Guidelines on

GOOD PRACTICE FOR AERIAL APPLICATION OF PESTICIDES

Guidelines on Good Practice for Aerial 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 presented guideline covers the application of pesticides using spray aircraft. A similar guideline covers the use of field crop, tree and bush crop sprayers:

Guidelines on good practice for ground 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 and in public health programmes. They have been drawn up to 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 to 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. Acceptable spray distribution is relatively easy to achieve with most ground-based directed spraying, but spray application with fixed and rotary wing aircraft presents more complex problems. The purpose of this guide is to identify some of the problems and to suggest means of addressing them. Although the number of aircraft licensed for aerial spraying has decreased recently, where large uniform areas have to be rapidly treated, aircraft application is usually considered to be more fuel-efficient than ground spraying. Aircraft are used to apply both liquid and solid materials as well as to broadcast seed when soil conditions prohibit the use of ground equipment.

The regulations and any country laws relating to aircraft spraying must always be observed.

These guidelines have been prepared to offer practical help to all those involved in applying pesticides by air for food and fibre production and apply equally for vector control in public health programmes. The potential for high productivity and safe aircraft deployment can only be realised when the spray operation is well organised and the people involved are fully trained and aware of their responsibilities.

Aerial spraying can be used to treat large areas quickly and, unlike ground spraying, can be carried out when field conditions prevent wheeled vehicle access, which enables the timing of spray treatments to be improved and soil compaction reduced. There are however, certain disadvantages associated with aircraft spraying. High wind speed and temperature inversion may limit treatment application whilst trees, waterways, environmental considerations and overhead power lines may also prevent some fields

from being treated. Accurate deposition in dense crop canopies can also be more difficult to achieve with aircraft. Volatility and spray drift can be a problem with aerial spraying and environmental contamination can be significant if spraying is incorrectly executed.

Where local codes of practice for pesticide use and application, and local Civil Aviation (CA) regulations are already in place, these guidelines are offered as additional guidance. The importance of referring to the existing legislation cannot be over emphasised, as the failure to comply may have legal implications if a product complaint arises or an off-target contamination incident occurs.

1.1 Guideline objectives

These guidelines have been drawn up to cover the application of both conventional aqueous undiluted sprays and ultra-low volume (ULV) formulations. They provide information and advice on safe practices.

For adequate aerial spray operation the following considerations must be addressed:

a) Close co-operation between the grower, the spray contractor and the pilot
b) Adequate pre-planning before spraying
c) Awareness and understanding of local environmental considerations
d) Consideration of the safety of people, animals and non-target crops
e) Accurate selection of approved products
f) Use of appropriate spray technology and well maintained equipment
g) Competent and well trained management and support staff
h) Pilot awareness

1.2 Training for pilots and ground support staff

Adherence to local requirements must be the starting point for all those involved in aerial spray application. Training is required for ground support staff as well as for the pilot. The local Civil Aviation Authority will normally administer the pilot's flying licence and a permit to apply pesticides, however, additional training in the techniques of spraying is usually required to qualify for agricultural work. Whilst a private pilots licence can usually be obtained locally, training for agricultural work may have to be undertaken elsewhere at a recognised centre.

A pilot must prove competence in the use of pesticides related to:

a) Appropriateness of the pesticide and formulation
b) The correct dose rate, application technique and procedures
c) Awareness of the hazards associated with the use of the product
d) First aid procedures in the event of an accident

In some countries spray contractors work to agreed company guidelines which are regularly checked and updated by the Civil Aviation and /or other authorities, who issue operator licences and register individual spray aircraft as airworthy and compliant with the specifications for spray operation.

Ground support staff (mixers, loaders and flagmen) must be adequately trained to ensure that they are fully protected and the spray operation is as safe as possible. Ground-based functions cover two distinct operations:

a) Mixers and loaders
b) Field staff and flagmen

a) The mixer/loaders

These staff must be fully conversant with their company procedures, operating manuals and practices so that products are safely mixed and

loaded into the aircraft hopper in the correct amounts at the recommended dilutions.

Protecting the mixer/loader is a high priority as exposure potential is high when handling concentrated pesticides. Where many aircraft sorties are flown from each airstrip this results in extended periods of exposure of the ground crews and increased risk. Engineering controls such as closed chemical transfer devices, returnable containers and pre-measured chemical dose packs should be used to reduce the risk to ground staff.

Training must therefore cover the safe and correct use of chemical loading and transfer systems and the use of personal protective equipment (PPE).

b) Field staff and flagmen.

Field staff members are responsible for meeting legal requirements for operational safety as well as for issuing warnings to those likely to be effected by the spray operation such as local beekeepers, and those adjacent to the area to be sprayed. Before spraying, the field staff will visit the site to be treated, noting obstacles such as trees, overhead power-lines, waterways, roads and houses which may be flown over during the spraying. Frequently an additional requirement of ground staff is to provide the link between the spray contractor and members of the general public.

The use of a Global Positioning Satellite (GPS) system for aircraft navigation is strongly recommended as a safer alternative to the use of human flagmen however, where human flagmen are used, they should be:

- able to select and use appropriate personal protective equipment;
- aware of the need to avoid contamination by working upwind from the flight path;
- aware that records of the pesticides used during the day must be readily available (e.g. for use in cases of intoxication of the worker or his family);

- able to communicate with the pilot and the staff at the loading area in the event of a change in the weather that might effect the spray operation. N.B. weather conditions at the airstrip may be very different from those at the site to be sprayed;
- appropriately trained and in possession of a recognised certificate of competence, which should be regularly updated.

Trainers, with specialist knowledge and understanding of aerial spraying, should be used to train ground crews.

1.3 Spray equipment selection

The selection and use of appropriate spray equipment plays an essential role in safe and efficient pesticide use. In order to obtain a licence, aircraft have to be checked by the local Civil Aviation Authority, however, spray equipment must also be approved. Much of the spray equipment is common to that which is used on terrestrial equipment, however, where aircraft are to be used for applying undiluted formulations (ULV), the sprayer system and components should be made from materials which are compatible with such formulations. Where reduced liquid flow rates for ULV spraying are used, a spray monitoring system and a flow meter are essential.

The Civil Aviation Authority, in collaboration with the Ministry of Agriculture or other designated institution, should verify the spray system. This should include checks on the spray system, calibration and spray distribution to ensure that all valves, anti-drip devices, and spray nozzles are working satisfactorily. The accuracy of calibration of spray monitoring systems should also be checked.

1.4 Using pesticides correctly

Product selection should be made taking into consideration the environmental risk, the potential operator exposure hazard and the

recommended dose rates. The products chosen must be used strictly in accordance with the label specification.

The majority of pesticide products and formulations approved for conventional aerial spraying are similar to products applied through conventional ground sprayers, however, when applied by air they are generally used at lower water volumes and therefore at higher spray solution concentrations. Where products used are not designed for aerial application, some formulations can present problems such as thickening, excessive foaming and emulsion inversion.

1.5 Managing operator exposure

The speed of operation and the large areas that can be rapidly treated using spray aircraft make managing exposure an important consideration when selecting a pesticide. Product toxicology influences operator exposure-time limitations and methods and techniques to keep operator exposure to a minimum should be carefully considered in the product selection process.

Label recommendations and the instructions on the use of PPE must be carefully followed.

Engineering controls, such as closed chemical transfer systems, to reduce operator contamination when handling and loading the concentrate material are essential to minimise operator exposure. These systems must be capable of accurately extracting and measuring products from their original containers and should be easy to calibrated for products of different viscosities.

Operator health surveillance to is an important requirement. All staff must undergo regular health checks, which should include blood tests. Effective worker health monitoring can indicate changes in health of an individual attributed to working with particular pesticides.

2. THE DECISION MAKING PROCESS

The use of a pesticide may put people, other life forms, and the environment at risk, therefore the decision to use a pesticide should only be taken when all other alternative control measures have been fully considered and its use controlled within an integrated control programme. (see 2.1 below)

2.1 Alternatives to pesticide use

The alternatives to pesticide use can be divided into Natural and Applied Control measures. Natural control may utilise naturally occurring pest enemies, or rely on meteorological conditions to effect pest and disease control. Applied Control can include crop rotation, the selection of disease resistant crop varieties, changes in sowing dates as well the use of pesticides. The system, which offers the least hazard should always be selected. If local pesticide regulations are not in place the *International Code of Conduct on the Distribution and Use of Pesticides (Amended version) FAO,* offers guidance.

2.2 Risk/Benefit consideration

The risks and benefits of using a pesticide must be addressed before selecting a pesticide product. By completing a risk assessment, harmful effects can be minimized.

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 numbers of pest and beneficial organisms 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 and the 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 following 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.

2.4 Label information

The manufacturer's product label is the main source of information for the end user. It should be read and understood by anyone using the product. The user must also make sure that the label terminology is fully understood. The label is attached to the product container and usually reproduced on the outer container or wrapper of the transport container or carton. In most countries, adhering to the label recommendations is a legal obligation.

DO NOT USE AN UNAPPROVED OR NON-LABELLED PRODUCT

The product label carries statutory instructions for the user, and must cover the crops for which it is registered, the recommended dose rate, the number of treatments permitted 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 PPE to be used when handling and applying the product and advise on environmental protection measures to be carried out. Such measures may refer to a "non-spray" barrier (buffer zone).

Buffer zones

A buffer zone is an untreated area wide enough to capture drift fallout adjacent to the sprayed area. Nozzle type, droplet size, product dose, dilution and spray technique should be considered when this unsprayed barrier (buffer) width is determined.

For aircraft spraying the buffer zone needs to be wider than for ground spraying as it is more difficult to make a precise spray cut-off with an aircraft operating at speed. The width of a buffer zone is also influenced by the pesticide product type and by the presence of adjacent waterways.

For example, a buffer zone of 5,000 m is recommended for certain organochlorine insecticides. This distance is considered adequate to capture sedimenting spray droplets following the completion of a spray run.

Some pesticides are highly toxic to aquatic life so that spray drift fallout over water should be carefully avoided with products with this classification.

The product label should provide application details, which should include nozzle selection, volume applied, and application timing. When ULV applications are to be made using rotary atomisers, liquid flow regulation and atomiser rotational speed should also be stated on the label.

The label usually carries first aid information to assist a doctor in the event of accidental contamination.

Information on cleaning (“decontamination”) and disposal of empty containers is also usually included on the label.

2.5 Tank mixing

Applying more than one product at the same time (tank-mixing) can improve the logistics and cost 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 present as crop scorch, which although it may be only transient, can often reduce final yield.

The most common limitation, however, is physical incompatibility, which can result in nozzle and filter blockage as well as phase separation in the spray tank where agitation is inadequate. This is common when during flights to the spray area (ferry flights) the spray pump is secured or turned off in the case of an electrically driven pump. This means that there is no circulation of the spray liquid back to the tank.

Where aircraft are refilled from a ground ("nurse") tank, frequent re-circulation of the contents will ensure that there is no phase separation within the nurse tank.

Product labels should give advice on tank mixing and approved mixture partners, information on the sequence of introducing the products into the tank and the need for agitation.

Water temperature, quality and pH can also influence chemical stability of tank mixes.

3. SAFETY ASPECTS

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

3.1 Operator health surveillance

The health of operators exposed to pesticide 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 with pesticides. Health surveillance should also help determine whether safety practices and the selection and use of PPE are adequate for the products being used.

3.2 Product transport and storage

Transporting pesticides by road is usually controlled within respective country 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 goods, which may include pesticides.

As well as the journey from the retailer to the end user, pesticide containers will also be moved in and out of store and to the airstrip on the farm. Containers must be checked for leaks and damage and must always remain fully and clearly labelled. This is particularly important for aircraft spraying where large drums are stored outside and are exposed to the vagaries of the weather.

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

It is usual for large quantities of pesticide to be stored and handled at permanent airstrips. Such stores must be secure, as they may be remote and not always attended. Shade must be provided for chemical stocks, particularly when they are packed in 200 litre drums.

Ground support staff must be fully conversant with procedures in the event of accidental spillage or operator contamination at airstrips, which must have fully maintained first-aid kits, an emergency shower unit and adequate quantities of absorbent materials to deal with spillage.

Pesticide stores and storage areas must be accessible in the case of an emergency.

Storing pesticides on the farm may be covered by local legislation. Correct and safe storage is essential to maintain a safe working environment, to maximise product shelf life and to minimise the risk of fire and spillage.

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, location, emergency procedures etc. can usually be obtained from national regulatory authorities.

Further information on product storage can be obtained from the *Guidelines for Packaging and Storage of Pesticides (FAO 1985)*, which also contains information on the establishment of permanent airstrips.

Under no circumstances must pesticides be stored near foodstuffs.

3.3 Product handling

The product label is usually the first reference for guidance on handling formulated pesticide products. It will usually describe the requirements for the use of Personal Protective Equipment (PPE) both for handling the undiluted (concentrate) product and for diluted spray solution.

Operator exposure and environmental contamination can be substantially reduced when closed filling systems are used to extract the product from its shipping container and deliver it either directly to the spray tank or via a metering system to a separate mixing tank. This avoids contact with the loading crew and accidental spillage. Some closed transfer systems can empty and rinse chemical containers automatically and can eliminate the need for rinsing empty containers and the disposal of the contaminated water.

3.4 Chemical container management

On no account must empty chemical containers be reused. Empty containers must be thoroughly washed and rendered unusable before disposal. Empty containers can be effectively cleaned by manual methods or by a closed transfer system that collects the washing water (rinsate). Empty containers must be collected and securely stored prior to disposal and should not be left unsecured at the mixing site.

Some countries allow controlled burial for empty and thoroughly cleaned containers whilst high-temperature incineration is permitted in other cases. Local environmental pollution control regulations must be consulted.

Chemical container management can be facilitated where products are purchased in returnable containers**.** In this case sealed containers are returned to the manufacturer for re-filling; a process, which often can be repeated several times during the life of a container. An approved, compatible extraction system to both measure and extract the chemical for use is required and systems must be capable of handling products of different viscosities and containers of different closure sizes.

3.5 Accident procedures

If spillage occurs during transport or handling a pesticide, this may result in a fire, injury to humans, property damage or environmental contamination. Rapid action must follow the accident to contain and minimise any adverse

effects. Pesticide transporters and users must be familiar with label recommendations and procedures to be followed. In the event of an accident, the appropriate authorities (Environment, Water, Police etc) must be notified. Records must be kept of all incidents and remedial action taken.

Only vehicles correctly equipped to carry pesticides must be used to transport product to the airstrip.

3.6 Personal protection

Pesticides enter the body through:

a) ingestion/swallowing through the mouth, accidental or deliberate;
b) dermal, through the skin when handling, measuring and pouring;
c) inhalation of small particles or dust when handling, spraying and flagging.

Of the above three routes, dermal exposure is the most common hazard. Avoiding exposure by the use of appropriate protective clothing and equipment (PPE), and paying attention to personal hygiene by washing exposed parts of the body after work and before eating, smoking and toileting will minimize risk. Personal protective equipment must be selected in accordance with the label recommendation. It must be comfortable to wear/use and be made of material, which will prevent penetration of the pesticide.

Where undiluted formulations are applied as ULV sprays, specific PPE requirements are stated on the product label. ULV treatments require PPE, which is approved for the particular product in use.

PPE must bear an approval mark and should be comfortable to wear and not restrictive in use. The material used for PPE manufacture must prevent penetration of the particular formulation to be used (break-through time).

PPE will only remain efficient if it is correctly maintained. Where damaged, repairs must restore it to its original specification and if this is not possible the item must be replaced.

Respirators must be checked on a regular basis and filter elements replaced in accordance with the manufacturer's instructions.

The operation of an airstrip involves additional safety considerations. As well as PPE for the ground crew and field staff, appropriate fire extinguishers must be provided for both the aircraft and the airstrip.

The pilot must have a crash helmet and an approved safety harness for cockpit use and a respirator/fresh-air mask.

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

It is essential that the equipment is appropriate for the pesticide formulation to be sprayed. Conventional aqueous solutions are applied through hydraulic systems but where materials are to be applied undiluted (ULV), suitable atomisers must be fitted to the spray booms instead of nozzles.

Pumping and plumbing layouts are common to both application techniques but certain system components may have to be changed in cases where an aircraft is used for ULV spraying. Liquid flow rates for ULV spraying are lower than those for conventional spraying so that aircraft using this method require to be fitted with a spray liquid flow meter.

4.1.2 Equipment serviceability

Before spraying, several key points related to the equipment must be checked:

- Structures on and around the airstrip: steps, ladders, handrails and loading equipment must all be checked for serviceability.

- Guards on engine driven pumping and filling systems must be in place and secure.

- The aircraft's maintenance manual and the spray equipment manufacturers instructions must always be consulted in the first instance.

- The pilot and the support staff are responsible for the aircraft's airworthiness, however, in many cases, the spraying system is maintained by an aircraft mechanic who must be trained and fully protected when working on the spray equipment.

- When starting up the system, before spraying it is advisable to initially rotate the spray pump by hand, irrespective of drive type (wind, hydraulic or electric) to ensure that it is free to turn.

- Blade angle on some wind driven pumps can be checked for adjustment and the transport brake, for locking the pump during ferry runs, must be fully clear when released.

- All filters must be in place and self fill valves and couplings clean and serviceable.

- Hoses and hose joints must be visually assessed, and where component parts are wired to the aircraft for security the condition of the wires must be checked.

- In the cockpit, operation of the three way valve must be positive and the hopper emergency dump mechanism safe and operational.

- Nozzles and nozzle bodies must be checked for wear and damage and the diaphragm check valves must be in good condition to ensure a positive spray cut-off. Rotary atomisers must be in balance and rotate freely. If they are blade driven, the blades must be free from damage and correctly adjusted for the selected rotational speed (droplet size control). Liquid flow restrictor adjustment must to be checked and adjusted for the required throughput for the desired application rate.

- It may not be possible to fully pressurise the spray system on the ground, particularly where the spray pump is wind driven, but at some stage the system must be checked for leaks. The aircraft will have to be flown to check the operation of the spray system and the efficiency of the pressure gauge. If the gauge does not return to zero when the spraying system is switched off the three way valve may not be closing correctly. This in turn will reduce the efficiency of the "suck-back" circuit when the spray is turned off.

- Aircraft mounted electronic equipment such as the spray liquid flowmeter, output printer and navigational aid system have to be checked and re-calibrated against manufacturers calibration figures.

4.1.3 Adjustment and control checks

The spray system on/off and liquid flow rate controls are adjusted by the pilot during the operational checks. The spraying system must be checked as outlined above (see Section 4.1.2) and the boom orientation in relation to flight direction may have to be adjusted to alter droplet size from hydraulic nozzles. Nozzle selection can be made according to product label recommendation but nozzle types; spray angles and throughputs must not be mixed on the boom. Boom orientation and nozzle positioning must be finally verified to ensure vortex creation is minimum.

Where rotary atomisers are used, they should be adjusted for similar speeds. Occasionally inboard atomisers are adjusted to compensate for the increase in air speed from fuselage "screw", and the manufacturer's instructions should be referred to. Where liquid flow rate is controlled using an adjustable restrictor, it is important to ensure that the liquid feed is the same for each atomiser. Atomiser speed is monitored via a tachometer unit that feeds information for individual atomiser rotational speeds to a cockpit-readout.

4.1.4 Conventional spray calibration

The Ministry of Agriculture may have in place a schedule of use guidelines for spray aircraft that include regular spray system calibration and distribution checks and general equipment serviceability assessments. To ensure such that checks are efficiently carried out the use of an independent agency or service is recommended.

Spray equipment calibration must be carried out at the start of each season, after equipment repair or when changing application technique. There are three major factors, which influence sprayer calibration:

a) Speed over the ground (km/h)
b) Swath width and lane separation
c) Liquid flow rate (1/min)

a) Forward speed over the ground can be determined by timing the aircraft over a measured distance flying in both directions to compensate for wind influence. This operation must be replicated three times to obtain an average speed and is necessary as the aircraft instrumentation will indicate only speed through the air.

b) Effective swath width is taken as the lane separation for each aircraft pass and will vary between conventional and ULV application. Recommended flying height should also be checked during field observation as a function of swathe width.

c) The spray liquid flow rate from the nozzles at a given operating pressure can be obtained from the nozzle manufacturer's information sheets. Such information is generated spraying clean water and presents a good starting point. However, unless the nozzles are specifically designed for it the special conditions and the low volume rates of aerial applications may result in different flow rates than indicated in the manufacturer's information.

The spray liquid output from an aircraft fitted with an electric or hydraulic driven pump can be determined on the ground but to determine the output from a wind driven pump system the aircraft will have to be flown at spraying speed.

4.1.5 ULV spray calibration

ULV spraying applies formulations, usually undiluted, in high concentrations of both active ingredient and non- volatile agents. There is a high degree of drift associated with the small droplets used for ULV spraying, which makes the technique more suited for large areas of crop, rangeland and for public health programmes. The actual field spraying using aircraft is more demanding than that for conventional work because

the viscosity and therefore the flow rate of formulations vary. Initial settings can be taken from the manufacturer's data for water but ready-to-use ULV formulations may have a higher viscosity and lower flow rate than water so will have to be corrected by multiplying the total flow rate by between 1.1 and 1.3 depending on the formulation viscosity.

Determining the speed of the aircraft over the ground is the same as for conventional spraying, however, with ULV spraying, the swath width will be wider as the aircraft is usually flown slightly higher. For ULV, there are fewer spray emission points on the boom than for conventional spraying and accordingly flying height should be increased by 2-3 metres to allow the spray plumes from each atomiser to fully develop and meet. Otherwise, there is the danger of leaving untreated strips on each pass, however, and alternative solution is to increase the number of outlet points on the booms (i.e. additional atomisers at closer spacing). Flying height can be re-confirmed following and assessment of spray distribution, which must be included as part of the calibration process.

Rotary atomisers are usually propeller driven by the aircraft slipstream but where slow aircraft or helicopters are used, electric or hydraulic drives may be necessary. This is particularly important for helicopter spraying where atomisers must quickly regain operational speed to maintain the correct droplet size following sharp turns "out of and into work".

4.1.6 Tank filling

The spray loader is at the highest risk when handling the concentrate pesticide and his exposure time will increase on airstrips handling more than one aircraft for multiple sorties.
In such cases, the use of a closed chemical transfer system will reduce the risk to both the operator and environment.

Aircraft hoppers can be top-loaded (solids), but most liquids are loaded via a self-filler valve located on the fuselage. These valves must be of the dry-

break type and large enough to facilitate rapid filling. The valve must be positive in action to eliminate spillage.

The tank filling procedure must follow label recommendations for product introduction into the hopper, however, as agitation of the spray solution is limited during filling and "ferrying", the use of a pre-mix facility is recommended.

The above point becomes more important in the case of a helicopter fitted with pannier tanks and an intermittent electric drive pump, which is only used when actually spraying.

Aircraft payload may need to be reduced to compensate for airstrip conditions or the effect of atmospheric conditions on engine performance, which in turn will determine how much spray liquid, can be loaded.

4.1.7 Prior warnings

Members of the public, not directly involved with the spray operation, may also be affected by an aerial pesticide application so the contractor/farmer may have a mandatory obligation to issue "prior warnings" to any person or organisation that might be affected or concerned.

Warnings must be given in ample time to beekeepers, owners of adjacent crops, livestock owners and those responsible for nearby environmentally sensitive sites. 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 make sure that the actual spraying is carried out under the safest conditions and accurate spray timing will help ensure that the product is used to optimum effect. Employers and operators must

make sure that all safety equipment, clothing and aircraft loading equipment is clean and in a good state of repair.

4.2.1 Field survey

The possible environmental effect of the selected product will have already been considered when the decision to use it is made. The pilot accepts the responsibility for treating a particular field and the decision to spray will be made following a preliminary inspection flight to note boundary locations and determine the method of ground marking. The pilot will also note the position of trees, overhead wires, habitations, waterways, livestock which might be frightened by low flying aircraft, and field undulations, which may affect aircraft performance and the number and position of the flagmen required. Adjacent crops must be noted and roads and railways observed, particularly where they are raised on embankments, which may restrict aircraft manoeuvring.

Spray pilots must observe national legislation regarding the dimension of mandatory "no-spray" (buffer) boundaries. The product label will stipulate the buffer widths where appropriate.

In some countries organisations are available to advise on field headland and boundary management and they can assist with local environmental risk assessment when a pesticide is 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 likelihood of rain all influence spray deposit. The distance a spray droplet travels depends on the droplet size and downward velocity, the release height and the ambient conditions. Vortices created by the aircraft passage will also influence spray distribution efficiency.

Wind

Aircraft spraying is normally carried out when the surface wind speed is less than 6-7m/s, which is a safe speed for aircraft handling and safety. However, in areas of exceptional turbulence the above figures may have to be reduced. Reference to local rules and guidelines may indicate the cut-off wind speed for aerial spraying, however, it is inadvisable to spray when wind speeds exceed 8m/s under most circumstances. Wind speed and direction will also influence flying height. When the wind speed is less than 3m/s, a boom height of between 3 and 4 m above the crop will ensure good lateral movement of the spray but flying height must be reduced if the wind speed exceeds 3m/s.

Spraying must be carried out taking into account the crosswind to ensure that the flying speed and the application rate remain the same for both flight directions. The distance that the spray moves will vary according to wind strength and aircraft altitude.

Temperature

In conventional (water-based) spraying, high temperature, combined with low relative humidity will reduce droplet size through evaporation, which will increase the risk of drift. As temperature increases so atmospheric turbulence rises. Spraying must not be carried out where there is upward air movement or where a temperature inversion prevents the spray cloud settling within the treated area.

For ULV spraying, conditions of mild turbulence, similar to those recommended for conventional spraying, are preferable.

The relative humidity can be calculated from tables, by determining the difference between the wet and dry bulb thermometers (hygrometer). When the difference between the wet and dry bulbs exceeds 8°, aqueous spray suspensions should not be sprayed.

4.2.3 Treatment timing

The optimum timing to spray will depend on the pest, weed and disease development stages. Treatment timing will also be governed by meteorological conditions, which may affect losses from drift and from volatile spray. Temperature, relative humidity, wind direction, wind velocity and rainfall can all influence spray deposit efficiency. The product label will indicate the period of time the treatment can be applied before rain and may also indicate the required dose rates for top-up application if the original spray is diluted by unexpected rain shortly after spraying.

If application timing is accurate, fewer spray treatments may be needed. The use of suitable computer modelling to predict spray timing may help to reduce the number of treatments required and accurate pest forecasting can be useful.

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 status of beneficial organisms to determine when to spray. An understanding of product mode of action in relation to crop development will also be advantageous.

4.2.4 Airstrip operation

The site should be as close as possible to the work area and must have good vehicle access. Aviation fuel and pesticide must not be stored together and the latter should be shaded from direct sunlight. A hard apron for loading and washing down aircraft is preferable for permanent airstrips where spills and washings should be retained and drained into a holding tank for processing.

Emergency and first aid equipment must be kept in good condition and clearly marked and sited. Facilities for washing and for storing PPE must also be available.

Operator and environment contamination may be reduced if products are handled and loaded using closed-transfer systems working with returnable containers (see 3.4 and 3.5).

When spraying with aqueous solutions the aircraft hopper should be half filled with water before adding the formulation. As spray tank agitation is usually limited, wettable powders must be pre-mixed before loading. The use of a separate, ground-based mixing tank will speed up the transfer operation and enable the spray mixture to be fully agitated before loading.

Pilots should not be in contact with the pesticide during the loading the pesticide solution into the aircraft, which is the responsibility of the ground staff who should be familiar with the products they are handling and the accident procedures in the event of a spill or a contamination incident. The ground staff members are also responsible for cleaning up any spills onto the aircraft itself during filling and for keeping the cockpit windscreen splash free and clean.

4.2.5 Field operation

Local regulations relating to aircraft operation must always be strictly followed.

Field staff members are responsible for on-the-ground site management.

Field marking is carried out following a reconnaissance flight made by the pilot prior to the operation commencing. Swath matching (lane separation) can be effected by various methods. The use of natural markers provide an inexpensive marking system but fixed markers can only be considered if the crop is to be treated many times and the wind direction remains consistent. Balloons and kytoons have been used to mark aircraft passes over tall crops but the most common method of field marking is still human flagmen, who must be fully protected at all times and remain visible to the pilot during the spray operation.

To reduce contact with the spray cloud flagmen must be positioned at least 100m away from the field edge and should move upwind when the aircraft comes out of the turn and levels in preparation for the spray run. The distance between spray runs should be measured, using a fixed length of rope. Wherever possible, the use of a GPS system is strongly recommended to eliminate the use of human flagmen. Field staff should never enter the treated area

Accurate aerial spraying over undulating rangelands and forest tracts is more difficult to achieve than when treating smaller crop areas and in these circumstances electronic track guidance may be financially justified. Both the self-contained Inertial Navigation System (INS) and the Doppler System require no external reference input during flight, but the size and complexity of these units confines their use to large aircraft. These systems are not precise enough for smaller-scale agricultural spraying.

Systems working with external references are also available. Positional information is received from a series of transmitting stations around the world, which produce hyperbolic lines of constant phase, which can be converted onboard into navigational guidance. Such systems eliminate the need for human flagmen, and constantly monitor and evaluate the spray process.

4.2.6 Sprayer field settings

During a flight, spray pressure, output and aircraft height above the crop can be adjusted if necessary however, as the pilot has to concentrate on flying the aircraft he may only occasionally check the spraying system.

The use of artificial targets within the treated crop is strongly recommended to check and evaluate spray deposit efficiency as well as confirm the lane separation distances. This is where the ground staff can report back to the pilot, via the radio, any problems with the spraying system such as blocked nozzles or incorrectly operating atomisers.

4.2.7 Chemical handling

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

Handling and loading chemical products must only be carried out by fully trained and protected staff. Only approved PPE must be used.

Absorbent material to contain chemical spills must be available at the filling site. Chemical stores must be kept secure at all times and must have a secure section for storing clean, empty chemical containers prior to their collection for disposal.

4.2.8 Chemical container handling

All operators must be trained to handle chemical containers, remove seals, measure and weigh dry formulations and pour liquid formulations and to correctly rinse empty containers.

Where mechanised container rinsing is not available, triple manual rinsing with clean water will remove chemical residues leaving the container ready for disposal. (Use 20% of the container volume in clean water for the three individual rinses). Containers must be rinsed immediately after use and the washing liquid(rinsate) emptied back into the spray or mixing tank.

Handling the concentrate material 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. Engineering controls, closed transfer systems, returnable containers, water dispersible sachets etc, should be used where possible.

Chemicals must be stored in their original containers and part-full product containers must be re-sealed and returned to the store.

EMPTY CONTAINERS MUST NOT BE RE-USED

4.2.9 Post-treatment warnings

Immediately after the spray has been applied warning notices must be posted around the treated area in accordance with any label recommendations. Recipients of warnings such as beekeepers can be informed that the application has been completed. The field notice should inform people of the treatment and the re-entry period. Notices should be removed when they are no longer required. Livestock must be kept out of the treated area for the period stipulated on the product label.

4.3 Post-application

Safety for the operator and the environment remain a prime consideration after spraying when cleaning or repairing spray and loading equipment. Such operations may be carried out by aircraft-maintenance staff who are not familiar with the protection required when handling contaminated equipment. They must be fully protected when cleaning or repairing the aircraft or the spray equipment.
Refer to the aircraft and sprayer manufacturer instruction literature for the correct maintenance procedures. Aircraft maintenance will be the subject of local Civil Aviation rules but no work should be started before the equipment has been thoroughly cleaned ("decontaminated").

4.3.1 Cleaning ("decontamination") of equipment and PPE

Following spraying, the aircraft and spray equipment must be washed internally and externally in the field and the rinse liquid sprayed onto a crop for which the product is registered, making sure that the recommended dose rate is not exceeded by over-spraying a treated area. Following a conventional spray application the spraying system should be rinsed three to four times with small amounts of water rather than once with a full tank. Particular care must be taken after working with wettable powders as residues can accumulate in the spray lines and filter housing.

Oil-based, ULV formulations cannot be washed out with water. An appropriate, recommended solvent must be used to rinse the spraying

system. Tank washings can be sprayed out onto waste land provided there is no likely environmental effect, or alternatively can be collected, treated and incinerated. If cleaning /decontamination is incomplete, product deposits may build up in un-purged areas or on rotary atomisers throwing them out of balance. Vegetable oil used as a spray carrier can be fully removed by washing with water and a detergent solution immediately after spraying is completed. Complete spray system rinsing and draining is important as some aircraft plumbing can retain as much as 30 litres of spray solution or ULV product when they are considered “empty”.

Personal Protective Equipment must be thoroughly cleaned after use, dried and stored in a well ventilated store away from other materials.

4.3.2 Disposal of surplus spray

Pesticide waste can be divided into surplus diluted spray solution (see 4.3.1) and surplus concentrate material. Contaminated safety equipment, protective clothing, cockpit filter elements and material used to absorb spills all have to be correctly disposed of. Pre-planning the spray operation should help to ensure that surplus spray solution is kept to a minimum and only enough product for the area to be treated is purchased and prepared. This may be difficult where product demand is high and the objective of the management is to keep aircraft working when conditions are right. Good stock control will keep surplus concentrates to a minimum.

In some cases, unused chemicals can be returned to the retailer otherwise an approved contractor will have to be used to dispose of the unwanted product. Where this service is used the waste chemicals must be securely packed and clearly labelled when transported.

Unused dilute spray and tank washings can cause serious problems, particularly where many aircraft use the same airstrip and many different chemicals are washed from the aircraft at the end of work periods. In such cases, installing a dedicated effluent plant to deal with such washings is likely to be the only practical solution.

4.3.3 Disposal of empty chemical containers

Before final disposal, empty chemical containers must be thoroughly cleaned ("decontaminated") either by using an approved rinsing nozzle or by the triple manual rinse technique (see 4.2.8). Wherever possible, the rinsing must be done immediately after the containers are emptied so that the washings can be added to the spray tank in the field. When this is not possible, the rinse water can be collected, clearly labelled and stored for future use as a spray diluent when the same product is used again.

Empty containers must be securely stored before disposal by an officially approved method.

Countries differ in their legislation on container disposal, which may include burial, (incineration) or removal by a specialist, registered contractor. Empty chemical containers must be thoroughly cleaned ("decontaminated") and punctured or 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 a burial site and the location, and the pesticide products originally stored in the buried containers must be recorded.

Even where legislation permits, not all containers should be incinerated. The product label will indicate whether the container was used to store a flammable product or was an aerosol. Containers must be thoroughly cleaned ("decontaminated**")** before incinerating. Incinerating containers may present a further hazard if smoke drifts over roadways or becomes an inconvenience. A simple incinerator based on a 200 l steel drum has been designed, which generates substantial heat, while producing little smoke.

4.3.4 Equipment maintenance and repair

When spraying has been completed, equipment must be prepared for storage. Both inside the spray hopper and the outer surfaces of the aircraft must be thoroughly washed and the liquid spray system fully rinsed through to ensure that all piping and hoses are clean. Washing the aircraft fabric is

particularly important to avoid damage to the aircraft components. All the surfaces of the aircraft controls must be cleaned and lubricated as appropriate.

The spraying system should be operated at a higher than the normal operating pressure to fully test the system to indicate leaks from worn or damaged hoses and or component parts. Pump drive systems, electrical, hydraulic or ancillary engine, must be maintained in accordance with the manufacturer's instructions and the spray circuit pipe system fully drained before storage.

All hydraulic nozzles should be removed for storage and all check-valve diaphragms inspected for damage and wear. The spray pressure gauge must be checked at zero when the spraying system is not in use.

Rotary atomisers must be thoroughly cleaned and cages checked for damage and balance. Seals must be inspected and spring-loaded working parts (cut-off valves/liquid restrictor valves) must be working correctly. Brakes used to stop the spray pump and atomisers rotating during ferrying must be clean and free from contamination from oil and grease.

All electrical components of the spraying system should be checked and couplings sealed for storage when units such as navigation aids and spray monitoring equipment are removed for storage. When new components are fitted to the spray system or existing ones repaired, work carried out must be recorded in the aircraft maintenance log.

4.3.5 Equipment storage

Refer to the relevant operator instruction manuals for both the spray equipment and the aircraft. Aircraft mounted spray equipment is often removed after spraying to release the aircraft for other duties. Both the spray equipment and the aircraft must be thoroughly cleaned ("decontaminated") and dried, before being stored. Aircraft storage will

depend on local regulations but the aircraft should be stored under cover and be fully secure.

4.3.6 Pesticide storage

Unused pesticide must be returned to store. Distressed or damaged containers must be emptied into clean replacement containers, which are fully labelled. Store stock control must ensure that existing chemicals are used first before recently purchased similar new products. Refer to the *International Code of Conduct on the Distribution and Use of Pesticides, FAO, 1989.*

Good stock control and accurate planning will mean that waste concentrate and diluted spray are 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 wherever possible and fully labelled.

5. RECORDINGS

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 as well as provide a useful reference guide to product performance for future decision making.

Where record keeping is mandatory, local enforcement officers are empowered to refer to records, sometimes up to three years after the actual application has been completed. Where operator health monitoring is mandatory, 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.

Aircraft use and maintenance recording should be carried out, usually in accordance with the local Civil Aviation Authority and the appropriate department of the Ministry of Agriculture and or other relevant ministry.

5.1 Field spray records

An accurate and comprehensive recording system must cover all relevant information and be simple to complete. An investigation into unsatisfactory product performance or an off-target contamination incident will begin with a check on the job-card or work sheet, which should be completed on the day of application. The job-card should include the following information:

Target pest and growth stage	Hectares sprayed
Application date and time	Total amount of product used
Crop, growth stage	Adjacent crops
Product and dose rate	Tank-mix information
Water volume used	Adjuvants used
Aircraft type and registration	Pilots name
"No-spray" barrier information	Start and finish time
Meteorological conditions at application	Field marking method
	Aircraft loading information
Lost time information	Operator exposure times
PPE used and operator monitoring	

5.2 Equipment repairs and maintenance

Repairs to spray equipment must be logged and changes in spray technique and calibration during the season must be listed for future reference.

Information on aircraft maintenance should be recorded in accordance with the local Civil Aviation Authority requirements.

Repairs to spray equipment repairs must be promptly carried out following which the aircraft must be re-calibrated and the swath width re-checked. This is normally required to comply with local legislation.

Spare nozzles, anti-drip diaphragms, atomiser blades, valve springs etc, should all be kept in stock throughout the spraying season.

5.3 Operator health surveillance

Where label recommendations demand operator health surveillance, a separate record must be prepared for each individual operator to cover name health details and previous health history.

Exposure periods must be listed to include the date of the initial exposure to a particular product, together with any recommendations coming from the clinical practitioner responsible for the monitoring programme. Operator contact with other chemical products during the monitoring period must also be recorded.

All staff involved with the spray operation should be submitted for health checks on a regular basis.

5.4 Personal protective equipment

PPE is only as good as its use and maintenance and must be provided and used on a strictly individual basis. To make sure that safety equipment gives maximum protection, operator training is important.

Wearing protective clothing does not guarantee operator protection. When chemical loading or handling equipment becomes defective through wear or damage regular visual checks must be carried out. Specialist equipment such as respirators must be checked according to the manufacturer's recommendation. Checks must be more frequent when working conditions are severe. Faults must be recorded and corrected before further use.

5.5 Local emergency contacts

In the event of an aircraft accident, chemical spillage or an environmental contamination incident, an accessible list of local emergency contacts must be available to cover appropriate medical facilities with access to poisons

information. The local chemical product manufacturer and or supplier must be listed as a source of up to date product information and accident procedure. Contacts, such as the local civil aviation authority, water authority, environmental and pollution control agency and the emergency services should all be listed, and a trained local first-aid practitioner appointed. The first-aid worker should be conversant with the chemical products in use and the emergency procedures in the event of an accident. He/she must have up-to-date product label information and access to a good supply of appropriate antidotes for the products in use. Pesticide poisonings are usually acute resulting from dermal contact (see 3.6). It is therefore essential that first-aid workers can recognise the different poisoning symptoms for the products in current use. Symptoms vary for different chemical products and may be mistaken for other illnesses, notably those resulting from heat exposure.

6. ANNEXES

6.1 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 ground 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, FAO, Rome 1990.

10. Guidelines on Good Labeling Practice for Pesticides, FAO Rome 1995.

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.

6.2 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, Aviation Authority, Police and Highway Control
7. Health and Safety authority
8. Approved waste disposal contractor