public Health programmes. They cover the main terrestrial and aerial spray application techniques.

The series consists of the following other guidelines:

Guidelines on minimum requirements for agricultural pesticide application equipment;
An important objective of these guidelines is to assist FAO and other agencies to ensure that sprayers purchased are safe to users and to the environment as well as being efficient and durable in operation. Even the cheapest sprayer models should meet minimum standards of safety and durability.

They take into account equipment that is already on the market, many of which already meet the requirements. The prime objective therefore is that member countries should adopt these guidelines immediately, to begin to eliminate substandard and unsafe sprayers from national markets and ultimately from the international scene.

Guidelines on standards for agricultural pesticide sprayers and related test procedures;
These guidelines are more demanding than the minimum requirements and provide more precise safety targets for spray equipment. They consist of detailed specifications and requirements, supported by test procedures to measure compliance with the proposed standards. The guidelines cover the major types of portable (operator-carried), vehicle-mounted and trailed agricultural pesticide sprayers manufactured in or supplied to FAO member countries.

Guidelines on procedures for the registration, certification and testing of new pesticide application equipment;
These guidelines outline a further way by which governments can influence pesticide safety by controlling the quality of the pesticide application equipment manufactured in or imported into the country. By incorporating into national legislation, a requirement for manufacturers and importers to declare that application equipment meets standard of safety and durability, it should be possible to gradually reduce and eventually eliminate sub-standard equipment from the market.

Guidelines on the organization of schemes for testing and certification of agricultural pesticide sprayers in use
This publication covers the testing and certification of the sprayers currently applying pesticides on commercial farms. They address an urgent need in many countries to ensure that where pesticides are used in crop production, they are applied through equipment, which is safe and fully functional. The issue applies to both large, field crop and orchard sprayers as well as operator-carried equipment.

Guidelines on the organization and operation of training schemes and certification procedures for operators of pesticide application equipment. These guidelines consider the training, testing and certification of those who actually operate pesticide application equipment. Even the most well designed and maintained sprayer can do immeasurable damage in the hands of an unskilled operator and the importance of these guidelines should not be underestimated.

1. INTRODUCTION

When using an approved pesticide the objective is to distribute the correct dose to a defined target with the minimum of wastage due to drift using the most appropriate spraying equipment. Pesticides only give acceptable field results if they are delivered safely and precisely. Unlike other field operations, the results from poor spraying may not become apparent for some time so that it is essential that those involved in pesticide selection and use are fully aware of their responsibilities and obligations, and are trained in pesticide use and application.

These guidelines have been prepared to offer practical help and guidance to all those involved in using pesticides for food and fibre production. They cover the main terrestrial spray application equipment such as knapsack sprayers, boom and air assisted sprayers using hydraulic spray nozzles. Reference is also made to the use of rotary atomizers. This code of practice has been designed to provide supportive information and practical advice on acceptable safe practices once a decision has been taken to use a pesticide.

1.1 Guideline objectives

The guidelines are aimed at decision-makers, managers, field supervisors and spray operatives. However, it must be emphasized that in some countries legislation is already in place to control safe and efficient pesticide use and application. Accordingly, local legislation, or voluntary codes must be the first point of reference with this set of guidelines offered as additional information. This is an important point, as compliance with local legislation may have legal significance in the event of a claim against the poor field performance of a pesticide. For other countries, the guidelines might serve as a guide until appropriate legislation is in place.

1.2 Operator training

Operators of spray equipment must receive suitable training before handling and applying pesticides. Training should be provided by a recognized provider and courses are frequently offered by local training groups, agricultural colleges, government extension departments, spray equipment manufacturers and the chemical industry. The satisfactory completion of a course may result in a recognized certificate of competence to cover:

- safe product handling,
- delivery of the product to the target
- instruction on using the relevant spray equipment.

It is important that as technology moves forward, field spray operators are be kept up to date with new methodology to help ensuring that pesticides are safely used. In some countries where spray operators are licensed, they can only renew their operator's license if they attended regular refresher courses. Operator training is best be organized and provided through sustainable permanent national structures.

1.3 Spray equipment selection

The selection of appropriate and suitable spray equipment is essential safe and effective pesticide use. International and national equipment testing schemes have been established in many countries where after thorough testing under laboratory and field situations, sprayers are given l certificates of approval. Where testing is not in place equipment manufacturers can be required to confirm that a sprayers complies with the requirements in countries where testing is mandatory or the equipment meets the appropriate FAO guidelines.

Equally important when selecting spraying equipment is access to spare parts, service and support facilities.

Ideally, equipment selection should not be based primarily on cost. Safety, design, comfort and ease of use must be major considerations, and ease of

maintenance must be a high priority. Knapsack sprayer maintenance should require only simple tools.

The combination of operator training to a recognized standard, combined with the selection of appropriate spray equipment will contribute to improving the accuracy of pesticide delivery as well as protecting the environment.

1.4 Using pesticides correctly

Pesticides should only be used if there is an economically important need and all pesticides must be used strictly in accordance with their label recommendation. Product selection must assess the potential exposure hazard of the selected formulation and determine what control measures and dose rates the label recommendations advocate.

1.5 Managing operator exposure

The use of Personnel Protective Equipment (PPE) is be essential for protecting operator health and advice on its use will be found on the product label. Effective health monitoring records will be able to provide early warnings and identify changes in operator health, which may be attributed to working with pesticides.

As well as the workers handling and spraying pesticides the public must be safeguarded, both during, and after spraying, for example where they might have access to a treated area. Maybe livestock also ought to be prevented from re-entering treated areas immediately after spraying.

2. THE DECISION MAKING PROCESS

The use of pesticides may put people, other life forms and the environment at risk; thus, the decision to use a pesticide should only be taken when all other alternative control measures have been fully considered.

Integrated Pest management IPM, as described in the International Code of Conduct on the Distribution and Use of Pesticides, FAO 1990, offers a pest management system that combines all appropriate control techniques to effect satisfactory results.

2.1 Alternatives to pesticide use

The alternatives can be divided into Natural and Applied Control measures. Natural Control may utilize naturally occurring pest enemies, or rely on meteorological conditions to effect pest and disease control. Applied Control may be based on crop rotation, cultivar or variety selection, changes in sowing dates and or alterations in cultivation practices. The use of some or all of the above techniques, together with carefully selected pesticides, can provide an integrated approach to weed, pest and disease control.

2.2 Risk/benefit considerations

The risks and benefits of using a pesticide must be addressed before chemical product selection. By completing a risk assessment, harmful effects can be kept to a minimum.

In some cases a prophylactic treatment e.g. seed treatment may be justified but the effect of weeds pest and disease on crop yield reduction should be monitored to determine when it is economically justified to use a pesticide.

Such information should be gathered by systematically by regular inspection of the crop to monitor pest numbers or weed species and their appearance frequency, in combination with the use of insect traps to assist treatment timing. An understanding of the pests life cycle and the crop's ability to compensate for any pest or disease damage, will also help in decision-making.

2.3 Product selection

The decision to select a given pesticide product must be based on an assessment of the risks and benefits, the materials hazard potential to both man and the environment.

In many, but not all, countries legislation is in place to control and regulate the manufacture, importation, distribution and sale of pesticides. Products are registered for use, after local field evaluation for safety and efficiency and only approved and recommended products can be used.

Where there is a choice of product, the material offering the least hazard should always be selected. Where local pesticide regulations are not in place the International Code of Conduct on the Distribution and Use of Pesticides (Amended version) FAO, offers guidance. Label information

The manufacturer's product label is the main source of information for the end user. It must be written in an appropriate local language, so that it can be read and understood by users. Label terminology must be understood by pesticide users. The label is attached to the product container and is usually reproduced on the outer container or wrapper of the transport container or carton. In most countries, adhering to the label recommendation is a legal obligation.

DO NOT USE AN UNAPPROVED OR NON-LABELED PRODUCT

The product label carries statutory instructions for the user, which must cover the crops for which it is registered, the recommended dose rate, the number of permitted treatments during the growing season and how many days before harvest the last treatment may be applied. Additionally, the label will inform the user of the correct Personal Protective Equipment to be used when handling and applying the product and advise on environmental protection measures to be carried out.

Labels may refer to “non-spray” barriers for when products are to be used near waterways or sensitive environmental areas. The widths of unsprayed barriers are dictated by the pesticide, the sprayer type and setting, and its drift potential. Equally important to prevent environmentally sensitive areas are the weather conditions at the time of application (see 4.2.2).

Label information on suitable application technology, nozzle selection, volume of spray solution and correct spray timing will also help to improve product safely.

The label also provides other relevant and useful safety information, which will include the product common name, chemical name, the manufacturers name and a contact in the event of an accident. The label must also be available for medical staff treating anyone who has been accidentally poisoned or contaminated by the pesticide. A good copy of the label must be retained as reference for the emergency services in the event of an accident.

Information on the decontamination and disposal of empty containers is also usually included on the label.

2.4 Tank-mixing

Applying more than one product at the same time (tank-mixing) can improve the logistics of spraying provided the respective treatment timings coincide and the formulations are chemically and physically compatible. Only approved mixtures should be used.

Risks associated with tank mixing may include a reduction in biological activity due to product antagonism. This may be seen as crop scorch, which although it may appear only transient, can reduce final yield.

The most common problem affecting the spraying operation is physical incompatibility, which can block nozzles and filters as well as causing separation in the tank if the agitation through the return to tank is inadequate.

Where trace elements are used as admixture candidates, blockages are common. The product label should give advice on suitable tank mix partners and the correct sequence of their introduction into the spray tank. Where an induction hopper is used to introduce products into the spray tank, it is advisable to add one product at a time. Agitation of the first material introduced into the tank is essential before the second formulation is introduced.

Water temperature and quality may also influence the chemical compatibility of tank mixes.

3. SAFETY ASPECTS

The overall safety of crop protection chemicals must be the objective of all pesticide users as well as those engaged in the storage, distribution and retailing of agrochemicals.

3.1 Operator health surveillance

The health of operators exposed to pesticides must be monitored. The surveillance should cover health records and medical checks, which can alert medical authorities of any health changes, which might be related to exposure during work. Health surveillance can also indicate that safety practices and the selection and use of PPE remain adequate for the products being used.

The hazard potential of the selected product, combined with the length of time of operator exposure during use will determine the health surveillance techniques and their frequency.

Local legislation will advise on which records are kept and for how long.

3.2 Application timing

In relation to safe and efficient pesticide use correct application timing is often poorly understood. The optimum time to spray is determined by the crop, pest, weed and disease growth stages. The product label will indicate treatment timing but it is usually at the start of an infestation that the lower label dose rates can be used. Application timing will also be influenced by meteorological conditions, which may result in physical, and volatility spray losses. Temperature, relative humidity, wind direction and velocity plus the possibility of rain can all effect the efficiency of spray dep

3.3 Product transport and storage

Transporting pesticides by road may be controlled by national regulations for the movement of dangerous goods where emergency procedures in the event of a road accident are already in place. Many pesticide manufacturers issue Transport Emergency Cards ("Tremcards") to vehicle drivers transporting hazardous pesticides. As well as the journey from the retailer to the end user, pesticide containers are also moved in and out of stores on the farm. In all cases, they must be checked for leaks and damage and must always remain clearly labeled.

PESTICIDES MUST ONLY BE TRANSPORTED AND STORED IN THEIR ORIGINAL TRANSPORT CONTAINERS AND PACKAGES

Care must be taken when using farm vehicles to transport pesticides as the chemicals must be secures and isolated and spills must be covered with a non-combustible absorbent material, which must be correctly disposed of.

Pesticide containers must be kept closed when not in use and must be secured against unauthorised interference, particularly when spray operators are working away from mixing areas and cannot always see the chemical containers.

The storage of pesticides on the farm should be covered by local legislation and farm stocks of pesticides must be kept to a workable minimum to cover peak demand. Correct storage is essential to maintain a safe working environment, to maximise product shelf life and to minimise the risk of fires and spillage. Varying climatic conditions and specific product demands (flammability-toxicity) make it difficult to offer other than general recommendations in these guidelines. *The Guidelines for the Packaging and Storage of Pesticides (FAO 1985)* offer a more comprehensive reference.

Pesticides must be kept in a dedicated store, which is accessible in case of emergency and can be locked when not in use. When considering erecting a pesticide store guidelines relating to construction materials, design, siting, emergency procedures etc can be obtained from FAO, or from national regulatory authorities.

Under no circumstances must pesticides be stored near foodstuffs!

3.4 Product handling

The product label is usually the first reference for guidance on handling the formulated pesticide products. It will usually describe the requirements for the use of Personal Protective Equipment (PPE) both for handling the concentrate and for the diluted spray solution to be used in the field. strength. The careful selection, use and maintenance of PPE are essential to ensure that the user is adequately protected.

Only approved safety equipment must be used. Certain toxic chemicals may only be approved for use if they are handled and dispensed via fully tested and officially approved closed dispensing systems. Such systems reduce operator and environmental contamination.

3.5 Chemical container management

Unfortunately empty chemical containers often have second-hand values, however, empty pesticide containers must never be re-used by users.

Containers can be thoroughly cleaned manually even when they have contained viscous formulations however automatic rinsing systems are becoming common and are mandatory on field sprayers in many countries.

Some countries allow controlled burial for empty containers; however, burial sites must not to be close to waterways. Hot incineration offers an alternative method of disposal, however, local regulations must be consulted.

The problems associated with container rinsing and disposal can be eliminated by using systems of returning chemical containers to suppliers, where they can be re-filled or recycled.

3.6 Accident procedures

If an accident occurs during transport or handling a pesticide, the spillage may result in fire, injury to humans, property damage or environmental contamination. Rapid action must follow the accident to minimise adverse effects. It is essential that pesticide transporters and users are familiar with label recommendations and procedures in the event of an accident and the appropriate authorities (Environmental, Water, Police etc) are informed of the accident and the corrective procedures followed. All spillage incidents and the actions taken must be accurately recorded.

Vehicles used to transport pesticides must be decontaminated following an accident or spillage.

3.7 Personal protection

There are three principal routes that chemicals enter the body:

a) Accidental or deliberate ingestion
b) Dermal, through handling, measuring and pouring the concentrate.
c) Inhalation of small particles or dust during handling and spraying

Dermal exposure represents the most common hazard. Avoiding exposure by using PPE and by paying attention to personal hygiene by washing exposed parts of the body after work and before eating, smoking and toileting will minimize risk. Personnel Protective equipment must be selected in accordance with the label recommendation (see 4.2.6). It must be comfortable to wear/use and be made of material, which will prevent penetration of the pesticide.

PPE will only remain effective if it is correctly selected and maintained. Where the equipment is damaged, repairs must restore it to its original condition otherwise the item must be replaced. Items such as the respirator must be checked on a regular basis and filter elements changed in accordance with the manufacturer's instructions.

Remember, products containing the same active ingredient but sold under different brand names may pose different risks due to the product formulation. Care must be taken to always refer to the individual label for the product being used.

4. APPLICATION

4.1 Pre application

Time taken to check spray equipment before use will reduce costly delays when the season begins. Pre-season operational checks can be carried out with clean water but safety clothing should always be worn. Any checks suggested in this publication will be additional to the procedures specifically laid out by the equipment manufacturers in their user instructions.

4.1.1 Spray equipment selection

Selecting the appropriate equipment for the pesticide formulation to be used is important. For example, most pesticides will be sprayed as aqueous solutions or suspensions through hydraulic spray systems. However, where materials are to be applied undiluted at Ultra Low Volumes (ULV) or diluted in water at Very Low Volume (VLV) with rotary atomisers or via Hot or Cold Fogging, specialised spray equipment is required. Rotary atomisers are of two types, which operate at different speeds to deliver different droplet sizes. Those designed to apply insecticides and fungicides produce small droplets and those designed to apply herbicides via coarser droplets. The insecticide droplets (<150mm) are moved downwind from their release point whilst the larger herbicide droplets (>200mm) fall predictably within a limited swath width. *(Pesticide Application Equipment for use in Agriculture, Vol. 1. FAO bulletin no 112/1).* Before selecting new spray equipment, it is advisable to check specification against the FAO guidelines on standards. (See 1.4)

4.1.2 Equipment serviceability

Tractor mounted and trailed sprayers

Structures for operator safety, steps, hand and guardrails must all be checked.

The power take off (PTO) guards must be in place and anchored and all lubrication points serviced.

It is advisable to initially rotate the pump by hand to ensure it is free.

Tyre pressures and wear on trailed machines should be checked.

With clean water in the tank, operate the sprayer above working pressure to check for hose leaks. Hose splits or cracks on the pump inlet side will reduce pump performance and increase tank foam.

On the pressure side, check hose joints, particularly where hoses bend when booms are folded, similarly, check hoses retained by hose clips. Ensure that the pressure gauge returns to zero when the sprayer is not working.

Roller vane pumps must be free to rotate and the rollers in good condition whilst positive displacement pumps (Diaphragm or Piston) will require sump oil level checks.

Where fitted, the air pressure in the pulsation damper must be inflated to the manufacturer's recommended pressure for the nozzle selection.

Fans on horizontal boom and mistblowers should be checked for balance and air deflector controls adjusted. Belt drive pulleys must be checked for alignment and belts checked for cracking and tension.

The spray tank must be fully retained and free from leaks, with all filters in place. Where fitted, internal tank rinsing systems must be working and tank content gauges must be clear and easy to read. Make sure that the filter meshes are appropriate size for the spray volume. The higher the mesh number the finer the filter.

Check boom suspension and break away system, lubricate pivot points where necessary and make sure the folding mechanism is working correctly. Poor boom suspension will effect spray distribution so check all wear pads are intact and shock dampers are working.

Nozzles and nozzle bodies must be checked for damage and where fitted, diaphragm check valves must make good seals when the pump output diverts to tank as the spray is shut off.

Self propelled sprayer cabs and tractor cabs must have adequate filtration when used for spraying. Different filter elements may have to be fitted but the manufacturers' instructions will advise on replacement intervals.

For rotary atomisers, drive mechanisms (hydraulic, cable or electric) must be checked and discs monitored for damage and balance. Belts on drive units may need to be replaced. Disc speed checks should be made for

formulated products, as they may be different from the readings obtained using water.

Controlled Droplet Application (CDA) for herbicide application usually uses products diluted in water and applied at volumes of 15 to 30 l/ha. Where a rotary atomisers are used for spraying an undiluted product at 3 to 5l/ha, the disc rotational speed is much higher and the smaller oil-based droplets are dispersed and transported by natural wind (1 to 3m/sec). These sprayers are now being used to apply volumes of up to 20l/ha (Very Low Volume, VLV) using conventional formulations are diluted in water with an anti-evaporant added to the tank to reduce droplet evaporation during flight.

Operator-carried sprayers

Lever and pivot points on lever-operated knapsack sprayers must be checked for wear and lubricated.

Trigger mechanisms must move freely and give a positive “shut off”.

Air inlet valves within the filler caps must also be clean and free to move. Shoulder straps must be in good condition.

Hand held rotary atomiser sprayers are battery driven, so a check on battery numbers and condition must be carried out before work.

Rotary atomisers are also used on air-assisted sprayers where they substitute for hydraulic nozzles. Rotation is controlled by the angle of the blades, which is driven air from the fan.

Liquid flow-rate on to the disc is critical and is controlled by using arrange of interchangeable variable restrictors. Accordingly, appropriate restrictors must be available to apply formulations of different viscosities to maintain accurate liquid flow onto to the disc.

4.1.3 Adjustment and control checks

Tractor sprayers

The operator must make sure that all controls are effective by working all functions. Where spray adjustments are electronically controlled, it is essential that the operator knows what action to be taken if the computerised control fails during work. The response time of automatic spray controls must be checked against manufacturer specification and adjusted before work commences.

Check the operation of the pressure control and relief systems making sure that the return to tank spray agitation is effective.

Boom height adjustment on tractor sprayers must be checked and spray controls, both spray on and off and individual boom section valves worked. Where the tank is loaded via an induction hopper, control taps must be functioning and any container rinsing device fitted must also be in good condition and free from blockage.

Operators must understand the sequence of events when working the valves for tank filling from induction bowls as incorrect use can damage hoses. Container probes for sucking chemical from the shipping container must be kept clean and the control valve closed when not in use. Air ingress via a partially open valve will increase tank foam. Filter maintenance during tank loading must isolate the plumbing to avoid operator contamination during maintenance.

Nozzle selection can be made in accordance with the label recommendation, which should suggest nozzle type, spray angle and liquid flow-rate at a given pressure. Never mix nozzles on the boom (Spray angle and or flow rate) and ensure that spray patterns are streak free, and correctly overlapping apart from the boom end nozzles.

Operator –carried sprayers

There is no hydraulic agitation on a knapsack sprayer, but spray pressure control systems or valves must be operational.

Hand carried rotary atomiser sprayers are gravity fed and rely on air ingression into the liquid container to ensure a constant liquid flow to the disc during work. Air inlets must always be kept clear.

Equipment to test the rotational speed of a spinning disc sprayer must be available

4.1.4 Spray calibration

Spray equipment should be calibrated at the beginning of each season, after equipment has been repaired, following tractor wheel changes or when new nozzles have been fitted.

Sprayers fitted with automatic monitoring systems (speed, liquid flow, area covered) must be regularly calibrated against manufacturers calibration figures.

There are three major factors, which influence sprayer calibration: Forward speed, swath width, and liquid flow rate.

Forward speed

Can be calculated by timing the tractor/operator speed over a measured distance, preferably on a surface similar to the one to be treated. This operation should be replicated three times with the tractor operating at spraying speed, and the engine delivering the correct p.t.o. speed, to determine an average forward speed.

Swath width

Is the effective width covered by the nozzle or boom assembly and can be calculated for a single nozzle or for an entire boom. Where a boom sprayer

is to be used, the width of cover can be calculated by multiplying the number of nozzles by the distance between individual nozzles. In the case of top fruit/orchard spraying the swath width will be the distance between the tree rows.
Swath width for ULV "drift" spraying is usually determined by row width and may be reduced as the inter-rows close so that an incremental droplet deposit is built up with each pass.

The liquid flow rate

Flow rate from the nozzle at a given operating pressure can be obtained from the nozzle manufacturer's information sheets. This information is generated when spraying clean water and is similar to applying conventional aqueous spray volumes at 150-300 l/ha. However, this may not be the case when applying low volume, higher concentration treatments.

When measuring the flow rate from actual nozzles it is advisable to test at least one nozzle from each boom section and average the total. Nozzles should be replaced when their liquid output increases by 5% above the catalogue output at a given pressure, or the variation between nozzles on the same boom exceeds ± 10%.

Determining the nozzle output from a mistblower is more difficult as individual nozzle output is piped to a measuring cylinder for the assessment. Such an operation is made easier, and safer, if the fan drive can be disengaged during the test. A more accurate method to determine the liquid output is to fill the empty spray tank with a known amount of water, then record the time taken to empty the tank. This operation should be replicated three times to find the average liquid throughput.
Determination of the liquid flow rate from a restrictor for a rotary atomiser can be done with the disc stationary in the case of an herbicide applicator. However, with the disc rotating on the ulv applicator the liquid flow-rate may be enhanced so must be checked with product, as both viscosity and temperature will also influence flow.

The figures generated must be recorded for future use and the tractor used for the calibration noted The above calculations remain robust for tractor units, but the smaller areas treated by knapsack sprayer will require additional calculations. Product dose rates per tank will be relatively small so precise measuring equipment must be to hand to ensure measuring accuracy.

NOTE 1 The conversion factor for a metric calculation is 600, but where Imperial figures (Feet, miles per hour, galls/acre) are used for the calibration the conversion factor will be 373

NOTE 2 For top fruit/tree spraying the concept of adjusting the applied spray volume in relation to increases in the foliage canopy is an approach to improving the efficiency of orchard spraying, although product labels often continue to refer to dose rates for tree spraying as litres per hectare. The "tree-row-volume" (TRV) concept measures the tree foliage volume in one hectare and adjusts the product dose rate and spray volume during the season as the leaf canopy increases. The product label will suggest a water volume rate for 1000 cu/m of leaf canopy, which can be calculated from the appropriate formulae.

Also, when working with a tree sprayer the operator must be aware of the machine's air volume output per hour so that the forward speed can be adjusted in relation to the tree foliage canopy, bearing in mind that the incoming air from the machine has to replace the stagnant air within the tree. An excessive forward speed will not allow the sprayer adequate time for the spray transported in the air stream to penetrate the tree foliage.

4.1.5 Tank filling

Appropriate protective clothing must be worn when handling the formulated pesticide and filling the spray tank.

Liquid formulations remain the most popular as they are easy to measure and pour. The spray tank is half filled with water and the pump engaged to

provide gentle agitation. The products must be introduced into the tank as per label recommendation, usually in the order of solids followed by liquids. The spray operator is at the highest risk when handling the pesticide concentrate. Where closed transfer systems are used for tank loading operator contamination is reduced. However, such systems must be thoroughly cleaned after use and transfer valves must be designed to be leak free when operated (dry-break couplings).

Chemical containers must be kept secure when in use in the field. When appreciable distances are involved for the sprayer and the containers are left unattended, they must always be closed and secured from unauthorised interference.

All spray operators must be fully trained and aware of the procedures to be carried out in the event of accidental spillage during tank filling.

4.1.6 Prior warnings

Members of the public, not directly involved with the spray operation, may also be effected by a pesticide application so there is an obligation to warn anybody or organization, which might be concerned. These groups must be notified in good time before an application. Neighbours growing susceptible crops, and local beekeepers should also be alerted. Where particularly toxic materials are to be used, it may be necessary to warn the emergency services, and the local environment and water authorities. The product label should give precise advice on prior warning and who to contact.

4.2 Field application

Adequate pre-preparation will help make sure that the actual spraying is carried out under the safe conditions and accurate spray timing will ensure that the product is applied with optimum effect.

Employers and operators must make sure that all safety equipment and clothing is clean and in a good state of repair.

The knapsack spray operator when using a forward-held hand lance is usually walking through a treated crop. As the crop grows, operator contamination increases so it is essential to make sure the operator has adequate body protection. Holding the hand-lance forward and to the down-wind side of the operator will help reduce contamination, but the use of a "tail-boom" should also be considered where appropriate.

4.2.1 Field survey

The effect of the selected pesticide product on the environment should have already been considered when the decision to use it is made. A pre-spray field survey will highlight surrounding areas of wildlife, scientific and environmental significance, and waterways. These can be can be located and mapped.

Where water is to be extracted from a natural source for filling the spray tank, it is important to comply with local legislation, as the practice is illegal in some countries to prevent "reverse siphoning" contaminating the water source.

Reference to the product label may recommend "no spray" barriers; Barrier widths may differ for different sprayers e.g. boom sprayers and mistblowers. Equally, the width may also be influenced by product classification and spray nozzle, as nozzles producing coarse droplets can reduce physical drift, to allow spraying closer to watercourses. Where rotary atomisers are used, barriers must be extended to make sure that the distance is adequate to capture the sedimenting droplets.

Spraying must start at a suitable distance upwind and away from the crop to ensure that the first field rows are adequately treated. The pre-treatment field survey will also identify areas where wind direction and strength will be influenced by field topography and obstacles.

In some countries, organisations are available to advise on field headland and boundary management that can assist with local environmental risk assessment when pesticides are to be used.

4.2.2 Meteorological considerations

Spray deposit efficiency is greatly influenced by local meteorological conditions at crop height. Wind velocity and direction, temperature, relative humidity and the frequency of rain all influence spray deposit.

The distance that a spray droplet travels depends on the droplets downward velocity, the height of release and the wind speed. The larger the drop the less it is effected by wind and the faster it falls thus reducing drift, but the distribution efficiency will also be reduced, which may in turn lessen the performance of a non-systemic product.

Wind direction must also be considered as spray droplets may be transported out of the treated area and onto adjacent susceptible crops or waterways. Wind speeds of between 1 and 2m/sec, (3.6 to 7.2 km/h) are generally considered ideal for hydraulic nozzle treatments. Table 1 lists various wind speeds as a guide to suitable conditions for spraying. *(Good Practice for Ground and Aerial Application of Pesticides, FAO Guidelines 1988)*

Table 1 Wind speed guide

DESCRIPTION	APPROXIMATE AIR SPEED	VISIBLE SIGNS	SPRAY DECISION
Calm	< 2 km/h	Smoke rises vertically	Do not spray
Light air	2-3 km/h	Direction indicated By smoke drift	Do not spray
Light breeze	3-7 km/h	Leaves rustle, wind Felt on face	Ideal spraying Conditions
Gentle breeze	7-10 km/h	Leaves in constant Motion	Avoid herbicide spraying
Moderate	10-15 km/h	Small branches move and dust is raised	

Where aqueous spray solutions are used, high temperature combined with low relative humidity will reduce the size of the spray droplets through evaporation and so increase the risk of drift.

Furthermore, temperature can affect product performance. Activity may be slow and reduced at low temperatures whilst applications carried out when temperatures are high may lead to crop scorch.

Information on the rain fastness of pesticides can usually be found on the label although for most products, however, showers 2 hours following treatment will not necessitate re-spraying.

4.2.3 Treatment timing

If application timing is accurate, fewer spray treatments may be needed. The use of computer models to predict spray timing may help reduce the number of fungicide treatments to such crops as potatoes, and accurate

pest forecasting may cut down the number of times crops such as cotton and top fruit are treated.

The time of day a treatment is applied can be important. The optimum spray timing for efficacy may coincide with the foraging time of beneficial insects. It is therefore important to know and understand crop, insect and disease development and the ecological balance to determine when to spray. An understanding of product mode of action in relation to crop development will also be advantageous.

4.2.4 Sprayer field settings

The main field settings are based on the selection of a suitable forward speed and the height at which the spray is released above the target. For a tractor sprayer, forward speed will be determined by the stability of the boom over the surface to be sprayed, where excessive speeds will lead to vertical boom bounce and horizontal yawl; effecting spray deposit efficiency.

For a knapsack spray operator, speed over the surface to be sprayed will have to be maintained for long periods so the chosen walking speed must be sustainable. Where a mistblower is being used to spray trees, the forward speed must match the volume of air generated by the fan to the tree volume as it replaces the still air within the tree canopy.

The nozzle angle on an air assisted boom sprayer can be adjusted in relation to the direction of travel and the density of the foliage. Similarly, the fan speed can also be adjusted. Less air will be required to penetrate a thin open crop than a dense crop canopy.

Nozzle height above the target must be finally set in the field. Boom height is determined by the nozzle spray angle and nozzle spacing. Boom height for a boom fitted with rotary atomisers will be determined by atomiser type and spacing. Too high a boom promotes excessive drift, however, if the boom is too low the spray pattern does not fully develop resulting in excessive overlap and local overdosing.

It is difficult for the knapsack spray operator to maintain a constant nozzle height so a trailing lightweight chain or wire may be used as a height indicator.

The distance between the mistblower nozzle and the target foliage is determined by the position of the sprayer between the tree rows but care must be taken where both the topmost and the lower nozzles on the U shaped boom are open as losses to the atmosphere and the ground respectively may increase.

Using a hand-carried herbicide controlled droplet applicator; the atomiser head should be approximately 20/30cm above the target foliage and carried at the correct angle to ensure that the product flows correctly. However, for a ULV insecticide or fungicide applicator, relying on the wind for droplet transportation, the atomiser head should be held approximately 1m above the crop when the wind speed is low and lowered to 0.5m when the wind speed is high.

4.2.5 Chemical handling

Water is probably the most sensitive environmental issue involved with pesticide use and the, site of the sprayer filling and pesticide mixing area is critical. Water and environmental agencies should be consulted when selecting filling sites.

Permanent filling sites, for example for tractor sprayer use, must provide a washing apron where rinse water and spillage's can be retained and an area that can be kept secure. Siting must take into consideration the proximity of waterways and the soil type in relation to the speed of liquid percolation. The use of filling and mixing sites adjacent waterway is common and temporary mixing sites should be regularly rotated between locations.

Absorbent material to contain spills must be available at the filling site, as should suitable first aid equipment and secure facilities for PPE. Where present, a dedicated chemical store must be kept locked when not in use

and should have a secure section for storing empty chemical containers before their disposal.

4.2.6 Chemical container handling

To help keep tractor sprayer-operator exposure to a minimum, wherever possible preference must be given to using pesticide packs handled via closed transfer systems.

All operators must be correctly trained to handle chemical containers, remove seals, measure, pour and them after use. Where mechanical rinsing is not available, triple manual rinsing will decontaminate empty liquid containers; three rinses with clean water (Use 20% container volume) will remove chemical residues and leave the container ready for disposal. Containers must be rinsed immediately after use and the rinsate emptied into the spray tank. If the operator is using the induction hopper to load the concentrate into the tank, the liquid level in the bowl must be high enough to prevent the pump drawing in air when introducing the chemical.

Where knapsack sprayers are being refilled from “nurse-tanks” containing pre-mixed spray solution it is important that the tank pumping system provides adequate re-circulation while the spray mix is standing. Where knapsack sprayers are being refilled from “nurse-tanks” containing pre-mixed spray solution it is important that the tank pumping system provides adequate re-circulation while the spray mix is standing.

Handling the undiluted pesticide presents the operator with the highest exposure risk so correct safety equipment and clothing must be available and operators trained to use and maintain it properly. Operator protection may be different for the actual application when the product is diluted with water.

Engineering controls, closed transfer systems, returnable pesticide containers, water dispersible sachets etc, should be used wherever possible.

EMPTY CHEMICAL CONTAINERS MUST NOT BE RE-USED

Partially used chemical containers must be re-sealed and then taken back to store.

4.2.7 Post treatment warnings

Immediately after the spray has been applied warning notices should be posted around the treated area in accordance with label recommendations. Recipients of warnings such as beekeepers can be told that the application has been completed. The field notice should alert people of the treatment and instruct them of the re-entry period. Notices should be removed. when no longer required. Livestock must be kept out of treated areas for the required time period.

4.3 Post application

Safety remains a prime consideration after spraying and when cleaning or repairing spray equipment appropriate safety clothing, particularly an apron, must be worn.

Firstly, refer to the sprayer manufacturer's instruction book for the correct maintenance procedures. Repairs may be carried out by persons who are not trained in pesticide use and application however; they must be fully protected even when working on clean ("decontaminated") equipment.

4.3.1 Cleaning ("decontamination") of equipment and PPE

After work, the spray equipment should be washed both internally and externally in the field and the rinse liquid sprayed onto a crop on which the product is registered, making sure that the recommended dose rate is not exceeded by repeatedly spraying the same area. Many sprayers are now fitted with internal tank rinsing systems, which are fed, from clean water tanks designed specifically for the purpose. These tanks may also provide water for rinsing empty containers and swilling protective clothing after use. It is advisable to rinse the spraying system three times with a small amount of water each time rather than one rinse from a full tank.

Where a knapsack sprayer is fitted with a large pressure chamber three to four short rinses will be necessary to fully clean the spray system. When a spraying machine is to be used to apply the same product or a similar compatible material the following day, the spray tank can be left retaining the rinse water or refilled with clean water for overnight storage. The external sprayer surfaces should also be rinsed in the field using a hand-lance, where fitted.

Care should be taken to ensure that where a spraying machine is stored out of doors, pesticide deposits on external surfaces of the sprayer are not washed off by rainfall, which can then contaminate surface water and drains.

Personnel protective equipment must also be fully decontaminated after use, dried, and then stored in a well-ventilated store.

4.3.2 Disposal of surplus spray

Pesticide waste is present in the form of surplus diluted spray solution and surplus undiluted product. Contaminated safety equipment and clothing, tractor cab filter elements and material used to absorb spills, also have to be disposed of.

Pre-planning should that surplus spray solution is kept to a minimum and only enough product for the area to be treated is purchased.

Unused dilute spray and tank washings can cause serious problems, particularly on horticultural holdings where many different chemical treatments may be used each day. Installing a dedicated effluent plant to deal with washings should be seriously considered.

Applying surplus spray and tank washings to the crop is a first priority, even if it means that the dose rate for the penultimate tank load is reduced so that the overall label dose rate is not exceeded.

Good product stock control will keep surplus concentrate materials to a minimum. In some countries unused chemicals can be returned to the retailer, otherwise a registered disposal contractor will have to be used. Where this service is used, the waste chemicals must be securely packed and clearly labeled in accordance with local legislation so as not to constitute a hazard when transported.

4.3.3 Disposal of empty chemical containers

Before final disposal, empty chemical containers must be thoroughly cleaned either by using an approved rinsing nozzle or by the manual triple rinse technique. Such rinsing must be done when the containers are first emptied so that the washings can be added to the spray tank in the field. If this is not possible, the rinsate must be collected, clearly labeled and stored for future use as a spray diluent. Empty containers must be securely stored before disposal by in accordance with local legislation.

Different countries have different approved ways of container disposal, which may include burial, incineration or removal by registered contractor. Empty chemical containers must be thoroughly cleaned and rendered unusable (punctured/crushed) before burial. The burial site must not be near surface or ground water. Soil type and natural drainage must be taken into consideration when selecting the site. Burial depth should be greater than 1m. Moreover, pits must avoid land drains. Site location and content must be recorded (See 4.2.5)

Not all containers can be burnt; reference to the product label will indicate if the container held a flammable product or was an aerosol. Containers must be thoroughly cleaned before burning. Additionally, burning containers may present a further hazard if smoke drifts over roadways or becomes an inconvenience.

4.3.4 Equipment maintenance and repair

When a spraying period is completed, machines must be prepared for storage by operators wearing appropriate protective clothing.

Both the inside and outside surfaces of the spray tank must be thoroughly washed and the liquid system fully rinsed through to ensure all piping and hoses are clean (see 4.3.1). It is essential to work all valves; particularly those on the induction-filling device, to make sure all spray residues are removed.

Spray nozzles and filters must be removed, washed and stored. Pumping clean water through the spraying system at a pressure higher than normal operating pressure will fully test the liquid system and indicate leaks from worn or damaged hoses.
Pump and compressor, where fitted, oil levels must be checked and performance against nozzle requirements and return to tank agitation monitored. All grease and lubrication points should be serviced and power take off guards checked for condition.
All controls should be working and the pressure gauge checked at zero when the spraying system is not in use. Control valves and pressure relief valves must be left open. Worn, damaged or broken parts must be repaired or replaced before final storage and completed work completed should be recorded.

All electrical connections should be checked and sealed for storage while pneumatic and hydraulic control couplings must be checked for damage.

CDA portable equipment must be washed through with water and a detergent, and the carrying handle wiped clean, whilst a ULV applicators should be rinsed through with a suitable cleaning fluid. Occasionally, discs must be removed and cleaned with a soft brush and checked for damage.

4.3.5 Equipment storage

Refer to theequipment instruction book for the manufacturer recommendations. Spray equipment should be dried before final storage, which should preferably be undercover and secure.

Where necessary, pumps and spray systems should be fully drained before storage and filled with frost-proof rust inhibitor in cold climates.

The tyres on trailed sprayers should be jacked up off the ground and batteries on self-propelled spray units removed and kept charged. Filter inlets on cabs should be sealed.

When CDA and ULV machines are prepared for storage all batteries should be removed and electrical contacts cleaned and dried.
Safety equipment and clothing should be checked for wear, and damaged and unserviceable items disposed of and replaced before the next spraying season.

4.3.6 Pesticide storage

Unused pesticide must be returned to store. Pesticides in or damaged containers should be emptied into clean replacement containers, which are fully labeled. Store stock control must ensure that old stock is used before recently purchased similar new products.

Good stock control and accurate planning will mean that waste concentrate and diluted spray is kept to a minimum. However, where old or obsolete chemical products have to be disposed of an approved contractor must be used. Chemicals for disposal must be secure in their original containers, fully labeled in accordance with local regulations.

5. RECORDS

Keeping records of pesticide use and application is good management. Good records can be referred to in the event of off-target contamination or if a complaint arises from poor field performance. Records can assist pesticide stock control and can provide a useful reference guide to product performance for future decision-making.

In some countries where record keeping is mandatory, enforcement officers are empowered to refer to previous years' records if an investigation is needed, sometimes up to three years. However, where operator health is monitored the records may have to be retained for considerably longer. Records should cover both details of the actual application and any operator health observations carried out.

5.1 Field spray records

An accurate and comprehensive recording system must cover all the relevant information and be simple to complete. The following information should be included:

Application date and time	Operators name
Field location	Adjacent crops
Treated crop and growth stage	Products used and dose rate.
Target pest and growth stage	Tank-mix information
Total chemical used	Adjuvants used
Water volume used	PPE used
"No-spray" barrier information	Meteorological conditions at and after spraying
Notes to cover errors/problems	Operator exposure, duration

5.2 Equipment repairs and maintenance

Repairs to spray equipment should be noted, and changes in spray technique during the season, nozzle and or operating pressure change, must be listed for future reference. Equipment repairs must be promptly addressed and replacement parts ordered. Spare nozzles, anti-drip valve diaphragms, pump diaphragms and valves for both tractor and knapsack sprayers should be kept in stock.

5.3 Operator health surveillance

Where label recommendations or local regulations demand operator health surveillance, a record should be dedicated to each operator to cover name and health details (previous health history) when working with a particular

product. Exposure time periods must be listed to include the date of the initial exposure to the product and any recommendations coming from a clinical practitioner completing the monitoring. Contact by the operator with other chemical products must also be recorded.

5.4 Personal protective equipment

PPE is only as good as its maintenance and should be provided to individuals. To make sure safety equipment gives maximum protection full operator training is important.

Wearing protective clothing on its own does not guarantee total protection if equipment becomes defective through wear or damage so regular visual checking must be carried out. Specialist equipment, such as respirator must be checked in accordance with the manufacturer's recommendation. The periods between checks will be more frequent when working conditions are more severe. Faults must be recorded and corrected before further use.

N.B. Selecting approved PPE in the first instance will make sure that operators receive the correct protection for the product to be

5.5 Local emergency contacts

In the event of an accident, an accessible list of local emergency contacts should be available to cover appropriate medical facilities with access to poisons information. A useful starting point would be the local chemical manufacturer and or supplier who should be up to date with product information and accident procedures. Contacts, such as local water authorities, environmental and pollution control agencies and the emergency services, should all be listed and a trained local first aid practitioner appointed. The first-aider should be conversant with the chemical products in use and the emergency procedures in the event of an accident. The first-aider should have copies of all the latest product labels for reference.

5.6 References

1. Guidelines on organization and operation of training schemes and certification procedures for operators of pesticide application equipment, FAO Rome 2001

2. Guidelines on procedures for the registration, certification and testing of new pesticide application equipment, FAO Rome 2001

3. Guidelines on the organization of schemes for testing and certification of spray equipment in use, FAO Rome 2001

4. Guidelines on good practice for aerial application of pesticides, FAO Rome 2001

5. Guidelines on minimum requirements for agricultural pesticide application equipment, FAO Rome 2001

6. Guidelines on standards for agricultural pesticide sprayers and related test procedures, FAO Rome 2001

7. International Code of Conduct on the Distribution and Use of Pesticides (Amended version), FAO Rome 2001

8. Guidelines for Personal Protection when working pesticides in Tropical Countries FAO, Rome 1990

9. Legislation on the Control of Pesticides, Guidelines FAO, Rome 1990

10. Guidelines on Good Labeling Practice for Pesticides, FAO Rome1995

11. Pesticide Storage and stock control manual, FAO Pesticide disposal series 3, Rome 1996

12. The WHO recommended Classification of Pesticides by Hazard

and guidelines to Classification 1996-1997

13. Pesticide Application Equipment for Agriculture, Volume 1 Manually carried Equipment, Volume 2 Mechanically powered equipment, FAO Agricultural Services Bulletin 112, FAO Rome

5.7 Local emergency contacts

1. Emergency medical assistance: - Doctor, Health centre and Hospital
2. Local manufacturers and suppliers of pesticide
3. Environmental and pollution control agency
4. Water authority
5. Emergency fire authority
6. Local authority, Police and highway control
7. Health and Safety authority
8. Approved waste disposal contractor