Desert Locust Guidelines

Appendixes

K. Cressman
H.M. Dobson

First edition – 2001

Food and Agriculture Organization of the United Nations

Rome, 2001

The designations employed and the presentation of material in this information product do not imply the expression of any opinion whatsoever on the part of the Food and Agriculture Organization of the United Nations concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

PREFACE

The Desert Locust plague of 1986-89 and the subsequent upsurges in the 1990s demonstrate the continuing capacity of this historic pest to threaten agriculture and food security over large parts of Africa, the Near East and southwest Asia. They emphasize the need for a permanent system of well-organized surveys of areas that have recently received rains or been flooded, backed up by control capability to treat hoppers and adults efficiently in an environmentally safe and cost-effective manner.

The events of 1986-89 showed that, in many instances, the existing strategy of preventive control did not function well, for reasons including the inexperience of the field survey teams and campaign organizers, lack of understanding of ultra low volume spraying, insufficient or inappropriate resources and the inaccessibility of some important breeding areas. These reasons were compounded by the general tendency to allow survey and control capacity in locust-affected countries to deteriorate during locust recession periods. To address this, FAO has given high priority to a special programme, the Emergency Prevention System for Transboundary Animal and Plant Pests and Diseases (EMPRES), that will strengthen national capacities.

Given the certainty that there will be future Desert Locust upsurges, FAO produced a series of guidelines primarily for use by national and international organisations and institutions involved in Desert Locust survey and control. The guidelines comprise:

1. Biology and behaviour
2. Survey
3. Information and forecasting
4. Control
5. Campaign organization and execution
6. Safety and environmental precautions

Appendixes (including an index) are provided for easy reference by readers.

This second edition has been produced to update sections on technology and techniques that have undergone changes in the seven years since first publication, to modify presentation of the material, to make it easier to understand and to facilitate updates in the future. The revision was carried out by K. Cressman of FAO and H.M. Dobson of the Natural Resources Institute, United Kingdom, with input from many locust and locust-related specialists around the world. This edition will be available in the three key languages of the locust-affected countries, English, French and Arabic.

I would like to extend my gratitude to all those who have been involved in this important contribution to improved Desert Locust management.

Louise O. Fresco
Assistant Director-General
FAO Agriculture Department

24 September 2001

Contents

ACKNOWLEDGEMENTS

FAO is grateful to P.M. Symmons who produced the first edition of the guidelines, to K. Cressman and H.M. Dobson who revised and updated it, and to S. Lauer who produced most of the illustrations. FAO would also like to thank T. Abate, B. Aston, F. Bahakim, L. Barrientos, T. Ben Halima, D. Brown, M. Butrous, M. Cherlet, J. Cooper, C. Dewhurst, J. Duranton, C. Elliott, A. Hafraoui, M. El Hani, T. Galledou, S. Ghaout, G. Hamilton, Z.A. Khan, M. Lecoq, J. Magor, G. Matthews, L. McCulloch, M. A. Ould Baba, J. Pender, (the late) G. Popov, T. Rachadi, J. Roffey, J. Roy, S. Simpson, P.M. Symmons and H. van der Valk for their comments and criticism on this new version. Acknowledgements are also due to R. Mitchell and C. Smith-Redfern for general editorial advice, K. Whitwell for indexing, Medway Design Team, University of Greenwich and Andrew Jones for production of digital artwork and to manufacturers for providing illustrations of their equipment. The Control guideline and parts of the Appendixes are outputs from a project funded by the United Kingdom's Department for International Development (DFID) for the benefit of developing countries and carried out by the Natural Resources Institute. The views expressed in these sections are not necessarily those of DFID.

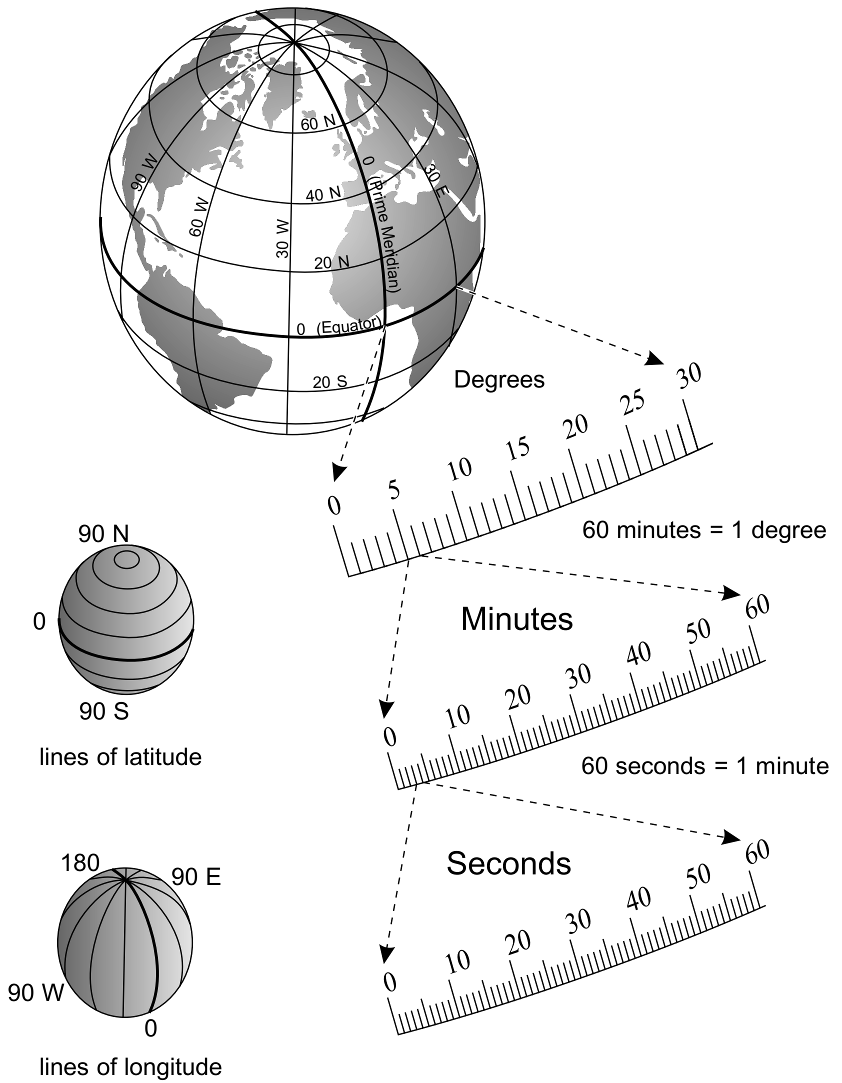
Appendix 1

Techniques and equipment

Summary of latitude and longitude:

- coordinates are reported as latitude / longitude
- every position on earth has a unique latitude and longitude

Figure 1 . Degrees, minutes and seconds of latitude and longitude.



1.1 LATITUDE AND LONGITUDE CONCEPTS (DEG/MIN/SEC)

On a map or in an atlas, it is very common to see a number of horizontal and vertical lines. These lines are used as reference points to assist the user in locating a position on the map. The horizontal lines are referred to as latitude and extend east-west; the vertical lines are called longitude, extending north-south.

The entire earth has been divided by lines of latitude and longitude. From the equator (the half-way point between the North and South Pole, known as 0°) to the North Pole is 90°; from the equator to the South Pole is 90°. Therefore, the lines of latitude extend from 0° to 90°N and from 0° to 90°S. Similarly, lines of longitude that extend from the North Pole to the South Pole encircle the earth for 360° (the number of degrees in a circle). If you take one point on the earth, the point exactly on the opposite side of the world will be 180° away from the first point. For convenience, an arbitrary point has been defined as 0° longitude. This is referred to as the Prime Meridian. It runs roughly north and south over Greenwich (UK) and Gao (Mali). Its counterpart, 180° away, is known as the International Date Line which is over the Pacific Ocean. Longitude lines from east of the Prime Meridian to west of the International Date Line are indicated as East; and those from west of the Prime Meridian to east of the International Date Line are indicated as West.

Each line is divided into degrees; each degree is divided into minutes, and each minute is divided into seconds (see Fig. 1). There are 60 seconds in one minute and 60 minutes in one degree. In most locust-affected countries, one degree is about 100-110 km, one minute is about 1.8 km and one second is about 30 metres.

Using this coordinate system of degrees, minutes and seconds of latitude and longitude, any point on the earth can be identified to within about one metre. For example, the coordinates of the Locust Outpost in Pasni, Pakistan is 251547N/632826E, or 25 degrees, 15 minutes, 47 seconds North (latitude) and 63 degrees, 28 minutes, 26 seconds East (longitude). Sometimes this can be written as 25°15’47"N/63°28’26"E. Note that the latitude coordinates are always written first, then the longitude.

		minutes	seconds	distance
1 degree	=	60	3 600	100-110 km
1 minute	=		60	1.8 km
1 second	=			30 m

Tip: many computer mapping programmes use decimal degrees rather than degrees, minutes and seconds. In this case, the minutes and seconds are expressed in tenths of a degree. For example,

18°50’20”N / 20°10’30”E = 18.8388N/20.1750E

Figure 2. Determining the latitude and longitude of a point on a map.

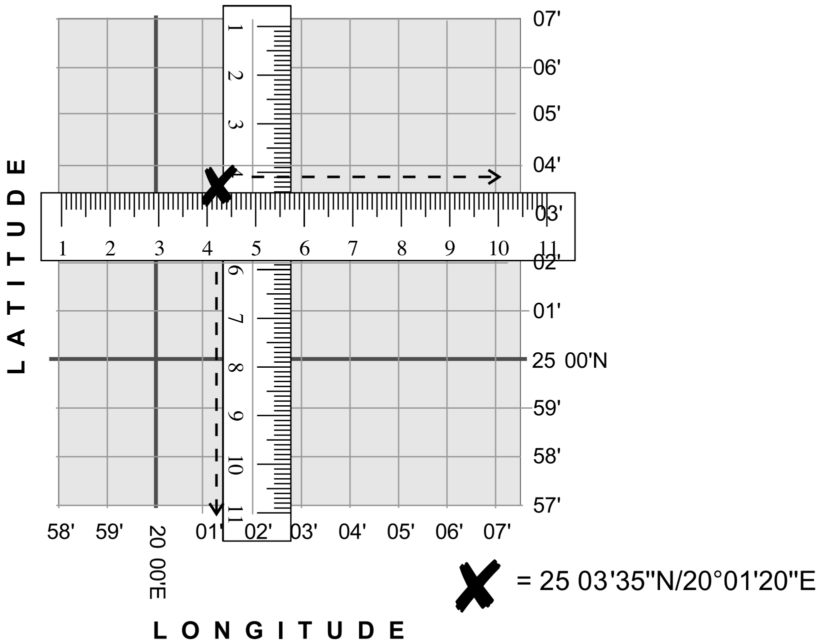
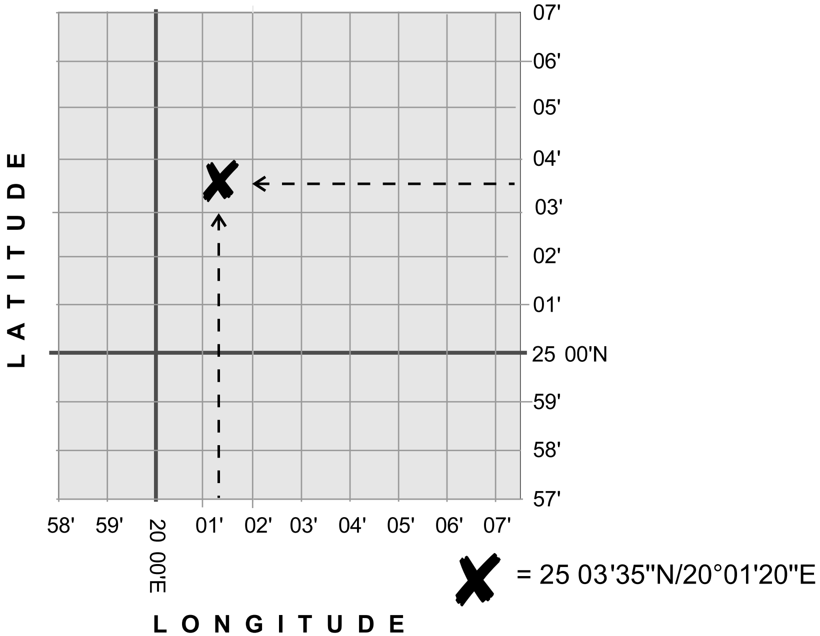


Figure 3. Plotting coordinates on a map.



1.2 MAP READING

Maps can be a powerful and useful tool for the survey officer because they contain a lot of information. All maps have information in common, regardless of the type of map or area of coverage. For example, most maps contain a legend that explains the meaning of the symbols used on that map; maps usually have a scale that shows the distance and units of measurement (miles, kilometres); horizontal and vertical lines of latitude and longitude; scales with the degrees (and sometimes minutes and seconds) listed on the right and left sides for latitude and at the top and bottom for longitude; north on most maps is at the top and it is indicated usually by a symbol.

To determine the latitude and longitude of a point on the map (see Fig. 2)

1. Lay a long ruler or a straight edge horizontally on the map to line up the point with the latitude scale on the right and left side to determine the latitude.

2. The ruler should be placed vertically to line up the point with the longitude scale on the top and bottom to determine the longitude.

If you know the latitude and longitude of a certain point and want to determine where on the map it is (see Fig. 3)

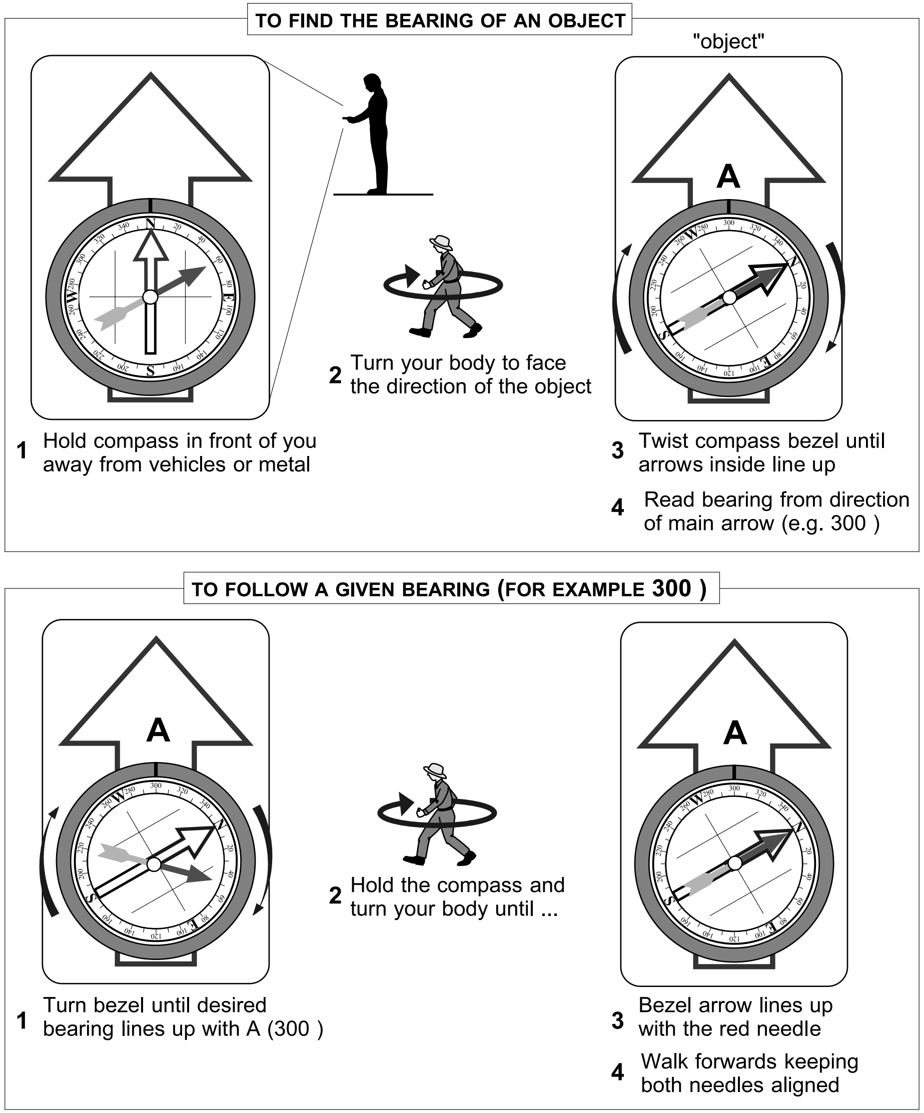
1. Find the latitude (degrees, minutes, seconds) on the right and left side scale and draw a horizontal line using a ruler or straight edge.

2. Then find the longitude (degrees, minutes, seconds) at the top and bottom scale and draw a vertical line using a ruler or straight edge.

3. Where the two lines cross is the position of the point.

Tip: it will not be possible to read seconds accurately from maps of greater than 250 000 scale.

Figure 4. Two common ways of using a compass.



Tip: do not try to use a compass in a car, or with the compass resting on the car bonnet. The metal in the car body or the magnetic fields caused by the car's electrical system can cause serious compass errors. It is best to stand at least 5 m from the car before taking a compass reading.

1.3 COMPASS

A compass is useful for navigating, giving other people directions and for recording direction of the wind or swarms. The floating needle of the compass will always turn so that the red end points towards magnetic north. This constant factor means that people can orientate themselves in relation to north.

Tip: you can give people or aircraft directions by telling them to travel, for example, southwest or east northeast, but it is much more accurate to give a compass bearing and a distance. Compass bearings range from 0 (north) through 90 (east), 180 (south), 270 (west) and back through 359 (north again).

Procedure for finding the bearing of an object in the distance or the direction of the wind or a moving object such as a swarm (see Fig. 4)

1. Position the compass so that the base plate arrow points directly away from you – it can help if you rest the compass base on your stomach.
2. Turn your body together with the compass so that you are facing in the direction for which you want the bearing. Do not turn the compass base – turn your body instead.
3. Twist the compass bezel until the bezel arrow lines up with the red needle.
4. Read the bearing off the bezel at the line marked A on the diagram.

Procedure for following a given compass bearing (see Fig. 4)

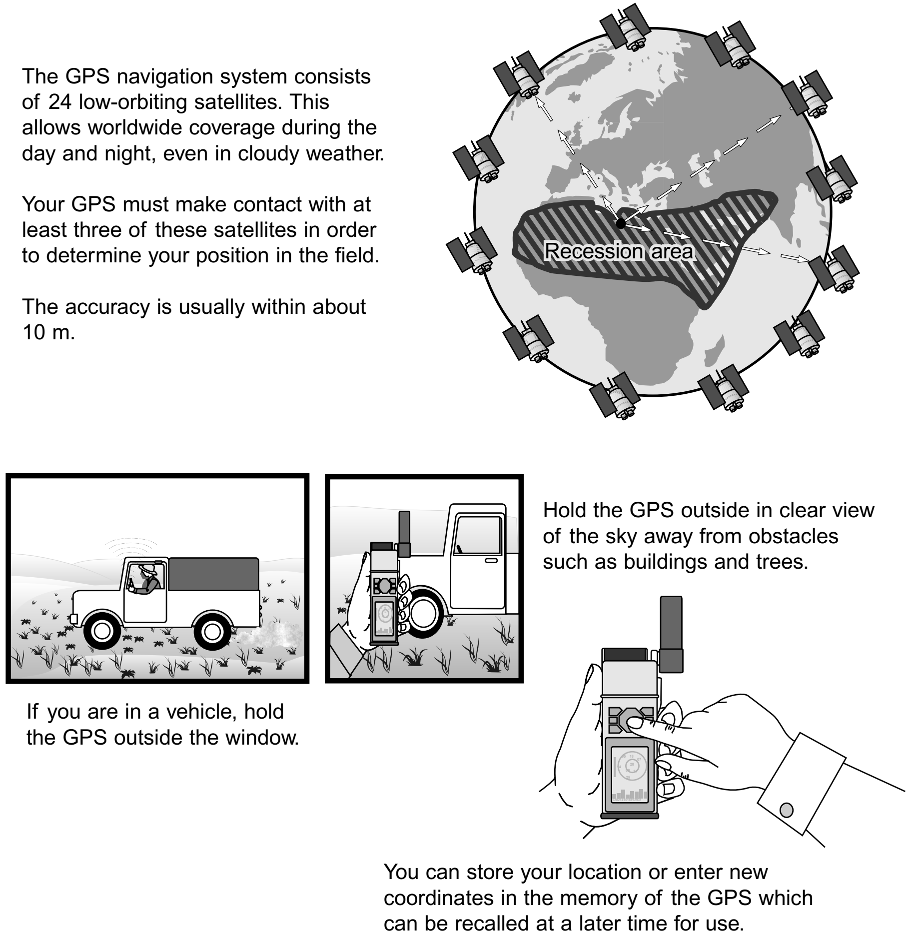
1. Turn the compass bezel so that the desired compass bearing lines up with the line marked A in Figure 4.
2. Position the compass so that the base plate arrow points directly away from you – it can help if you rest the compass base on your stomach.
3. Turn your body together with the compass until the bezel arrow lines up with the red needle
4. Pick an object in the distance that lines up with the base plate arrow direction and start walking towards it.

Tip: when following a compass bearing, do not look at the compass while walking because it will be very difficult to walk in a straight line or in the right direction. It is better to use the compass to select a distant object in the desired direction, then put the compass away while walking. When you reach the object, use the compass again to select another distant object on the right compass bearing, and so on.

Using GPS in locust operations:

- ground and aerial survey/control teams can determine exactly where they are and follow a route even in terrain without features such as hills or wadis
- ground survey teams can give an exact location of favourable breeding areas or a swarm or hopper bands (when maps are not available or when they are not accurate) so that an aircraft can find them and spray the target
- ground teams can accurately describe the edges of a large spray block to a pilot or drivers by giving the coordinates of the corners
- with signal error correction, aircraft can spray accurate track spacings without the need for ground markers

Figure 5. Using a handheld Global Positioning System (GPS).



1.4 GPS

A Global Positioning System (GPS) is a device that picks up signals from any of 24 low-orbiting satellites and calculates its position (latitude/longitude and height above sea level) from their relative position (see Fig. 5). Civilian units can tell where they are anywhere in the world to an accuracy of around 10 m. If there is a ground station or a subscription to a satellite correction signal, primarily for Differential GPS equipment, the accuracy increases to less than a metre. A GPS also has a memory so that the coordinates of a current position can be captured or someone else’s coordinates entered manually. From these basic capabilities comes the ability to do several other things such as calculating speed and direction of the unit if it is mounted in a car, boat or aircraft and giving navigation information such as instructions to go left or right to keep on track when heading for a stored position, and to predict the time to reach a programmed location.

Aircraft-mounted GPS units in combination with other equipment can store and output a record of the exact spray path and how much was sprayed (see the next Appendix).

Exact operating details vary between manufacturers, but some general principles apply (see Fig. 5):

- GPS units must be able to see the satellites, i.e. they must be used in the open air, and not too close to tall buildings and trees. They are not affected by cloud so they can be used in any weather.
- You may need to initialize the GPS if it is being used for the first time, after moving more than 500 km since last use, or if the batteries have gone flat and position data have been lost. You can do this by leaving the GPS switched on for several minutes while it searches the sky. Alternatively, you can enter a rough latitude and longitude of where you are, or on some units you can select the country where the unit is being used.
- You should make sure that in the setup options for latitude and longitude, degrees/minutes/seconds have been selected, not decimal degrees or minutes.
- After switching on, you must wait for the GPS to find enough satellites before it can calculate the position. The minimum number of satellites to give a position fix is three but, if altitude is also required, a minimum of four are required.
- All GPS units have the ability to mark the current position as a waypoint. This means that the latitude and longitude of your current position are stored in the GPS memory. This waypoint can be given a name and added to a list of other waypoints.
- Most GPS units have a GOTO facility which can guide you to any of the stored waypoints or to any coordinates entered manually.

Other features of some GPS units are map displays, the facility to download coordinates to a computer and the ability to create waypoints manually at specific distances from other waypoints.

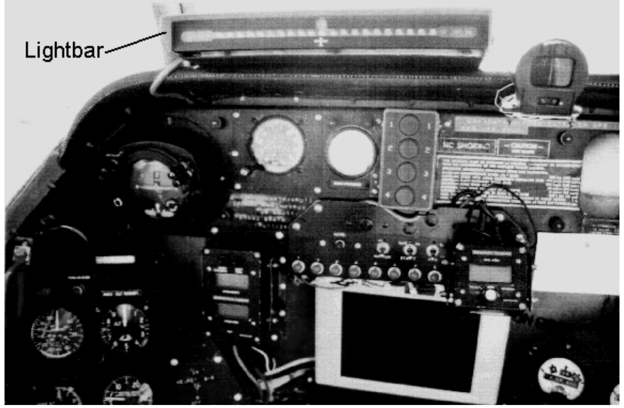
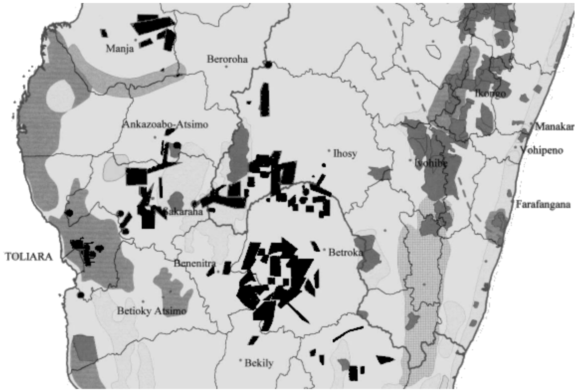


Figure 6. Aircraft cockpit showing lightbar at top.

Figure 7. Map of part of southern Madagascar showing some of the areas sprayed in 1999 (black) and ecologically sensitive zones (other shades).



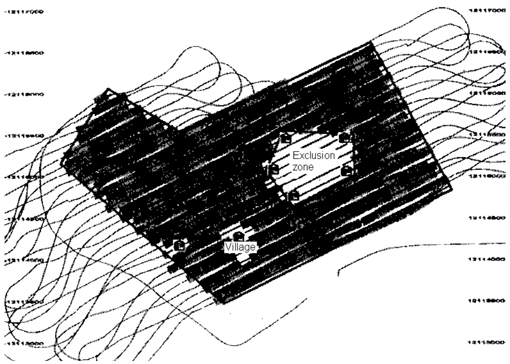


Figure 8. Aircraft trace showing result of an active spray system where GPS switched off sprayer pumps when overflying exclusion zones.

1.5 SATELLITE NAVIGATION AIDS FOR AERIAL USE

Special GPS receivers are available for aircraft (see Appendix 5.7 for addresses). When one of these is integrated with a computer and graphics display with specialized spraying software, it can perform several additional useful functions for aerial spraying:

- automatically calculate the GPS coordinates of the ends of spray tracks for a given track (or barrier) spacing and display them on a cockpit monitor
- display the real-time position of the aircraft on this monitor which helps to guide the pilot during turning on to the start of the next spray pass
- once a new spray pass is started, guide the pilot along it with a left/right guidance arrow or a lightbar, without the need for ground marker teams (see Fig. 6)
- display and record the trace (actual path flown) for the entire flight together with intended spray path for later analysis and archiving

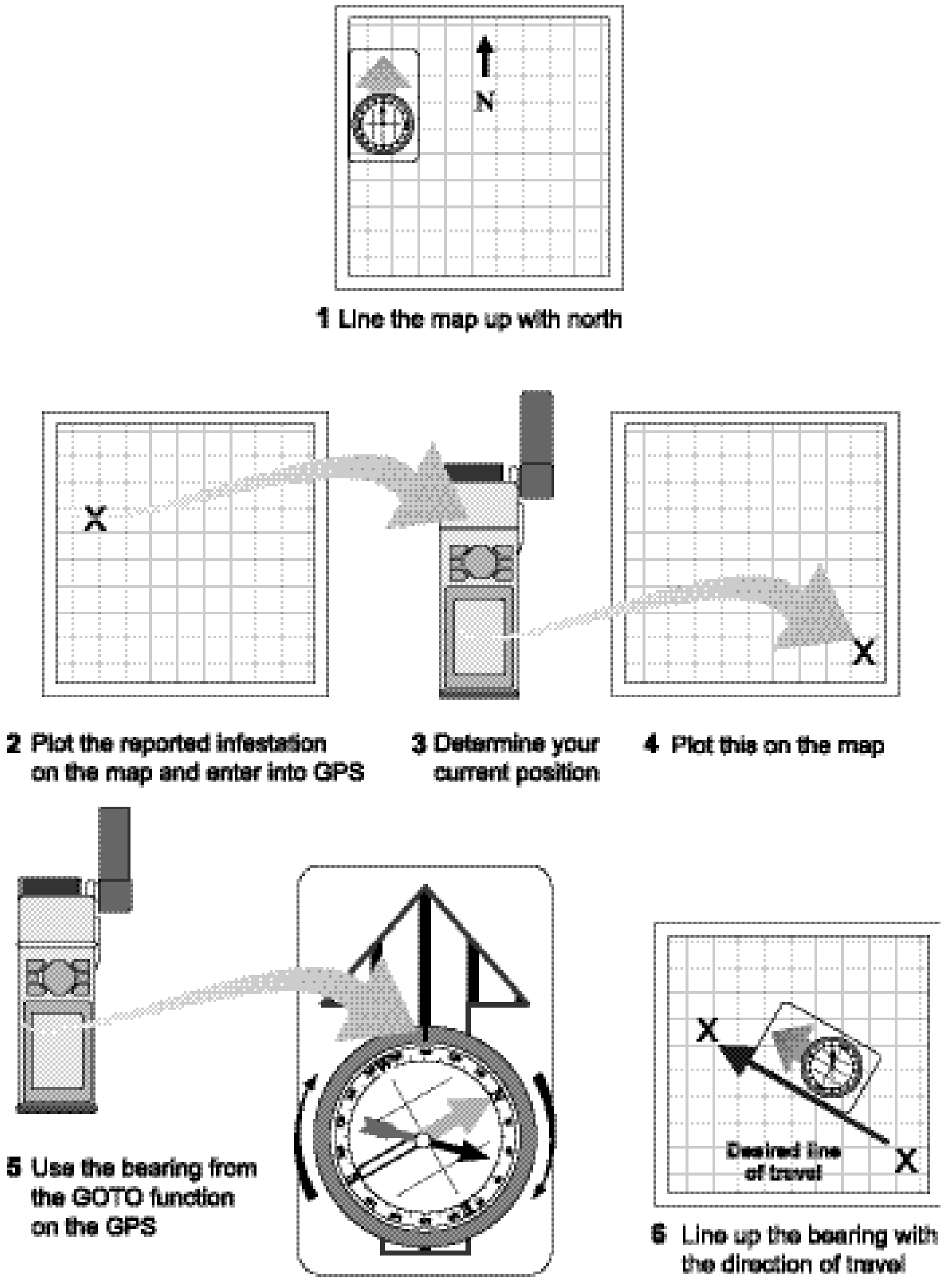
GPS systems can produce an archive of application locations that will assist with identifying areas that have been sprayed more than once, or any instances of spraying habitations or ecologically sensitive zones (see Fig. 7). When such GPS systems are coupled with equipment to monitor flow rate and forward speed, pesticide doses can be calculated at the sprayed locations.

Active spray systems are an additional level of technology that promise even greater application accuracy and are likely to be adopted on a large scale in the future. Instead of the GPS simply guiding the pilot, it can also actively control the spraying equipment based on where the aircraft is and how it is flying. Active spray systems can regulate the flow rate to compensate for varying forward speed and track spacings. They can also switch off the pump at the end of spray runs and as the aircraft overflies water bodies, habitations or other sensitive zones. Figure 8 shows an active spray system in action, switching off automatically over a water body. However, these systems were developed for high-volume spraying and the dark stripes are not necessarily where the small ULV droplets are actually depositing. Appropriate buffer zones are necessary around the exclusion areas to allow for drift.

The problems of refinding marked targets, navigating accurate spray passes, applying the correct dose and avoiding sensitive areas are applicable equally to vehicle spraying, albeit on a smaller scale. Although pioneered for aerial spraying, it is likely that these GPS, track guidance and active spray technologies will be transferred to vehicle-mounted spraying systems in the coming years.

The accuracy of GPS signals has recently increased so that positional error has been reduced from about 100 m to about 10 m. It is possible to subscribe to a corrected GPS signal that, with the right equipment, can reduce the positional error still further to about 1 m. This system is known as differential GPS (DGPS). For locust operations, positional errors of up to 10 m are acceptable and the recent increase in non-DGPS signal accuracy may make it sufficiently precise for track guidance. This still needs to be validated under field conditions.

Figure 9. Using a map, compass and GPS together.



1.6 USING A MAP, COMPASS AND GPS TOGETHER

During survey and control operations, the field officer should always carry a map, compass and GPS. These three items can be used together for estimating locations and directions when navigating in the field (see Fig. 9). Although navigation using this equipment is more accurate in the air or on the sea where you can travel in straight lines, it can also be used on the ground with reasonable success.

Finding the location of a previously reported locust infestation

Assume that you have received a report of a locust infestation at a specific coordinate location and you want to go to the location by vehicle. The problem is that you do not know in what direction you must travel and for how many kilometres. You can determine this by using a map, compass and a GPS.

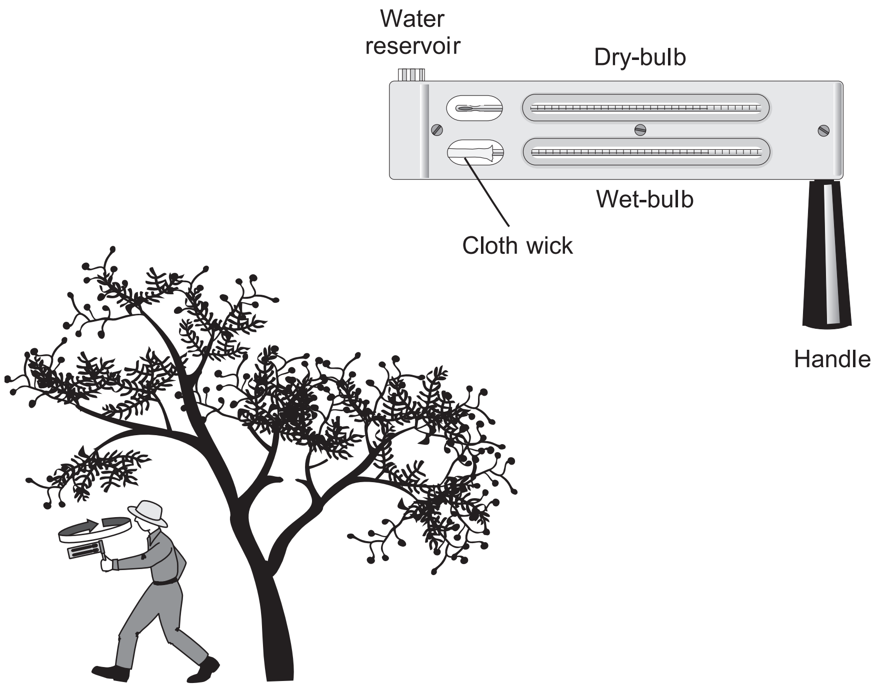
1. Orient the map to north
   (find the north on the map – this is usually the top of the map; turn compass bezel to 0° (N), place compass on map edge along the latitude scale or longitudinal lines, and turn map and compass together until bezel arrow and red needle are on top of each other).
2. Plot the position of the locust infestation using the reported coordinates on the map (if these are already in your GPS, go to step 4.
3. Enter these coordinates in the GPS.
4. Use the GPS to determine your current coordinate position.
5. Plot this position on your map (you now have two positions plotted).
6. Use the GOTO function on the GPS to navigate from your current position to the reported locust infestation.
7. The GPS will indicate a bearing and a distance (in a straight line) from your current location to the infestation.
8. Place the compass on the map and rotate the compass bezel until the GPS bearing is at the indicator mark.
9. Rotate the compass itself until the bezel arrow and red needle are on top of each other.
10. A straight line from the direction the compass is pointing indicates the direction of the locust infestation. The distance will usually be a little greater than indicated on the GPS because it is difficult to drive in a straight line if the terrain is rough or uneven.

This same method can be used to travel to known reference points such as hilltops, villages and other landmarks. It can also be used to guide aircraft pilots to control targets.

Using a whirling hygrometer:

- whirl the hygrometer in the shade (use your body to shade it if necessary)
- whirl the hygrometer for at least one minute
- always read the wet bulb first (before it starts to warm up to air temperature again), then the dry bulb

Figure 10. A whirling hygrometer and its use.



Tip: although humidity is not very important in control operations, air temperature is important because it affects locust target behaviour and distribution of the spray droplets. However, a static thermometer will always read more than the air temperature even if it is in the shade, because of heat radiating from sunny areas and conduction of heat from surfaces that have been warmed by the sun. Using a whirling hygrometer is a simple way of getting a more accurate reading of air temperature.

1.7 WHIRLING HYGROMETER

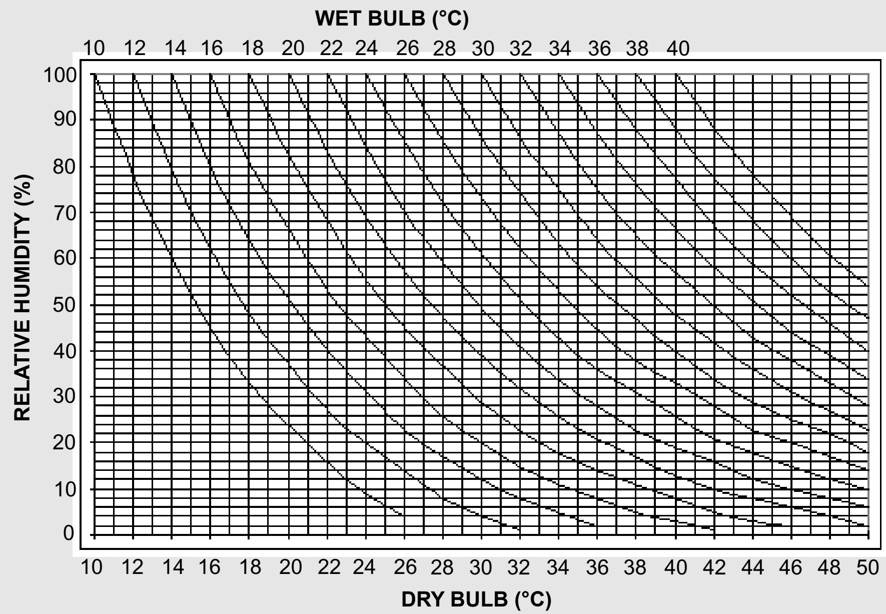
A whirling hygrometer is used to measure the air temperature and the relative humidity. It has two thermometers – one dry and one wet (see Fig. 10). The dry bulb gives the air temperature, and the difference between that and the wet bulb is used to derive the humidity, using conversion tables. The smaller the difference, the higher the humidity.

Step 1. Put water into the reservoir and make sure the wick is wet and covers the wet thermometer bulb properly.

Step 2. Find some shade, for example under a tree or behind a vehicle. If there is no shade nearby, use your body to shade the hygrometer.

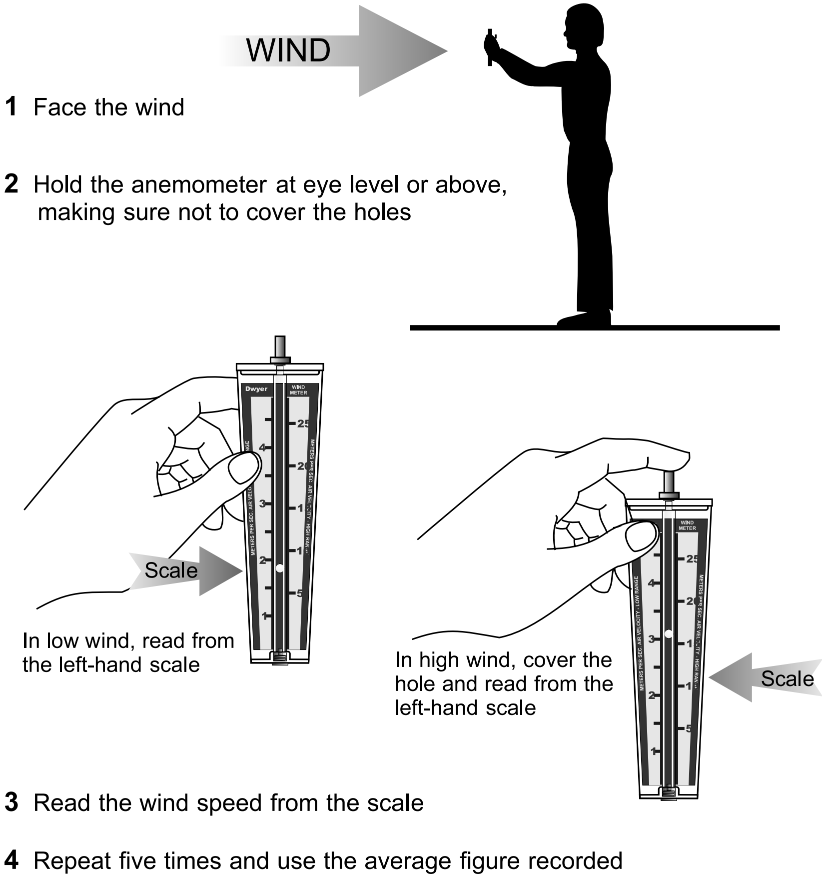
Step 3. Whirl the hygrometer rapidly in the shade for at least one minute and read the wet bulb temperature and then the dry bulb temperature.

Step 4. Use the wet and dry temperatures and the calibration table, the slider or the table below to determine the relative humidity.



Instructions: read the dry bulb temperature from the bottom scale and the wet bulb temperature from the corresponding curve inside the graph (using the top scale). Where the two cross, determine the relative humidity from the scale on the left.

Figure 11. Using a pith ball anemometer.



Tip: after using an anemometer regularly, it is possible to estimate the wind speed reasonably accurately, but it is worth keeping one with you to check your estimates from time to time.

1.8 ANEMOMETER

Anemometers are used for measuring wind speed. The most common types are pith ball anemometers and spinning cup anemometers.

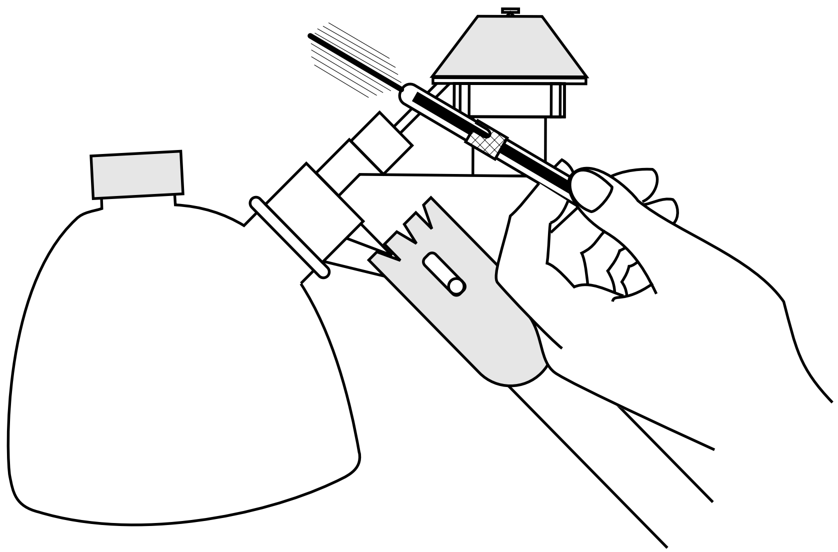
Whichever type of anemometer you use, hold it at a height of around 1.5 m above the ground and use it away from buildings, trees and vehicles (see Fig. 11).

If the anemometer does not have an electronic averaging facility, take around five readings and calculate the average.

Tips:

- ***do not stand near any buildings or trees***
- ***hold the anemometer towards the wind direction and at eye level or above. With the small round hole facing the wind, read the wind speed from the left-hand scale***
- ***if the wind is very strong, put your finger over the top hole and read from the right-hand scale***

Figure 12. Using a Vibratak vibrating tachometer to check rotational speed of a spinning disc.



Tip: do not press the needle itself on the atomizer – it is the tachometer body which should be pressed firmly onto the vibrating surface.

1.9 VIBRATING TACHOMETER

A vibrating tachometer is a device for measuring the rotational speed of a motor (see Fig. 12). It is useful for checking the battery level of handheld spinning disc sprayers and for checking that the settings on vehicle-mounted sprayers are producing the right atomizer rotational speed.

Step 1. Start the motor or atomizer to be tested. With the needle fully retracted, press the tachometer handle on any firm part of the motor or atomizer to be tested (but not the spinning disc/cage itself).

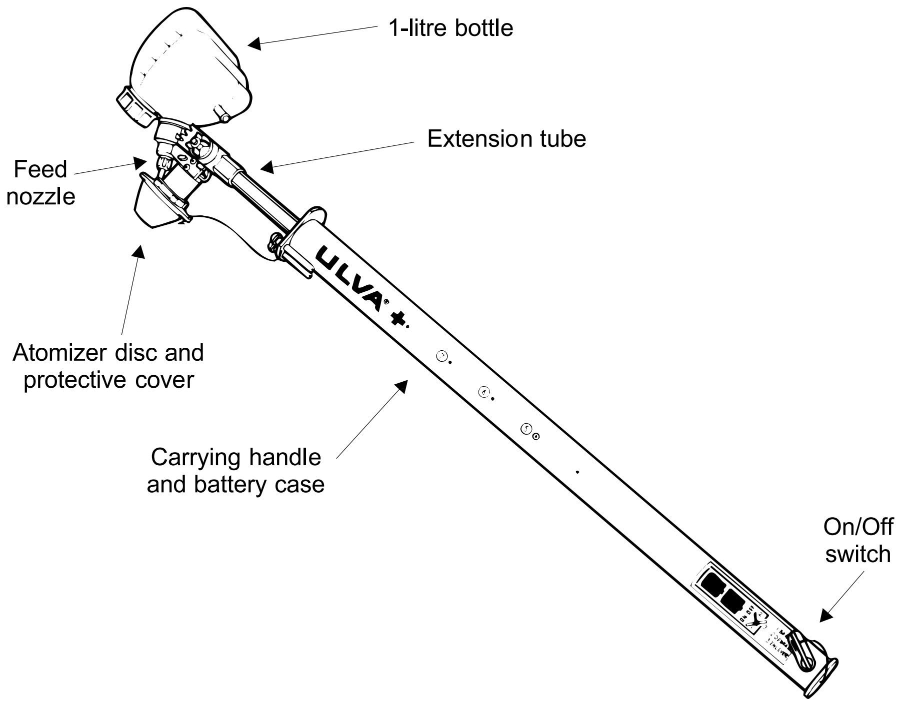
Step 2. Slowly begin to push the tachometer needle out of the handle, keeping the handle pressed firmly on the equipment.

Step 3. Watch the needle closely – when it begins to vibrate it is near to the correct length. Move the needle in and out slowly until the point of maximum vibration is achieved.

Step 4. Read the number from the tachometer body that is in line with the top of the moving slider and multiply by 1 000 to get the rotational speed of the atomizer in revolutions per minute (rpm).

Tip: the rpm will be slightly lower for any rotary atomizer when there is liquid passing through it. However, it is difficult to check rpm during spraying without being contaminated so the* dry *rpm is usually used.

Figure 13. Micron Ulva + handheld spinning disc sprayer.



Tips:

- ***some spinning disc sprayers have teeth on the edge of the disc to help produce a good droplet spectrum. Take care not to damage these teeth and do not remove the disc with a screwdriver for cleaning. Either unscrew the disc fixing screw and pull off the disc or, if there is no screw, remove the disc by pulling on the central spindle with a pair of pliers. Always put the protective cap back on after use***
- ***keep the screw thread on the pesticide bottle clean because air passes up through this to replace the pesticide which is coming out of the nozzle. If the thread is clean and the nozzle is not blocked, the flow rate will remain constant as the bottle empties***

1.10 SPRAYERS

This Appendix contains descriptions of some of the most commonly used types of locust sprayers and some tips on use and sprayer care. It is not intended as a substitute for the manufacturer's handbooks, which contain details on assembly, installation, settings, operation and servicing; a copy should be kept with each sprayer. If a manufacturer's handbook has been lost, a new one should be obtained from the manufacturer (addresses at the end of this section). Information on calibration and use of ULV sprayers is provided in Appendixes 2.3 and 5.3. See Appendix 5.4 for performance evaluation of some locust sprayers.

ULV sprayers (with rotary atomizers)

Portable sprayers

Handheld spinning disc sprayers. Examples of such sprayers are Micron Sprayers Micro-Ulva and Ulva+, Berthoud C5 and Goizper.

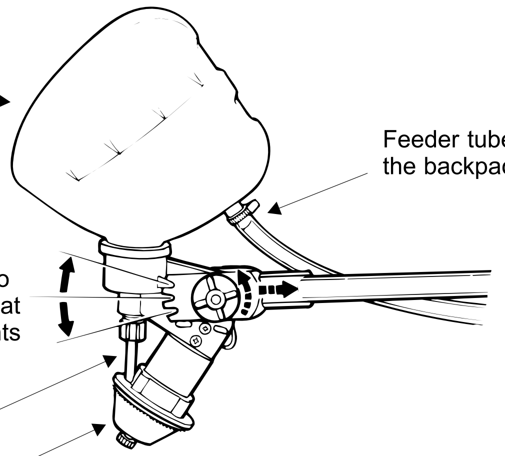
These are lightweight devices that are carried by hand. They consist of an atomizer disc spun by an electric motor, a handle containing the batteries and a bottle to hold the pesticide (see Fig. 13). They produce a narrow droplet spectrum. They can be used singly, or up to four units can be used simultaneously by a team. Some models can be used with a larger backpack tank as a reservoir to reduce the time and effort spent filling the sprayer (see Fig. 14).

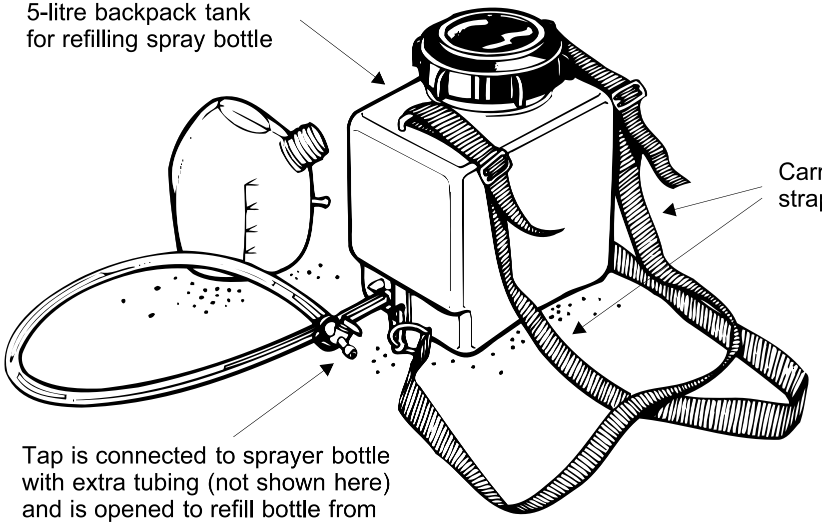
Some models can also be used for very low volume spraying (VLV) which means using a mixture of emulsifiable concentrate (EC) pesticide with a small quantity of water, to give a volume application rate (VAR) of between 10 and 20 l/ha. This method is not usually used for locust control.

Pesticide is fed by gravity on to the disc and the flow rate is controlled by different coloured restrictors that have different hole diameters. It is important to use a filter when filling the pesticide bottle otherwise the restrictor can become blocked. The filter also keeps the thread joining the bottle to the spray head clean since air has to pass up through this to replace pesticide coming out.

Droplet size is determined by disc speed (and to a lesser extent by the flow rate). The disc speed is determined by the number of batteries and their condition (voltage). Consult the manufacturer's handbook to check how many batteries to use. Cheap batteries should last for at least three days if used for two hours per day. They last longer if used in short spells. Long-life alkaline batteries should last up to 20 hours. A Vibratak tachometer should be used to check the rotational speed of the disc (see Appendix 1.9). When this has dropped to two-thirds of the original speed, the batteries should be changed because the sprayer will be producing much larger droplets that will not be so effective. A voltage meter can be used instead to check the batteries directly, or they can be put into a torch. If the bulb glows only dimly, the batteries are exhausted.

Figure 14. Micron Ulva + spray head and optional backpack tank for refilling.





The spray height can be varied according to wind conditions. If the wind speed is very low, the spray head can be held above head height to ensure that the spray is carried a sufficient distance by the wind. If the wind is very strong, the spray head can be held at knee height to ensure that the spray is not carried out of the target area.

After spraying, the sprayer bottle should be washed with diesel or kerosene. A small amount of the wash liquid should then be sprayed off over waste ground to remove pesticide left in the restrictor and under the disc. The handle and spray head should be wiped down with a piece of rag soaked in diesel or kerosene. The spray head must not be immersed in wash liquid as this may interfere with electrical connections. The snap-on cover should then be replaced to protect the disc in transit and storage.

Tips:

- ***flow rate should really be checked with the disc spinning since the liquid flows slightly faster than when the disc is stationary. This means using the loss technique, but the collection technique will give an approximate measure of flow rate. See the Control guideline for more details***
- ***as with all ULV sprayers, the sprayer should always be held downwind of the operator's body to avoid contamination during spraying***

Figure 15. Knapsack mistblower fitted with Micronair AU8000 rotary cage atomizer.

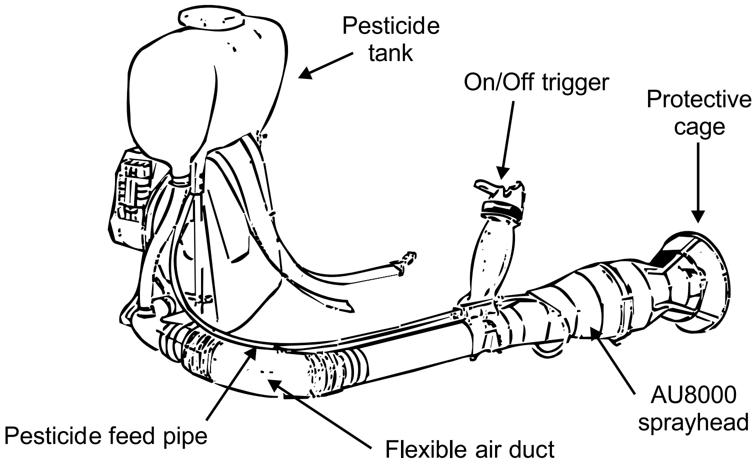


Figure 16. Operator using Micronair AU8000 on a knapsack mistblower.

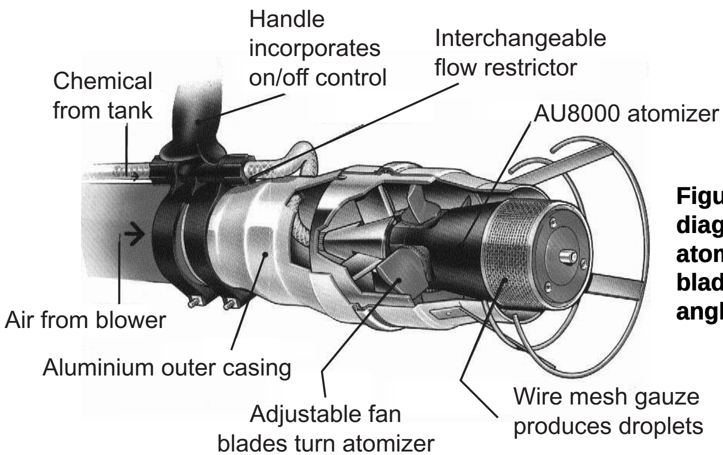


Figure 17. Cutaway diagram of the AU8000 atomizer showing fan blades with adjustable angles.

Knapsack mistblower ULV sprayers. Examples of these sprayers are Micronair AU8000, Jacto P50 and Solo 423.

These types of sprayers are carried on the back and consist of an engine-driven fan, a pesticide tank and a nozzle mounted in the airblast (see Fig. 15). Pesticide is delivered to the nozzle either by a mechanical pump or by pressure in the tank (see Fig. 16). Most of these sprayers are designed for higher volume application and are not well suited to ULV spraying, e.g. they may not be able to produce a low enough flow rate, they may not have pipes resistant to ULV pesticide and they may have simple air shear nozzles that produce a wide droplet spectrum. However, some are specifically designed for ULV spraying and have rotary nozzles and some have special ULV conversion kits to reduce the flow rate. Some knapsack mistblowers can also be used for dusting after special dusting attachments have been fitted.

Flow rate control can either be in the form of a tap that varies the diameter of an orifice in the pesticide pipe, or by different sized restrictors that are fitted in the pesticide feed pipe.

Droplet size can be controlled on some of these sprayers; e.g. the blade angles of the rotary atomizer can be changed on the Micronair AU8000 (see Fig. 17). On other models, if the throttle is reduced, the airblast speed will be reduced and the droplets will be a slightly larger.

Emission height and direction of airblast can be varied by holding the air delivery tube higher or lower. When it is held higher, the flow rate on most sprayers varies because the liquid pressure at the nozzle is reduced. Some models have a mechanical pesticide pump to overcome this problem.

These sprayers are sometimes preferred when locusts are densely packed at roosting sites, especially if they are in dense vegetation. The airblast should help the pesticide penetrate to all locusts. However, the airblast should not be considered a substitute for suitable wind to carry the spray, and it should never be directed upwind e.g. if locusts are roosting on the downwind sides of bushes. The most efficient way to use these sprayers is to walk across the wind, directing the airblast downwind in a slightly upward direction.

! **Never spray upwind, for example if locusts are resting on the downwind side of bushes. The airblast will take the spray away from operators at first, then the wind will carry the spray back on to them.**

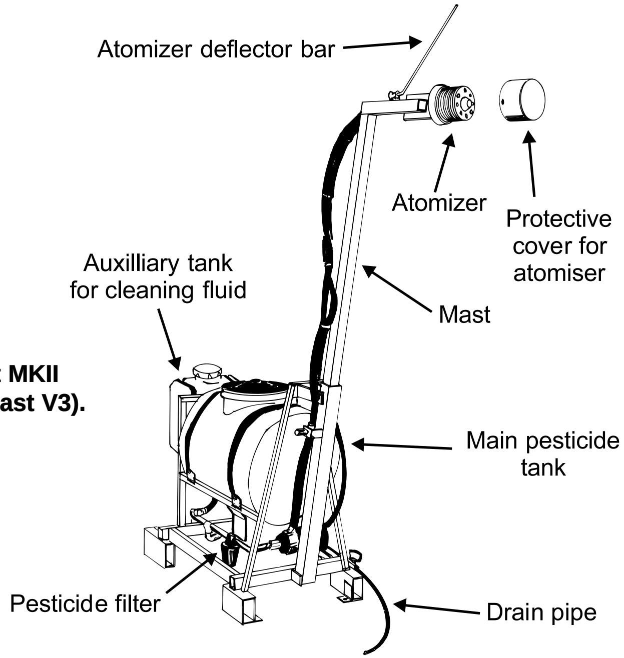


Figure 18. Micron Ulvamast MKII (now superseded by Ulvamast V3).

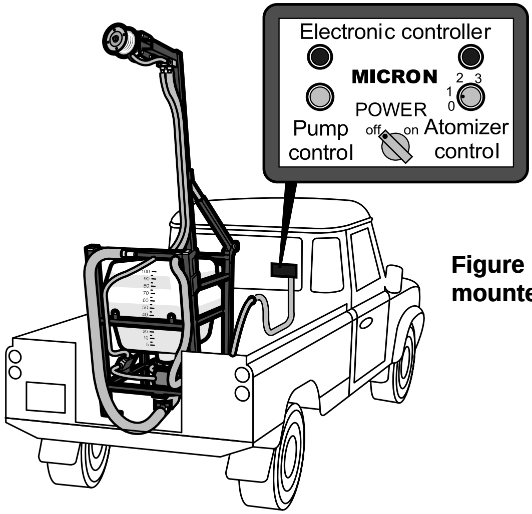


Figure 19. Micron Ulvamast V3 mounted on a pick-up truck.

Figure 20. Micronair AU7010 mounted on a pick-up truck (model discontinued).

Vehicle-mounted ULV sprayers

Vehicle-mounted passive-drift ULV sprayers. Examples of such sprayers are the Micron, Ulvamast V3 (which supersedes Ulvamast MKII) and Micronair AU7010 (now discontinued).

These sprayers consist of a rotary atomizer with stacked discs or cages powered by an electric motor, a pesticide tank and an electric pump which deliver the pesticide to the spray head (see Figs. 18-20).

Drop size can be controlled on some models by altering the speed of rotation of the atomizer either by adjusting the motor voltage at the control box, or by switching to different drive belt pulleys (see manufacturers handbook for details)

Flow rate is controlled either by a needle valve, a variable restrictor in the pesticide feed line, or in the Ulvamast V3 by dialling in a preset flow rate at the electronic controller. Emission height cannot be adjusted.

Some models have a small extra tank in addition to the main pesticide tank. If this is filled with cleaning fluid such as diesel fuel or kerosene, it is easy to flush and clean the pipes and atomizer at the end of the spraying day.

Tips:

- ***all vehicle-mounted sprayers should be mounted on vehicles with an enclosed driver's cab – an open jeep is not safe because the wind may shift and blow spray on to the driver***
- ***on sprayers with electric pumps, flow rate measurements should be carried out with the vehicle engine running so that the electric pump receives the operating voltage (around 13.5V) rather than the voltage of the battery at rest (around 12V). During this process, point the vehicle upwind so that any drips are not blown onto it***
- ***always disconnect the cable plug from the control box in the vehicle cab when the sprayer is not in use. This prevents either the pump or the atomizer being switched on accidentally. Also lower the spray head to avoid the chance of it colliding with a tree or building***

Figure 21. Micronair AU8115 mounted on a pick-up truck (which supersedes the Micronair AU8110).

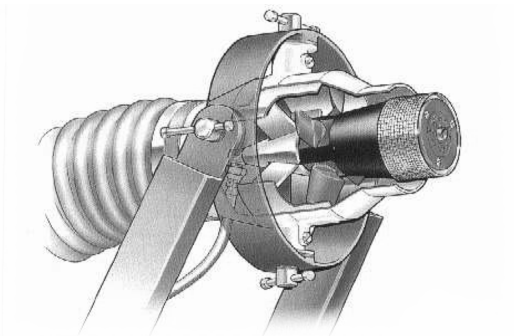


Figure 22. AU8110 atomizer head showing adjustable angle blades.

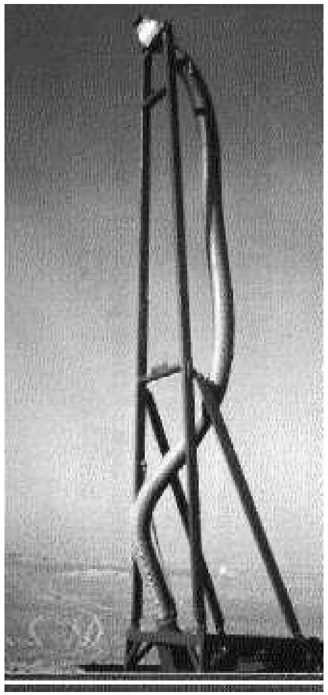


Figure 23. Optional high reach atomizer head for treatment of settled swarms in bushes and trees.

Vehicle-mounted ULV airblast sprayers. An example of such sprayers is Micronair AU8115 (which supersedes the Micronair AU8110).

These consist of a rotary atomizer with windmill blades, driven by the airblast from a large fan, a pesticide tank and an electric pump or airblast pressure to deliver pesticide to the spray head (see Figs. 21-22).

Flow rate is controlled by a variable restrictor unit (VRU) which allows easy selection of different sized restrictor holes, together with the adjustment of pressure.

Drop size can be changed by adjusting the angle of the blades, which in turn will alter the atomizer rotational speed (see Fig. 22).

The emission height cannot be adjusted directly, but the airblast can be directed at an angle upwards, or even straight upwards so that the spray cloud is carried up a few metres before the wind takes over in distributing the spray downwind. It is incorrect to assume that the airblast can replace the wind as the agent of dispersal of the spray and that the sprayer can be used with no wind. The 5 m or so throw by the airblast is negligible when compared with the swath width of over 100 m required to permit the use of a track spacing of 50 m.

However, the airblast has the advantage that a wider track spacing can be used with these sprayers than with passive-drift vehicle sprayers. Also, since the pesticide is initially thrown away from the vehicle by the airblast, operators are less likely to be contaminated during operations.

There is an extended version of the Micronair AU8115 with the spray head mounted on a 4 m extension frame which allows spraying to be carried out at about 5 m above the ground (see Fig. 23). This can be useful if swarms are roosting in trees up to around 10 m height. However, if the ground is bumpy, the sprayer should be used with the vehicle stationary, i.e. the vehicle needs to be moved after each short burst of spraying.

Tip: always make sure that any vehicle-mounted sprayer is firmly mounted on the vehicle with bolts – if the sprayer is loosely fitted or is only tied on with rope, it will quickly be damaged when travelling over rough ground.

Figure 24. Micronair AU5000 atomizer mounted on a boom.

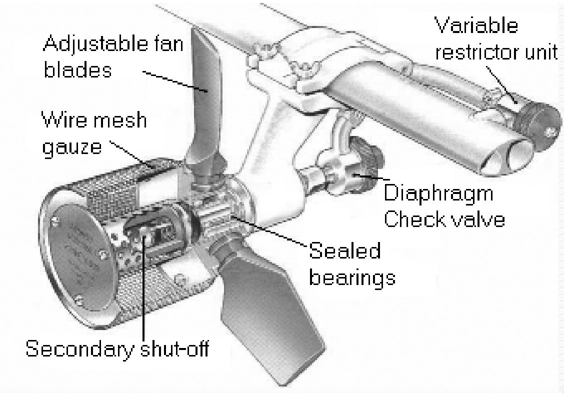


Figure 25. Close-up of atomizer body showing blade angle markings. In this example the blades are set to 35 degrees.

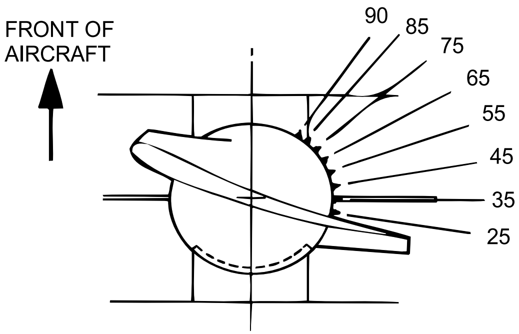
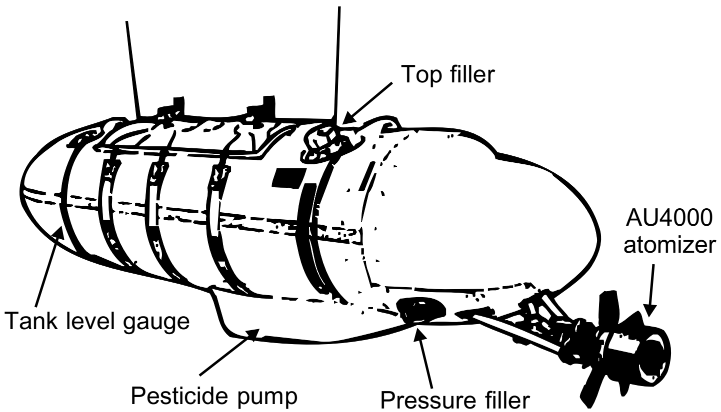


Figure 26. Micronair self-contained spray pod system.



Aircraft-mounted ULV sprayers
Examples of aircraft-mounted sprayers are Micronair AU4000, AU5000 and AU7000.

These consist of a rotary cage atomizer, a pesticide tank and an electric or propeller-driven pesticide pump (see Fig. 24). The spray cloud is produced by a mixture of rotary atomization and air shear at the surface of the cage, caused by the aircraft airspeed. The atomizer is usually driven by windmill blades in the slipstream of the aircraft, but there are versions of the AU5000 that are driven by an electric motor. These are particularly useful for mounting on helicopters where forward speed is less than on a fixed-wing aircraft.

The flow rate is adjusted with a variable restrictor unit (VRU) and by varying the pump pressure. Some installations have a flow meter which means that the flow rate can be checked in flight. Manual flow rate checks should also be made from time to time to check that the flow meter is working properly. These should be done with the aircraft engine running, if possible, so that the pump receives the full operating voltage. Droplet size is adjusted by altering the angle of the blades on the atomizer (see Fig. 25). Further details can be found in the manufacturer's handbook.

A version of the Micronair is available which is incorporated in a pesticide pod to form a self-contained streamlined unit for mounting under the wings of an aircraft (see Fig. 26). Installation requires hard points on the aircraft wings. An aircraft such as a Britten-Norman Islander or a De Havilland Beaver can then be converted from passenger to spray use (and back again) very quickly. It is possible to use the aircraft to transport goods and people with the pods in position, but load capacity and cruising speed are reduced. Two pods can hold a pesticide load of about 380 litres, which is less than would be carried in a normal spray tank.

Tips:

- ***care must be taken with blade angle settings – the system differs on the AU4000 and the AU5000 so the correct manufacturer's handbook should be consulted***
- ***the blade angle settings given in the Micronair AU4000 manual are for boom-mounted units, but the atomizers on the pod system are somewhat shielded from the airstream and rotate less quickly for a given blade angle setting. Compensation must be made for this and a slightly finer blade angle used in order to maintain the required rpm***

Figure 27. Lever-operated knapsack (LOK) sprayer.

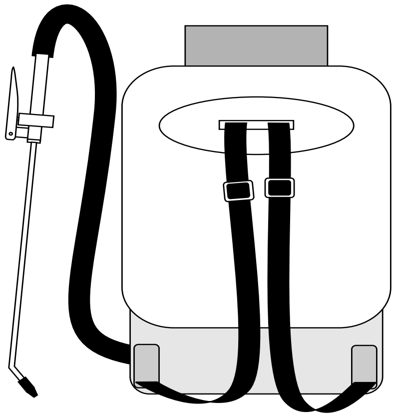
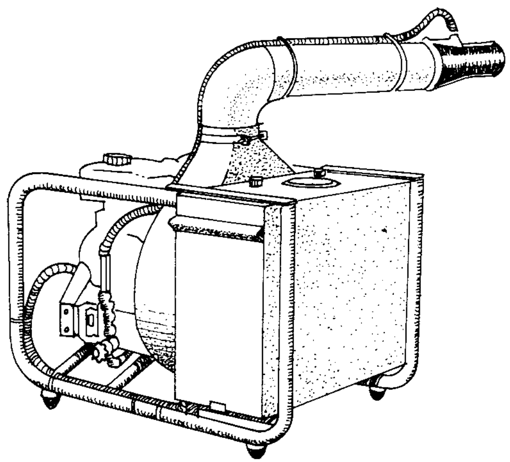


Figure 28. A Berthoud cannon sprayer.



Other sprayers used for locust control (usually without rotary atomizers)

Some other sprayers are used for locust control. They are usually sprayers designed for pest control in field crops with high-volume water-based sprays, but are sometimes used for locust control (either ULV or higher volumes) wen true ULV sprayers with rotary atomizers are not available.

Portable sprayers

Lever-operated knapsack sprayers. These are simple devices made by a number of manufacturers which consist of a tank, a lever-operated pump and a hydraulic nozzle (see Fig. 27). Hollow cone nozzles are better than flat fan nozzles for knapsack sprayer use since they usually produce finer spray and the cone of spray gives good coverage on uneven surfaces such as bushes.

These sprayers are slow and inefficient for locust control when using the high volumes for which they were designed because of the small track spacing and the time wasted in frequent refilling. They are sometimes fitted with a very small nozzle in an attempt to make small droplets and used to apply oil-based ULV formulations. However, this is strongly discouraged because the droplet spectrum is very poor, making them extremely inefficient and even ineffective.

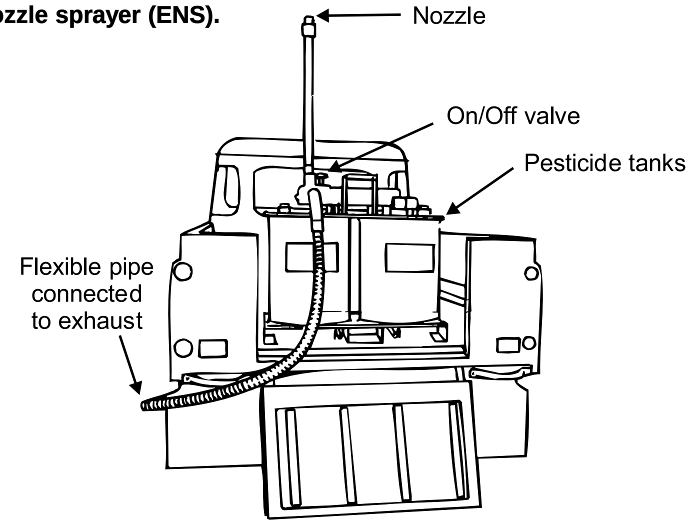
Vehicle-mounted sprayers

Cannon-type sprayers. These are airblast sprayers which consist of a pesticide tank, a pump or air pressure to deliver the pesticide to the nozzle, and a large fan which blows air across a simple nozzle to atomise the pesticide (see Fig. 28).

The droplet spectrum is poor and it is sometimes difficult to set a flow rate low enough for ULV spraying. Most canon sprayers are designed for high-volume spraying. Like the airblast ULV sprayers, the airblast cannot be used as a substitute for a good crosswind. The throw of the spray in zero wind conditions is only a few metres.

This type of sprayer can also be used to treat settled swarms on low vegetation but, because of the droplet spectrum, is not very efficient with pesticides.

Figure 29. Exhaust nozzle sprayer (ENS).



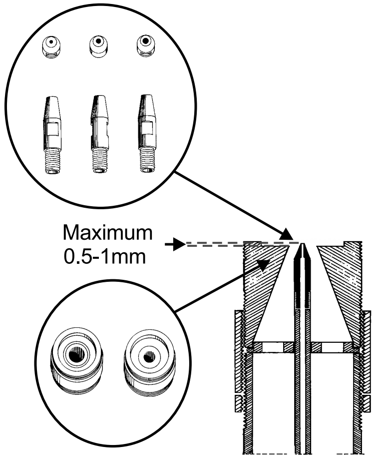


Figure 30. Diagram of ENS nozzle showing alternative pesticide restrictors (developed in Tunisia) and exhaust restrictors. Also shown is the recommended pesticide nozzle clearance above the exhaust restrictor. If it is more (or less), the droplet spectrum is even worse than normal.

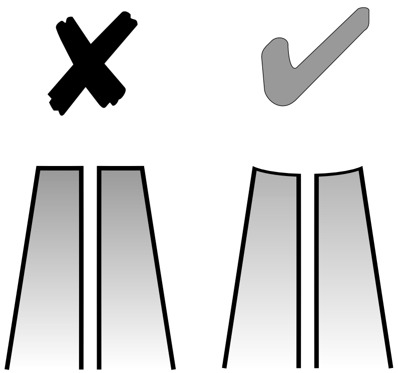


Figure 31. The nozzle with a slightly concave (curved inwards) top gives a better droplet spectrum than the flat-topped one.

Exhaust nozzle sprayer (ENS). This type of sprayer was developed in the 1950s specifically for ULV locust control, long before the development of rotary atomizers. As a result it has been used as a simple, robust field sprayer for locust control for many years. The original model was produced by Francome Fabrications in the United Kingdom, but modified versions have also been made in several countries including India, Yemen and the Islamic Republic of Iran (see Fig. 29).

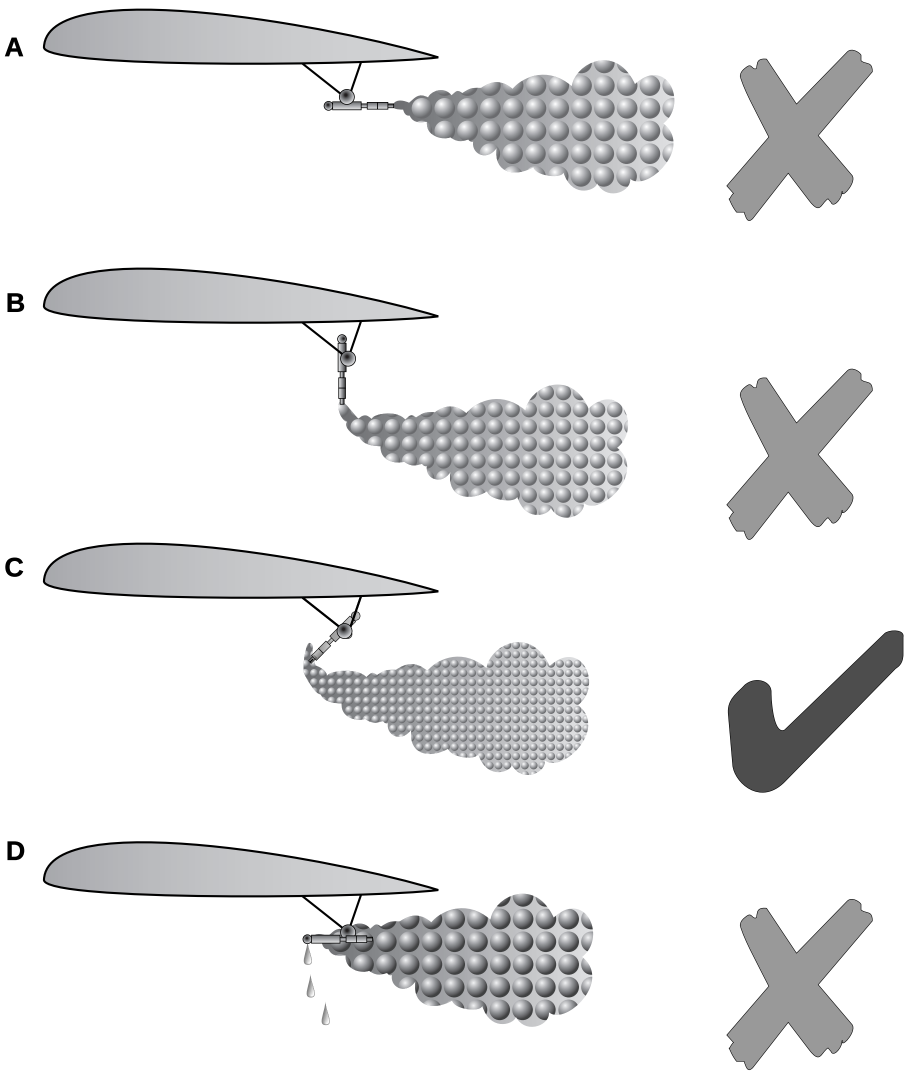
This sprayer uses the engine exhaust gases to deliver the pesticide to the nozzle and also to atomize it. No other power source or pump is required. However, the sprayer produces a relatively poor droplet spectrum with droplets as small as 10 µm and as large as 200 µm diameter and is therefore not very efficient. Also, flow rate cannot be adjusted satisfactorily and, in any case, is likely to fluctuate under working conditions as the vehicle throttle setting is varied. Experienced users say that the back pressure on the exhaust gases causes damage to the vehicle exhaust and engine. It is also not possible to switch the sprayer off from the cab at the end of each spray pass, other than using a different gear so that exhaust pressure is less.

The sprayer consists of a tank (or two tanks) which are pressurised by the exhaust gases, an exhaust restrictor which allows the gases to escape at high speed, and a pesticide nozzle which lets the pesticide out into this high speed airblast (see Fig. 30). Different types of vehicle and engine type (diesel or petrol) produce different volumes and pressures of exhaust gas, so the exhaust gas restrictors have to be chosen to suit the vehicle being used for spraying. Generally, flow rates are too high (and very variable) although some countries have made smaller nozzles to reduce the flow rate. A gear should be chosen to give a comfortable forward speed for the terrain – usually between 5 and 10 km/h – while providing an exhaust pressure of 0.3 kg/cm^2 or more.

After spraying, the tank and nozzle should be cleaned by flushing with a few litres of kerosene or diesel fuel and spraying it over fallow land. Water should never be used to clean the ENS as this can cause corrosion of the steel components.

Tip: the nozzle should be set up to protrude from the exhaust restrictor by 0.5-1.0 mm, otherwise a very poor spectrum will be produced (see Fig. 30). The droplet spectrum is also improved when the nozzle has a concave top (see Fig. 31). Flat-topped nozzles should be modified in the workshop.

Figure 32. If the only equipment for applying ULV pesticide is boom and nozzle, it must be fitted with very small nozzles and they should be angled forward as in C below in order to get a fairly small drop size.



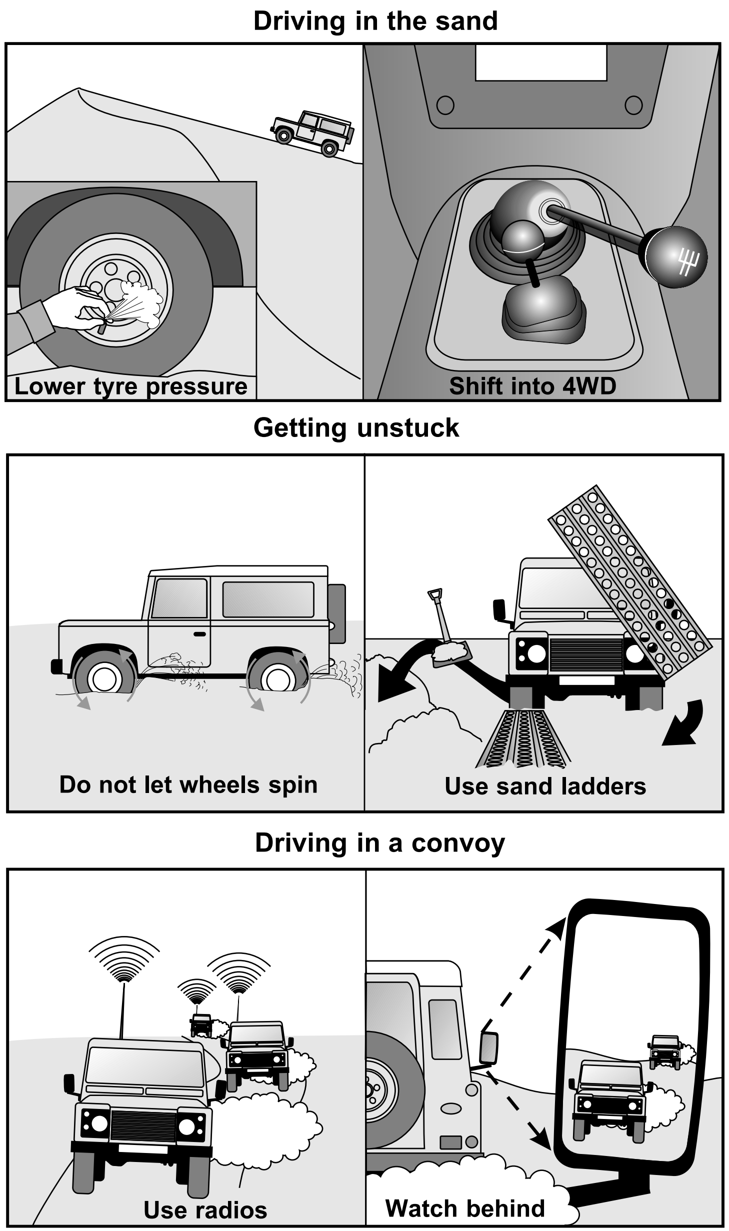
Aircraft-mounted boom and nozzle sprayers

Locusts can be controlled with high-volume EC sprays, but the slow work rate (narrow track spacing and amount of time spent on ferrying and refilling) means that they are not very efficient for spraying locusts.

Sometimes the only aerial spray equipment available is a conventional boom and nozzle sprayer. This consists of a pesticide tank, an electric or propeller-driven pump and numerous hydraulic nozzles mounted on a boom under the wing (see Fig. 32). The hydraulic atomization process is assisted by some airblast effects caused by the speed of the aircraft through the air, but the droplet spectrum is still usually too wide to use ULV pesticides efficiently.

If aerial spray teams have ULV pesticides but only high-volume boom and nozzle spraying equipment is available, small nozzles must be fitted to provide a low flow rate and the equipment must be operated at high pressure to produce a small droplet size. The nozzles must be set up as shown in Figure 32C in order to obtain the smallest drops and narrowest spectrum possible. It may be necessary to block some of the nozzles to achieve a flow rate that is low enough.

Figure 33. Some tips for driving in the sand.



1.11 DRIVING TIPS

There are several techniques and tips that can be used when driving in sandy areas. These are listed below as well as shown in Figure 33.

In the sand

- Lower tyre pressures far below the normal minimum.
- Shift into 4WD.
- Keep in as high a gear as possible (to give maximum torque) and keep your speed up but drive gently.
- Do not accelerate quickly, otherwise wheels will dig into the sand instead of floating on top.
- Avoid sharp rocks, if possible, when the tyres are deflated.
- In soft sand, do not use the brakes; instead, allow the car to coast to a stop.
- Drive slowly and cautiously when the sun is behind you because it will be more difficult to see patches of soft sand, dune slopes and previous tracks.
- If you accidentally go over the edge of a dune, it is better to accelerate to reach the bottom rather than brake which will cause the front of the vehicle to dig in and cartwheel to the bottom.
- Be careful when crossing other vehicle tracks because they will have created a small patch of soft sand and you may become stuck.
- Pump up the tyres once a hard-surfaced road is reached.

Getting unstuck in sand

- As soon as forward movement stops and before the wheels start to dig into the sand, depress the clutch pedal and stop.
- Do not allow the wheels to spin which will only dig the car deeper into the sand.
- Use sand ladders and place them in front of the front wheels.
- Engage in 4WD low ratio and drive forward and out.
- If you are stuck in deep sand, first dig the sand out so the vehicle body is not resting on the sand and then use the sand ladders.
- Keep the front wheels straight.

In a convoy

- Before starting out, decide upon the order of the vehicles for each day and do not vary this.
- Leaders should watch the vehicles behind and not lose them; if they get too far ahead, they should wait for the other vehicles.
- Each vehicle should have a mobile HF and UHF radio so everyone can keep in contact.

Fixed-wing aircraft for survey and control

Manufacturer model	Hopper capacity (litres)	Fuel [1] Type	Fuel Capacity (litres)	Fuel Consumption (litres/hr)	Take-off distance (metres)	Ferry range (km)	No. of seats
Air Tractor							
AT-401B, 402A-B	1 514	A	477	151	401	724	1
AT-502B	1 893	K	644	189	236-347	998	1
AT-802A/B	3 028	K	1 438	250-322	610	982/1 287	1/2
Antonov							
An-3	2 200	A	?	?	?	?	?
Ayers Turbo Thrush [2]							
400	1 515	?	515	133-178	366	725	2
510	1 930	?	863	133-178	366	1 238	2
660	2 500	?	863	170-283	457	966	2
Brit Norman							
Islander BN2B-26	600	?	492-814	95	189	704-1 156	?
Islander BN2B-20	600	?	492-814	110	215	617-1 021	?
Islander BN2T	600-1 000	?	814	172	255	710	?
Islander BN21A	500	?	522	113	500	1 111	?
Defender 4000	600-1 000	?	1 131	200	356	905	?
Cessna							
185		A	246-333	?	?	870-1 194	6
188 AgTruck	280	?	204	?	?	537	1
Croplease Fieldmaster							
NDN6	2 000	K	924	170	354	1 296	2
de Havilland							
DHC-2 Beaver	400	A	522	79	381	833	4
DHC MK III	500	?	?	?	250	741	?
Fletcher							
no information available							
Grumman/Schweizer							
Ag Cat [3]	?	?	?	?	277	?	?
Pacific Aerospace							
no information available							
Piper							
Brave	1 041	A	341	66	488	861	1
Pawnee C235	568	A	144	53	244	435	1
Super Cub 135	416	A	136	29	61-93	926	2

[1] *A = AVGAS, K = kerosene (JET A1); fuel consumption at cruising speed of each aircraft.*
[2] *Turbo Thrush take-off distance at 4 218 kg (400 model), 4 400 kg (510 model), 5 670 kg (660 model). Ferry range at 45 percent power and 217 km/h at 2 286 m (400 and 510 model), 50 pecent power and 265 km/h at 3 658 m.*
[3] *Ag-Cat is a biplane.*

1.12 AIRCRAFT SPECIFICATIONS

Specifications for aircraft commonly used in Desert Locust survey and control operations are presented in two tables: fixed-wing aircraft and helicopters. The information presented in these tables is that currently available. FAO does not assume any responsibility for inaccurate or missing data. Manufacturers are encouraged to contact FAO with more complete information to allow the tables to be updated.

Helicopters for survey and control

Manufacturer model	Hopper capacity (litres)	Fuel Capacity (litres)	Fuel Consumption (litres/hr)	Ferry range (km)	No. pilots + passengers
Aerospatiale					
SA-315B Lama [1]	?	452	217	515	1+4
Bell [2]					
47	455	125	?	520	2+1
205	1 759	?	?	511	2+12
206 [3]	635	344	106	721	2+3
212	2 268	818	375	420	2+13

[1] Suitable for high altitude work, up to 12 442 m.
[2] Hopper capacity in kg.
[3] Ferry range at sea level with takeoff weight of 1 179 kg and long-range cruise speed.

Figure 34. Satellites relevant to locust work, navigation and research.

Satellite	Owner	Type	Coverage	Resolution [1]	Frequency
Used operationally by FAO DLIS for planning and forecasting					
Cloud detection and rainfall estimation (visible, infrared, water vapour imagery)					
Meteosat	EUMETSAT	geostationary	Africa	2.5 x 2.5 km 5 x 5 km	30 minutes 30 minutes
Vegetation detection (NDVI imagery)					
SPOT VGT [2]	Europe	polar orbit	global	1 x 1 km	daily
MODIS [2]	USA	polar orbit	global	250 m-1 km	1-2 days
Used for navigation in the field					
NAVSTAR	USA	circular orbit	global	ca. 10 m	continuous
Used for research purposes [3]					
Meteorological (visible, infrared, water vapour imagery)					
GOES	USA	geostationary	N. America	2.5 x 2.5 km 5 x 5 km	30 minutes 30 minutes
INSAT	India	geostationary	India	2.5 x 2.5 km 5 x 5 km	30 minutes 30 minutes
Meteorological and environmental monitoring (thematic maps)					
NOAA	USA	polar orbit	global	1.1 x 1.1 km	12 hours
Earth resource mapping and environmental monitoring (thematic maps)					
LandSat 7	USA	polar orbit	global	15 x 15 m	16 days
SPOT	France	polar orbit	global	10 x 10 m	26 days
RADARSAT	Canada	polar orbit	global	8 x 8 m	24 days
RESURS 01	Russia	polar orbit	global	170 x 170 m	21 days
IRS-1A	India	polar orbit	global	36 x 36 m	22 days
ERS1	ESA	polar orbit	global	26 x 26 m	35 days

[1] *Maximum spatial resolution (or size of pixel).*
[2] *Currently being evaluated for operational use.*
[3] *Some of the more common satellites; the list is not meant to be exhaustive.*

1.13 SATELLITES RELEVANT TO LOCUST WORK

Data and images obtained by satellite can be used for locust monitoring and forecasting. Their operational use will depend on practical characteristics such as spatial coverage, time (repeat frequency) and cost (see Fig. 34). You should also consider how reliable a product is and how easy or difficult it is to interpret. At present, Meteosat and NDVI (normalized difference vegetation index)-based imagery are used, primarily by DLIS.

Meteosat

The Meteosat satellite is positioned 36 000 km above Africa where the equator and the Prime Meridian meet. As this is a fixed position, Meteosat imagery covers Africa, most of Europe, the Near East to about 55°E, and the eastern portion of South America.

Meteosat imagery shows clouds and other features such as dust storms at all levels between the satellite and the earth. For locust purposes, visible and infrared images are examined to identify those clouds that may produce rainfall. A derived product, cold cloud duration (CCD) image, consists of a composite of ten days of infrared images showing only those clouds below a certain temperature threshold (e.g. -40°C) which are thought to be cold enough to produce rainfall. For example, cumulo-nimbus clouds that reach high in the atmosphere and get very cold tops are often associated with convective storms that normally produce rain. CCDs can give a relatively good approximation of rainfall during the summer but not during the winter or spring, especially along the Red Sea, when rainfall is associated with warmer clouds.

Most national meteorological services have Meteosat receivers.

SPOT-VGT and MODIS

The only operational satellite products that have potential for the continual monitoring of ecological conditions in locust habitats are those based on the NDVI. Currently, these are derived from SPOT-VGT (vegetation) and MODIS data. Global coverage, a spatial resolution of 250 m to 1 km, high frequency and relatively low cost of the data counterbalance any shortcomings in interpretation and reliability. The imagery is being evaluated at DLIS but is expected to have increased applications within locust-affected countries for planning surveys and delimiting the relatively large areas that must be checked by survey teams. Studies are in progress to improve the reliability of the data when used for monitoring desert areas and to provide rapid transmission of images to affected countries.

There are several other satellites that are primarily used for research purposes for detailed mapping of the earth's resources such as land use, agriculture, forestry, fisheries, geology and oceanography; for environmental monitoring such as hydrology, forest fires and pollution; and for cartography. The high cost, low repetition and relatively small spatial coverage of many of these make them unsuitable for the regular monitoring of locust habitats.

Appendix 2

Procedures and tasks

Figure 35. FAO Desert Locust Survey and Control Form: survey and ecology.

FAO DESERT LOCUST SURVEY AND CONTROL FORM page *1* of *2*

please send to FAO HQ by fax (+39-06-57055271) or email (eclo@fao.org)

(indicate appropriate information as required)

1	SURVEY STOP	1	2	3	4	5	6
1-1	date	29.07.99	29.07.99	30.07.99	31.07.99	31.07.99	31.07.99
1-2	name	Wadi Hamid	Berika	Khor Amer	Bir Bou Ali	Shardi	Abu Qashim
1-3	latitude (N)	210255	210544	203149	200411	200159	194842
1-4	longitude (E or W)	331218	340122	342402	335512	334536	331514
2	ECOLOGY						
2-1	area (ha) of survey	100	250	20	100	200	50
2-2	habitat (wadi, plains, dunes, crops)	wadi	dunes	wadi	plains	plains	dunes
2-3	date of last rain	15.07.99	2 weeks ago	12.07.99	about 1 month	13.07.99	13.07.99
2-4	rain amount (mm, Low Moderate High, ?)	L M H ?	L M H ?	L M H ?	L M H ?	L M H ?	L M H ?
2-5	vegetation (dry, greening, green, drying)	greening	green	green	drying	green	greening
2-6	vegetation density (Low Medium Dense)	L M D	L M D	L M D	L M D	L M D	L M D
2-7	soil moisture (wet/dry)	W D	W D	W D	W D	W D	W D
3	LOCUSTS						
3-1	present or absent	P A	P A	P A	P A	P A	P A
3-2	area infested (ha)		100		100	200	
4	HOPPERS						
4-1	hopper stages (H123456F)	H 1 2 3 4 5 6 F	H 1 2 3 4 5 6 F	H 1 2 3 4 5 6 F	H 1 2 3 4 5 6 F	H 1 2 3 4 5 6 F	H 1 2 3 4 5 6 F
4-2	appearance (solitary, transiens, gregarious)	S T G	S T G	S T G	S T G	S T G	S T G
4-3	behaviour (isolated, scattered, groups)	I S G	I S G	I S G	I S G	I S G	I S G
4-4	hopper density (/site, /m2, Low Med High)		L				
5	BANDS						
5-1	band stage (H12345F)	H 1 2 3 4 5 F	H 1 2 3 4 5 F	H 1 2 3 4 5 F	H 1 2 3 4 5 F	H 1 2 3 4 5 F	H 1 2 3 4 5 F
5-2	band density (/m2 or Low Medium High)				5/m2		
5-3	band sizes (m2 or ha)				10 m2		
5-4	number of bands				5		
6	ADULTS						
6-1	maturity (immature, mature)	I M	I M	I M	I M	I M	I M
6-2	appearance (solitary, transiens, gregarious)	S T G	S T G	S T G	S T G	S T G	S T G
6-3	behaviour (isolated, scattered, groups)	I S G	I S G	I S G	I S G	I S G	I S G
6-4	adult density (/transect, /ha, L M H)					25/300x4m	
6-5	breeding (copulating, laying)	C L	C L	C L	C L	C L	C L
7	SWARMS						
7-1	maturity (immature, mature)	I M	I M	I M	I M	I M	I M
7-2	swarm density (/m2 or Low Medium High)				50/m2		
7-3	swarm size (km2 or ha)				1 ha		
7-4	number of swarms				1		
7-5	breeding (copulating, laying)	C L	C L	C L	C L	C L	C L
7-6	flying (direction, time passing)						
7-7	flying height (Low Medium High)	L M H	L M H	L M H	L M H	L M H	L M H
8	CONTROL						
8-1	pesticide name & formulation				Feni ULV		
8-2	application rate (l/ha or kg/ha))				0.4		
8-3	quantity (l)				25		
8-4	area treated (ha)				100		
8-5	ground or air	G A	G A	G A	G A	G A	G A
8-6	estimated % kill				80		
9	COMMENTS						
			area between Hamid & Berika is dry with no DL habitats	swarm seen by farmer flying southwest 2 days ago in the early morning	see attached Spray Monitor Form	adults seen in sorghum crops; no DL outside of crops	good DL habitat which should be checked after 1 week

kc 99.03

Was a GPS used to determine locations? yes no

Is a brief interpretation or analysis of the results included? yes no

Country: *Sudan*

Locust Officer : *Mohamed Abu El Hassan* date : *31.7.99*

cleared by : *Ben Osman El Kif* date : *1.8.99*

2.1 COMPLETING THE FAO DESERT LOCUST SURVEY AND CONTROL FORM

When to use

This form should be used during Desert Locust recession, upsurges and plagues to report results of surveys and control operations. The form should also be used to report survey results where no locusts were found.

How to use

The results of the first survey stop should be recorded in the first column, the second stop in the second column and so on.

Survey stop (see Fig. 35)

Date	write the day / month / year of the survey
Name	write the name of where you have stopped (**?** = name unknown)
Latitude (N)	degrees / minutes / seconds north; use a GPS
Longitude (E or W)	degrees / minutes / seconds west or east; use a GPS

Ecology (see Fig. 35)

Area of survey	estimated area of survey at the stop in ha (this can be based on the estimated area of green vegetation at the site)
Habitat	describe the survey stop (wadi, plains, dunes, crops, etc.)
Date of last rain	write the day / month / year (if known), or estimate (i.e. 2 days, 3 months, etc.), or **?** if unknown
Rain amount	write the exact amount (mm), or circle **L** for low (1-20 mm), **M** for moderate (21-50 mm), **H** for heavy (50+ mm), or **?** if unknown
Vegetation	write **dry**, **greening** (becoming green), **green** (already green), **drying** (becoming dry)
Vegetation density	circle **L** for low (more bare ground than vegetation), **M** for medium (same amount of bare ground and vegetation), **D** for dense (more vegetation than bare ground)
Soil moisture	circle **W** for wet (if the soil is moist to about 10-15 cm), **D** for dry

Figure 36. FAO Desert Locust Survey and Control Form: locusts, hoppers and bands.

FAO DESERT LOCUST SURVEY AND CONTROL FORM page *1* of *2*

please send to FAO HQ by fax (+39-06-57055271) or email (eclo@fao.org)

(indicate appropriate information as required)

1	SURVEY STOP	1	2	3	4	5	6
1-1	date	29.07.99	29.07.99	30.07.99	31.07.99	31.07.99	31.07.99
1-2	name	Wadi Hamid	Berika	Khor Amer	Bir Bou Ali	Shardi	Abu Qashim
1-3	latitude (N)	210255	210544	203149	200411	200159	194842
1-4	longitude (E or W)	331218	340122	342402	335512	334536	331514
2	ECOLOGY						
2-1	area (ha) of survey	100	250	20	100	200	50
2-2	habitat (wadi, plains, dunes, crops)	wadi	dunes	wadi	plains	plains	dunes
2-3	date of last rain	15.07.99	2 weeks ago	12.07.99	about 1 month	13.07.99	13.07.99
2-4	rain amount (mm, Low Moderate High, ?)	(L) M H ?	L (M) H ?	L (M) H ?	L M H (?)	(L) M H ?	(L) M H ?
2-5	vegetation (dry, greening, green, drying)	greening	green	green	drying	green	greening
2-6	vegetation density (Low Medium Dense)	(L) M D	L M (D)	(L) M D	(L) M D	(L) M D	(L) M D
2-7	soil moisture (wet/dry)	(W) D	(W) D	(W) D	W (D)	(W) D	(W) D
3	LOCUSTS						
3-1	present or absent	P (A)	(P) A	P (A)	(P) A	(P) A	P (A)
3-2	area infested (ha)		100		100	200	
4	HOPPERS						
4-1	hopper stages (H123456F)	H 1 2 3 4 5 6 F	H 1 2 3 (4 5 6) F	H 1 2 3 4 5 6 F	H 1 2 3 4 5 6 F	H 1 2 3 4 5 6 F	H 1 2 3 4 5 6 F
4-2	appearance (solitary, transiens, gregarious)	S T G	(S) T G	S T G	S T G	S T G	S T G
4-3	behaviour (isolated, scattered, groups)	I S G	(I) S G	I S G	I S G	I S G	I S G
4-4	hopper density (/site, /m2, Low Med High)		L				
5	BANDS						
5-1	band stage (H12345F)	H 1 2 3 4 5 F	H 1 2 3 4 5 F	H 1 2 3 4 5 F	H 1 2 3 4 (5 F)	H 1 2 3 4 5 F	H 1 2 3 4 5 F
5-2	band density (/m2 or Low Medium High)				5/m2		
5-3	band sizes (m2 or ha)				10 m2		
5-4	number of bands				5		
6	ADULTS						
6-1	maturity (immature, mature)	I M	I M	I M	I M	(I) M	I M
6-2	appearance (solitary, transiens, gregarious)	S T G	S T G	S T G	S T G	(S) T G	S T G
6-3	behaviour (isolated, scattered, groups)	I S G	I S G	I S G	I S G	(I) S G	I S G
6-4	adult density (/transect, /ha, L M H)					25/300x4m	
6-5	breeding (copulating, laying)	C L	C L	C L	C L	C L	C L
7	SWARMS						
7-1	maturity (immature, mature)	I M	I M	I M	I (M)	I M	I M
7-2	swarm density (/m2 or Low Medium High)				50/m2		
7-3	swarm size (km2 or ha)				1 ha		
7-4	number of swarms				1		
7-5	breeding (copulating, laying)	C L	C L	C L	C (L)	C L	C L
7-6	flying (direction, time passing)						
7-7	flying height (Low Medium High)	L M H	L M H	L M H	L M H	L M H	L M H
8	CONTROL						
8-1	pesticide name & formulation				Feni ULV		
8-2	application rate (l/ha or kg/ha))				0.4		
8-3	quantity (l)				25		
8-4	area treated (ha)				100		
8-5	ground or air	G A	G A	G A	(G) A	G A	G A
8-6	estimated % kill				80		
9	COMMENTS						
			area between Hamid & Berika is dry with no DL habitats	swarm seen by farmer flying southwest 2 days ago in the early morning	see attached Spray Monitor Form	adults seen in sorghum crops; no DL outside of crops	good DL habitat which should be checked after 1 week

kc 99.03

Was a GPS used to determine locations? (yes) no

Is a brief interpretation or analysis of the results included? yes (no)

Country: *Sudan*

Locust Officer : *Mohamed Abu El Hassan* date : *31.7.99*

cleared by : *Ben Osman El Kif* date : *1.8.99*

Locusts (see Fig. 36)

Present or absent — circle **P** if any stage of locusts is present or **A** if locusts are absent

Area infested (ha) — write the estimated number of hectares that contain locusts at the survey stop

Hoppers (see Fig. 36)

(If individual hoppers or groups are present, give details. Refer to the Survey guideline for more instructions)

Hopper stages — circle which instars (**1,2,3,4,5,6**), hatchlings (**H**) or fledglings (**F**) are present

Appearance — circle **S** for solitary (greenish colour), **T** for transiens (green/black), **G** for gregarious (black or yellow/black)

Behaviour — circle **I** for isolated (individual hoppers), **S** for scattered (several hoppers), **G** for groups (clumping together)

Hopper density — examine at least ten samples of 1 m^2 each (or 10 bushes) and record the lowest and highest number seen or, if you make a rough estimate, write **L** for low, **M** for medium, **H** for high

Bands (see Fig. 36)

(If hopper bands are present, give details. Refer to the Survey guideline for more instructions)

Band stage — circle which instars (**1,2,3,4,5**), hatchlings (**H**) or fledglings (**F**) are present

Band density — number of hoppers per bush or m^2 (e.g. 30/m^2) or write **L** for low (more bare ground or vegetation visible than band), **M** for medium (same amount of bare ground and band), **D** for dense (more band than bare ground)

Band sizes — write the estimated size of band in m^2 or indicate the minimum and maximum sizes

Number of bands — write the number of bands present at the survey site

Figure 37. FAO Desert Locust Survey and Control Form: adults and swarms.

FAO DESERT LOCUST SURVEY AND CONTROL FORM page *1* of *2*

please send to FAO HQ by fax (+39-06-57055271) or email (eclo@fao.org)

(indicate appropriate information as required)

1	SURVEY STOP	1	2	3	4	5	6
1-1	date	29.07.99	29.07.99	30.07.99	31.07.99	31.07.99	31.07.99
1-2	name	Wadi Hamid	Berika	Khor Amer	Bir Bou Ali	Shardi	Abu Qashim
1-3	latitude (N)	210255	210544	203149	200411	200159	194842
1-4	longitude (E or W)	331218	340122	342402	335512	334536	331514
2	ECOLOGY						
2-1	area (ha) of survey	100	250	20	100	200	50
2-2	habitat (wadi, plains, dunes, crops)	wadi	dunes	wadi	plains	plains	dunes
2-3	date of last rain	15.07.99	2 weeks ago	12.07.99	about 1 month	13.07.99	13.07.99
2-4	rain amount (mm, Low Moderate High, ?)	L M H ?	L M H ?	L M H ?	L M H ?	L M H ?	L M H ?
2-5	vegetation (dry, greening, green, drying)	greening	green	green	drying	green	greening
2-6	vegetation density (Low Medium Dense)	L M D	L M D	L M D	L M D	L M D	L M D
2-7	soil moisture (wet/dry)	W D	W D	W D	W D	W D	W D
3	LOCUSTS						
3-1	present or absent	P A	P A	P A	P A	P A	P A
3-2	area infested (ha)		100		100	200	
4	HOPPERS						
4-1	hopper stages (H123456F)	H 1 2 3 4 5 6 F	H 1 2 3 4 5 6 F	H 1 2 3 4 5 6 F	H 1 2 3 4 5 6 F	H 1 2 3 4 5 6 F	H 1 2 3 4 5 6 F
4-2	appearance (solitary, transiens, gregarious)	S T G	S T G	S T G	S T G	S T G	S T G
4-3	behaviour (isolated, scattered, groups)	I S G	I S G	I S G	I S G	I S G	I S G
4-4	hopper density (/site, /m2, Low Med High)		L				
5	BANDS						
5-1	band stage (H12345F)	H 1 2 3 4 5 F	H 1 2 3 4 5 F	H 1 2 3 4 5 F	H 1 2 3 4 5 F	H 1 2 3 4 5 F	H 1 2 3 4 5 F
5-2	band density (/m2 or Low Medium High)				5/m2		
5-3	band sizes (m2 or ha)				10 m2		
5-4	number of bands				5		
6	ADULTS						
6-1	maturity (immature, mature)	I M	I M	I M	I M	I M	I M
6-2	appearance (solitary, transiens, gregarious)	S T G	S T G	S T G	S T G	S T G	S T G
6-3	behaviour (isolated, scattered, groups)	I S G	I S G	I S G	I S G	I S G	I S G
6-4	adult density (/transect, /ha, L M H)					25/300x4m	
6-5	breeding (copulating, laying)	C L	C L	C L	C L	C L	C L
7	SWARMS						
7-1	maturity (immature, mature)	I M	I M	I M	I M	I M	I M
7-2	swarm density (/m2 or Low Medium High)				50/m2		
7-3	swarm size (km2 or ha)				1 ha		
7-4	number of swarms				1		
7-5	breeding (copulating, laying)	C L	C L	C L	C L	C L	C L
7-6	flying (direction, time passing)						
7-7	flying height (Low Medium High)	L M H	L M H	L M H	L M H	L M H	L M H
8	CONTROL						
8-1	pesticide name & formulation				Feni ULV		
8-2	application rate (l/ha or kg/ha))				0.4		
8-3	quantity (l)				25		
8-4	area treated (ha)				100		
8-5	ground or air	G A	G A	G A	G A	G A	G A
8-6	estimated % kill				80		
9	COMMENTS						
			area between Hamid & Berika is dry with no DL habitats	swarm seen by farmer flying southwest 2 days ago in the early morning	see attached Spray Monitor Form	adults seen in sorghum crops; no DL outside of crops	good DL habitat which should be checked after 1 week

kc 99.03

Was a GPS used to determine locations? yes no   Is a brief interpretation or analysis of the results included? yes no

Country: *Sudan*   Locust Officer : *Mohamed Abu El Hassan*   date : *31.7.99*

cleared by : *Ben Osman El Kif*   date : *1.8.99*

Adults (see Fig. 37)

(If individual adults or groups are present, give details. Refer to the Survey guideline for more instructions)

Maturity	circle **I** for immature, **M** for mature, or both if present; try to estimate the percentage of each maturity and record in the Comments section
Appearance	circle **S** for solitary (brown colour), **T** for transiens (brownish/pink or brownish/yellow), **G** for gregarious (pink or yellow)
Behaviour	circle **I** for isolated (individual hoppers), **S** for scattered (several hoppers), **G** for groups (clumping together)
Adult density	count the number of adults when walking about 250-400 m (and indicate the length and width of the foot transect) or estimate the number of adults per hectare. (e.g. 4/1000 m^2 or 20/ha) or write **L** for low, **M** for medium, **H** for high
Breeding	circle **C** for copulating, **L** for laying

Swarms (see Fig. 37)

(If swarms are present, give details. Refer to the Survey guideline for more instructions)

Maturity	circle **I** for immature, **M** for mature, or both if present; try to estimate the percentage of each maturity and record in the Comments section
Swarm density	number of adults per bush or m^2 or write **L** for low (more bare ground or vegetation visible than swarm), **M** for medium (same amount of bare ground and swarm), **D** for dense (more swarm than bare ground)
Swarm size	write the estimated size of the swarm in km^2, m^2 or ha
Number of swarms	write the number of swarms present at the survey site
Breeding	circle **C** for copulating, **L** for laying
Flying	the direction swarms are flying FROM and TO, the time (hours, minutes) that they took to pass overhead
Flying height	estimated height of flight or write **L** for low (less than 100 m), **M** for medium (100-500 m), **H** for high (500+ m)

Figure 38. FAO Desert Locust Survey and Control Form: control and comments.

FAO DESERT LOCUST SURVEY AND CONTROL FORM   page 1 of 2

please send to FAO HQ by fax (+39-06-57055271) or email (eclo@fao.org)

(indicate appropriate information as required)

1	SURVEY STOP	1	2	3	4	5	6
1-1	date	29.07.99	29.07.99	30.07.99	31.07.99	31.07.99	31.07.99
1-2	name	Wadi Hamid	Berika	Khor Amer	Bir Bou Ali	Shardi	Abu Qashim
1-3	latitude (N)	210255	210544	203149	200411	200159	194842
1-4	longitude (E or W)	331218	340122	342402	335512	334536	331514
2	ECOLOGY						
2-1	area (ha) of survey	100	250	20	100	200	50
2-2	habitat (wadi, plains, dunes, crops)	wadi	dunes	wadi	plains	plains	dunes
2-3	date of last rain	15.07.99	2 weeks ago	12.07.99	about 1 month	13.07.99	13.07.99
2-4	rain amount (mm, Low Moderate High, ?)	L M H ?	L M H ?	L M H ?	L M H ?	L M H ?	L M H ?
2-5	vegetation (dry, greening, green, drying)	greening	green	green	drying	green	greening
2-6	vegetation density (Low Medium Dense)	L M D	L M D	L M D	L M D	L M D	L M D
2-7	soil moisture (wet/dry)	W D	W D	W D	W D	W D	W D
3	LOCUSTS						
3-1	present or absent	P A	P A	P A	P A	P A	P A
3-2	area infested (ha)		100		100	200	
4	HOPPERS						
4-1	hopper stages (H123456F)	H 1 2 3 4 5 6 F	H 1 2 3 4 5 6 F	H 1 2 3 4 5 6 F	H 1 2 3 4 5 6 F	H 1 2 3 4 5 6 F	H 1 2 3 4 5 6 F
4-2	appearance (solitary, transiens, gregarious)	S T G	S T G	S T G	S T G	S T G	S T G
4-3	behaviour (isolated, scattered, groups)	I S G	I S G	I S G	I S G	I S G	I S G
4-4	hopper density (/site, /m2, Low Med High)		L				
5	BANDS						
5-1	band stage (H12345F)	H 1 2 3 4 5 F	H 1 2 3 4 5 F	H 1 2 3 4 5 F	H 1 2 3 4 5 F	H 1 2 3 4 5 F	H 1 2 3 4 5 F
5-2	band density (/m2 or Low Medium High)				5/m2		
5-3	band sizes (m2 or ha)				10 m2		
5-4	number of bands				5		
6	ADULTS						
6-1	maturity (immature, mature)	I M	I M	I M	I M	I M	I M
6-2	appearance (solitary, transiens, gregarious)	S T G	S T G	S T G	S T G	S T G	S T G
6-3	behaviour (isolated, scattered, groups)	I S G	I S G	I S G	I S G	I S G	I S G
6-4	adult density (/transect, /ha, L M H)					25/300x4m	
6-5	breeding (copulating, laying)	C L	C L	C L	C L	C L	C L
7	SWARMS						
7-1	maturity (immature, mature)	I M	I M	I M	I M	I M	I M
7-2	swarm density (/m2 or Low Medium High)				50/m2		
7-3	swarm size (km2 or ha)				1 ha		
7-4	number of swarms				1		
7-5	breeding (copulating, laying)	C L	C L	C L	C L	C L	C L
7-6	flying (direction, time passing)						
7-7	flying height (Low Medium High)	L M H	L M H	L M H	L M H	L M H	L M H
8	CONTROL						
8-1	pesticide name & formulation				Feni ULV		
8-2	application rate (l/ha or kg/ha))				0.4		
8-3	quantity (l)				25		
8-4	area treated (ha)				100		
8-5	ground or air	G A	G A	G A	G A	G A	G A
8-6	estimated % kill				80		
9	COMMENTS						
			area between Hamid & Berika is dry with no DL habitats	swarm seen by farmer flying southwest 2 days ago in the early morning	see attached Spray Monitor Form	adults seen in sorghum crops; no DL outside of crops	good DL habitat which should be checked after 1 week

kc 99 03

Was a GPS used to determine locations? yes no   Is a brief interpretation or analysis of the results included? yes no

Country: *Sudan*   Locust Officer : *Mohamed Abu El Hassan*   date : *31.7.99*

cleared by : *Ben Osman El Kif*   date : *1.8.99*

Control (see Fig. 38)

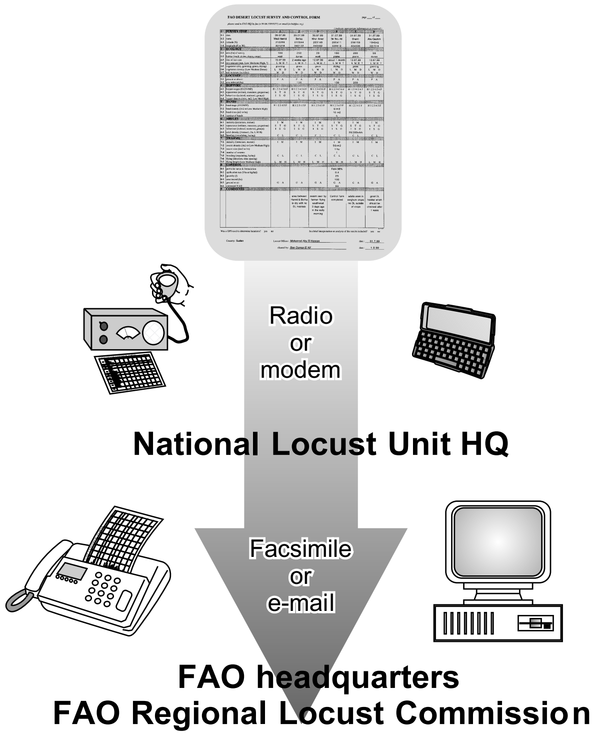
(if control was carried out, give details)

Pesticide	write, for example, MAL for Malathion, FEN for fenitrothion and formulation (ULV, EC, dust, bait)
Application rate	write the number of litres or kg used per ha
Quantity	write the total number of litres or kg used
Area treated	write the total number of hectares sprayed or covered
Ground or air	circle **G** for ground of **A** for aerial control
Estimated % kill	estimate the number of locusts killed out of 100. Examine several 1 m^2 samples. Note how long after spraying the estimate was made.

Comments (see Fig. 38)

Use this section to indicate important information that could not be written above. For example, if there were more of one type of locusts present than another (such as more transiens than solitary or more fifth instar hoppers than second); if you tried to estimate the percentage of immature and mature adults present; if crops are present; what was the ecology between survey stops; unconfirmed reports from nomads, etc.; if you know the time of swarm departure or arrival; and if it was a ground or aerial survey.

Figure 39. How to transmit the FAO Desert Locust Survey and Control Form.



Version	Language [1]	What to do	How to send to DLIS
PDF [2]	E/F/A	1. Print hard copy of form 2. Fill in form at the survey stop	fax: +39 06 570 55271
MS Excel	E/F	1. Save to computer 2. Open file in MS Excel application 3. Enter data and save file	e-mail: eclo@fao.org [4]
Handheld [3]	E/F	1. Save to handheld computer 2. Enter data while at the survey stop 3. Save and export to computer or RAMSES	e-mail: eclo@fao.org

Notes:

[1] *E = English, F = French, A = Arabic*

[2] *The free Adobe Reader software must be installed on your computer in order to view, print and save PDF files. You can obtain this software on the Internet at: www.adobe.com*

[3] *A handheld computer used by locust officers in the field*

[4] *If e-mail is not available, the form can be faxed to FAO DLIS*

How to use this form by radio or e-mail

This form can be used to transmit information by radio or telephone. You can refer to each section by the appropriate number. For example, "1-5-1 = 1,2,3" indicates that first, second and third instar hoppers were seen at survey stop number one (1 = survey stop number one, 5 = development section, 1 = instar or fledgling, 1,2,3 = hopper instars).

What to do with this form after completion (see Fig. 39)

The information on this form should be transmitted from the field to the National headquarters and to FAO DLIS, Rome. If you are filling out the form by hand, the information can be sent by radio or the form can be sent by fax to the National headquarters directly from the field. If you are using a handheld computer and entering the information directly into this at each survey location, you can send the data directly to the computer at the National headquarters if you have access to an HF radio modem. From the National headquarters, the data should be sent to FAO DLIS and, if possible, to the appropriate FAO Regional Locust Commission within two to five days of the end of the survey. A short interpretation should be sent with the form suggesting what the results mean to you, which is your opinion based on your experience. You should keep a copy for your records.

Questions and problems

If you have any questions and problems or require additional forms, please contact the Desert Locust Information Service (DLIS) at FAO headquarters:

telephone:	+39 (06) 570 52420
fax:	+39 (06) 570 55271
e-mail:	eclo@fao.org

You may also wish to contact the secretariat of your regional locust commission.

Where to obtain the latest form

The latest version of the FAO Desert Locust Survey and Control Form can be requested from DLIS (see above) or downloaded directly from the internet at:

www.fao.org/news/global/locusts/pubs1.htm

Figure 40. Calibrate your pace length by counting the number of paces required to walk along a marked 100 m line.

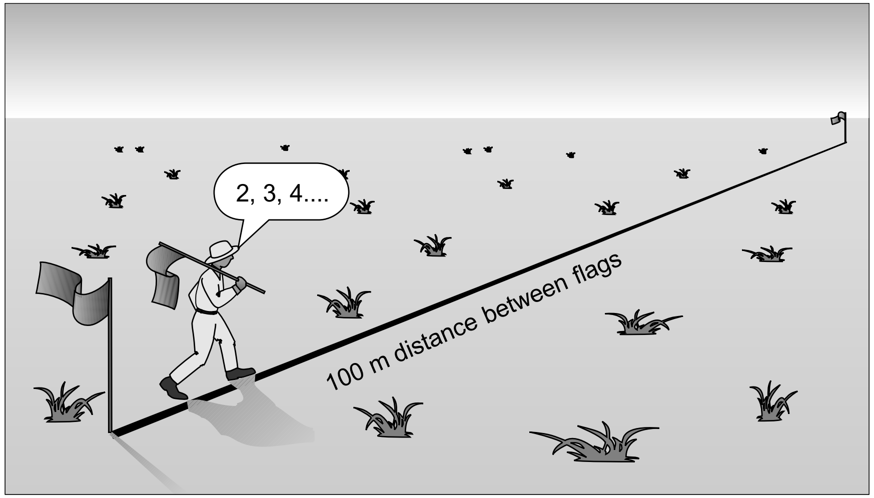


Figure 41. Table for making calculations after counting paces.

Name	Distance covered (m) (A)	Number of paces (B)	Length of pace (m) (A/B)
	Average		

2.2 CALIBRATING PACE LENGTH

For control with all types of sprayer, even aircraft, it is necessary to calibrate the length of the operator/flag person's pace so that track spacings can be estimated fairly accurately (see Fig. 40). Some people assume that a person's pace length is always 1 m, but most people's pace length is between 70 and 90 cm.

Step 1. Measure out a distance (suggested distance 100 m) using a tape measure and plant flags or other markers at each end. Enter the distance in the table in Figure 41.

Step 2. Walk along the distance between the flags at normal walking speed and count the number of steps you use. Enter this number in the table opposite. Repeat the walk twice more so that you have three numbers of steps entered in the table.

Step 3. Calculate the length of your pace (A divided by B) for each of the three figures, then calculate the average of the three pace lengths by adding them and dividing by three.

Tips:

- ***it is much easier and more accurate to measure distances in the field with a calibrated pace length, than it is to try to walk with strides exactly 1 m long***
- ***most track spacings will be multiples of 10 m so it is useful to calculate the number of paces to walk 10 m. For most people, this will be 11-15 paces***

Figure 42. Table for calculating sprayer speed.

Name	Distance (m) (A)	Theoretical time to walk or drive 100 m (s)	Actual time taken to walk or drive 100 m (s) (B)	Actual speed (m/s) (A/B)

2.3 CALIBRATING SPRAYER SPEED

For any sprayer, speed has a direct effect on dose applied. Aircraft usually have good airspeed indicators, but operators of ground equipment are often not sure what speed they are driving or walking at.

The procedure is very similar for portable or vehicle-mounted sprayers.

Step 1. Calculate the desired forward speed to achieve the correct VAR and dose. Calculate the time it should take to travel 100 m if you are travelling at the correct speed.

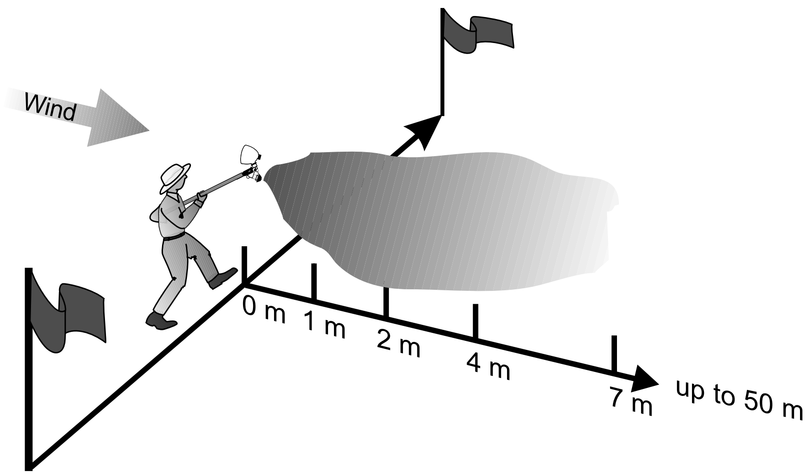
Step 2. Using a measured distance of 100 m marked out with flags, try to walk or drive between the two flags at the estimated correct speed and record the time taken. In a vehicle note the gear used and the engine speed (if the vehicle is fitted with a tachometer).

Step 3. Enter the data in to the table in Figure 42 and calculate the actual speed you were travelling.

Step 4. If the speed is not correct, adjust your speed and try again. Carry on with this trial and error technique until you can easily move at the required speed.

Tip: when an operator has done the exercise once for a particular speed, it only has to be done again if a different speed is required or occasionally to check that the speed is still being estimated fairly accurately.

Figure 43. Spraying a single swath and sampling the spray downwind.



2.4 MEASURING SWATH WIDTH OF ULV SPRAYERS

The swath is the spray deposition downwind at right angles to a crosswind spray run. It is useful to test the swath width for a sprayer under a variety of different conditions. This is done by collecting droplets on samplers placed at different distances downwind (see Fig. 43).

Samplers do not behave like locusts, so sampling the spray will only give an estimate of deposition on locusts. However, with small ULV drops, narrow samplers (1 cm wide) positioned vertically will collect droplets more effectively than wide samplers or samplers placed horizontally, e.g. on the ground.

The most convenient types of samplers are oil-sensitive papers. When an oily ULV spray droplet lands on this type of paper, it leaves a dark mark. It is important to check that the pesticide being used does in fact mark the paper since there are some that do not. Others produce marks that fade quite quickly so analysis must be carried out soon after spraying. Another method is to use white photographic paper as a sampler, but this means that a coloured dye needs to be put into the spray liquid so that the droplets show up on the surface.

These sampling papers can be mounted vertically, facing into the wind, on narrow sticks positioned downwind. These sticks should be 1 cm or less in diameter and around 50 cm long. The total length of the spray sampling line will vary with the type of sprayer – usually up to 75 m for a portable sprayer, 250 m for a vehicle sprayer and 600 m for aircraft. Samplers should be closer together near the sprayer since the deposit changes most near to it.

If a handheld spinning disc sprayer is being used, for example, samplers can be set at distances of 0, 1, 2, 4, 7, 10, 15, 20, 30, 40 and 50 m downwind.

Figure 44. Template for counting droplets on sampling surfaces.

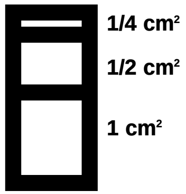


Figure 45. Graph axes for drawing sprayer deposition profile.

Figure 46. Layout of data template for droplet counting.

Distance downwind (m)	Area used (1/4, 1/2 or 1 cm²)	Number of drops (four counts)				Average number of drops	Average number of drops per cm²

Procedure for measuring swath width

Step 1. Find the direction of the wind and, using flags, mark out a spray line at right angles (90 degrees) to the wind direction. The length of this spray line should be at least the intended length of the line of samplers.

Step 2. Put out a line of sampling sticks running downwind from the spray line as described above.

Step 3. Attach a piece of oil-sensitive paper in a vertical position, facing upwind near the top of each of the sticks, using sticky gum or glue. Care must be taken with this paper because it can easily be marked if handled roughly and fingerprints can make counting drops difficult. Handle the paper only by the ends of the strips and do not touch the middle.

Step 4. Spray along the spray line using the normal sprayer height and forward speed. Measure the wind speed, wind direction, temperature and humidity during spraying. Record the sprayer settings for flow rate and for droplet size.

Step 5. Collect the papers, label them with their downwind distance from the spray line and stick them on to a sheet of A4 paper. Do not allow anything to touch the surface of the papers as the drops may get smudged and be difficult to count. Analyse the papers as soon as possible after exposure since the marks from some pesticides fade quickly after impact.

Step 6. Use a counting template as shown in Fig. 44 to count the number of drops on the papers. If there are many drops, count the number seen in the 0.25 cm² window and multiply by four to give the number of drops/cm². If there are very few drops, use the 1 cm² template and no mathematical correction is necessary to give number of drops/cm². Record these data in a table (see Fig. 46).

Step 7. Plot a graph of the number of drops/cm² (on the vertical or y axis) against distance downwind (on the horizontal or x axis) (see Fig. 45).

Tip: equipment required for setting flow rate of ULV sprayers:

- ***notebook***
- ***pen***
- ***stop watch or watch with a second hand***
- ***measuring cylinder [1]***
- ***bucket***
- ***protective clothing***
- ***soap and water***
- ***sprayer***
- ***plastic bags to put over aircraft atomizers***
- ***insecticide with label***

[1] ***100 ml, 500 ml or 2 litres depending on the type of sprayer***

2.5 MEASURING FLOW RATE ON AIRCRAFT

Measuring the flow rate from an aircraft is much easier if the spray system is fitted with an electric pump. In this case, the flow rate can be checked by using the collection technique i.e. measuring the amount of liquid emitted over a timed period with the aircraft on the ground (see the Control guideline for tips).

Aircraft with windmill-driven pumps cannot usually develop sufficient pump pressure while they are on the ground so they have to be calibrated in flight by using the loss technique (see the Control guideline). Accurate flow-rate checks can only be carried out with the pesticide itself. If pesticide is used, efforts should be made to make productive use of it by carrying out the calibration over locust targets. If this is not possible, the calibration spraying should be carried out at altitudes of over 1 000 m to reduce the risk to humans, livestock and the environment on the ground. If calibration is carried out with water, diesel fuel or other liquid, different flow rates will be obtained and these figures can only be converted to pesticide flow rate if a correction factor has previously been established.

The procedure for aircraft flow-rate measurement in flight is as follows:

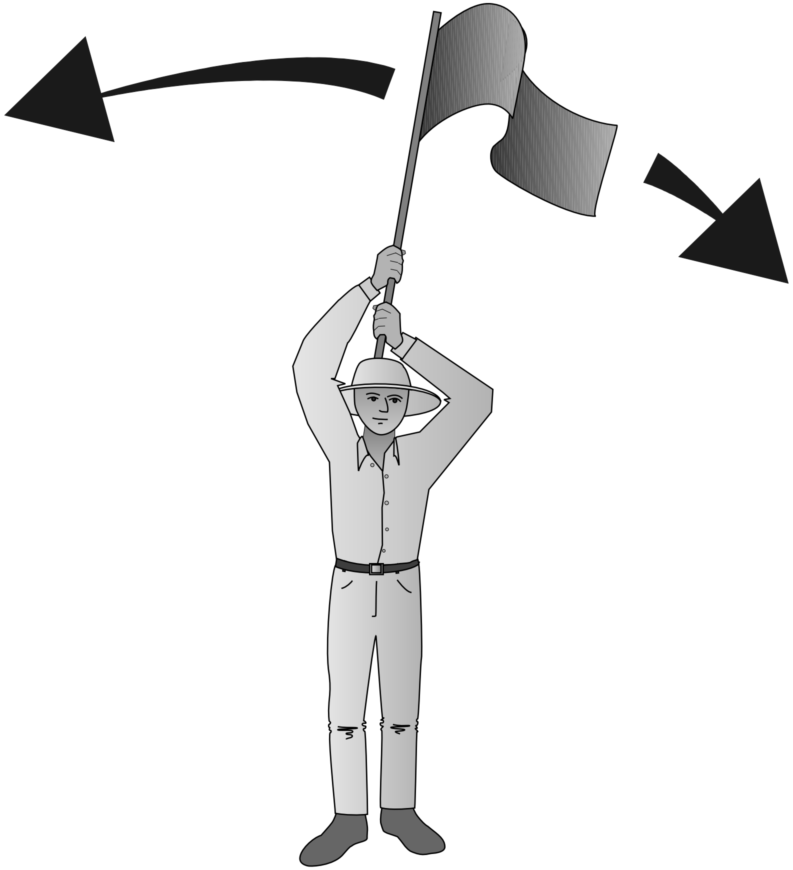
Step 1. *Calculate the desired flow rate from the aircraft*
Calculate the volume of pesticide that should be emitted per minute in order to apply the correct dose (see the Control guideline).

Step 2. *Set the approximate flow rate*
Use the sprayer manufacturer’s literature to set the flow rate. This will be an initial setting based on tables in the user’s handbook.

Step 3. *Prime the pipework in the spraying system*
The pipework in an aircraft spray system can contain up to 30 litres of liquid so it is important to ensure that the pipes are full before trying to measure the flow rate. Put around 50 litres of spray liquid (see notes above) into the spray tank. Take off and spray, but switch off the spray and land as soon as the pump pressure begins to fall.

Step 4. *Measure the flow rate*
Put the volume of spray liquid that should be emitted per minute into the spray tank. Take off, start spraying and use a stop watch to record the time taken before the pump pressure begins to fall again, i.e. how long it takes to spray the amount put in. The time taken should be exactly one minute. If there is more than a 5 percent difference from this, the flow rate should be adjusted and checks repeated until there is less than a 5 percent error.

Figure 47. The flag person should hold the flag high in the air and wave it quickly from side to side so that the pilot can easily see it from the air.



2.6 GROUND TEAM PROCEDURES DURING AERIAL SPRAYING

(if in-flight track guidance instrumentation is not available)

The job of the ground team is very important. It must give support and guidance to the pilot so that he can do a safe and efficient spray job. Ideally the ground team would have two vehicles, GPS, vehicle HF radio (for communicating with the locust base and airstrip), VHF radio (for communicating with the flying aircraft), large flags, signalling mirrors, compass, anemometer and whirling hygrometer.

If a swarm or block of bands has been found by the survey team and a GPS reading taken (or a good description given) of its exact position, the basic procedure for the ground team is:

- Step 1. Go to the target before the aircraft has taken off. If long-range radio communication is available, send a message to the airstrip confirming that the target is still at the given location and that meteorological conditions are suitable for spraying.
- Step 2. Drive around the target, marking with a GPS the corners of the target.
- Step 3. Determine the wind direction and go to the downwind edge of the target.
- Step 4. Give some indication of the wind direction for the benefit of the pilot. This can be done by lighting a smoky fire with tyres or wood and fresh vegetation, or by positioning a vehicle facing into the wind (agree on this with the pilot beforehand).
- Step 5. Position flag people at the ends of the first spray track at the downwind edge of the target (see Fig. 47).
- Step 6. When the aircraft arrives, if communication is possible by radio with the pilot, communicate the bearing of the wind direction, the size of the target and confirm that the ground party is ready for the spraying to start.
- Step 7. The two flag people should wave their flags in the air at the ends of the first spray line. Remember, flags always look very small from the aircraft so they should be held high and moved quickly from side to side, making sure that the cloth does not get tangled around the pole. When the aircraft is about 100 m away from any of these flag people and the pilot has obviously seen the flag, the flagman should move quickly upwind to avoid being sprayed.
- Step 8. As soon as the aircraft has passed the first flag, the person should pace out (or drive and measure on the vehicle odometer) 100 m track spacing upwind and get into the next position.
- Step 9. When the aircraft has passed the second flag, this person should move quickly on foot or by vehicle 100 m upwind to mark the start of the second spray track. This marking should continue until the end of the spray block.
- Step 10. If radio communication is possible, give the pilot feedback on any problems, e.g. flying height, navigation, changing weather conditions.
- Step 11. When the spray block has been completed, the flag people should roll up their flags and keep them low so that the pilot knows that the job is done.
- Step 12. Collect any marker flags left in the field, put out any fires and return to base or to the next spray target.

Recommendations on aerial spraying equipment

All aircraft carrying out ULV locust spraying should be fitted with:

- Micronair AU5000 rotary atomizers to provide a narrow droplet spectrum. User's handbooks should also be available for engineers and locust staff assisting with calibration;
- an electrically powered pesticide pump, since windmill-driven pumps make calibration difficult;
- a flow meter – once it has been calibrated it is a quick way to monitor flow rate and total volume used;
- an application monitor with mini-printer (linked to the flow meter) to record and print out date, time, spray duration and pesticide volume used;
- a tachometer on at least one of the atomizers to measure the rotational speed. This should also be linked to the application monitor and will give an indirect check and record of droplet size;
- a global positioning system (GPS) with flow metre and track guidance equipment including lightbar in order to guide the pilot. The system should include a datalogger to provide a record (trace) of the path of the aircraft. It must have a demonstrated position accuracy of 10 m or better 95 percent of the time and a velocity accuracy of 95 percent. Differential GPS units can provide this accuracy and conventional GPS units may now also be sufficiently accurate although field validation is still underway. Such a system will allow checking of parameters such as volume applied and track spacing. The data should be downloadable in some form, either floppy disk or computer card, so that it can be put into an archive of control information[1];
- a spray system which is linked to the GPS track logging equipment so that there is an indication of the trace where spraying was taking place and where not;
- An audible warning system which is triggered by proximity to exclusion zones (coordinates previously entered);
- VHF radios (in addition to any other standard radio equipment) so that suitably equipped ground teams can communicate with the aircraft;
- a first-aid kit containing supplies with which to treat any cases of pesticide poisoning among aircrew or ground-support staff.

[1] *All spray information from aircraft should be given to the National Locust Unit at the end of each spray day*.

2.7 PILOT AND ENGINEER BRIEFING FOR AERIAL SPRAYING

Instructions to pilots and engineers involved in aerial spraying of locusts using the ULV technique

You will receive a briefing from a senior PPD staff member before you carry out any locust control spraying. The briefing will be based on the Control guideline and on the accumulated experience of the National Locust Unit. This summary sheet is being distributed to all pilots and engineers for their reference during control operations. If there are any points you do not understand, or instructions you do not agree with, discuss with PPD staff during the briefing and BEFORE any spraying is carried out.

Operational instructions

Most Desert Locust control uses ultra low volume (ULV) insecticide formulations applied by aircraft. The success of any large campaign depends on carrying out this aerial spraying efficiently and effectively. ULV spraying uses a different technique from normal crop spraying in that it uses widely spaced crosswind spray runs, relying on the wind to spread the pesticide and overlap the swaths. Unless the correct technique and equipment settings are used, the campaign may be a failure and/or large quantities of pesticide will be wasted, resulting in financial loss and unnecessary risk of environmental damage.

It is important that the pilot and engineer understand how the National Locust Unit requires them to carry out the control operation. These notes summarise the technique and equipment settings required to spray locusts with ULV insecticide in a safe and effective way. Discuss the sprayer settings and techniques with a Locust Field Officer before operations start so that everyone is in agreement on how things should be done.

Size of target

ULV spraying is a drift technique for use over relatively large targets (>25 ha). Spot treatment of small areas by aerial ULV spraying is not possible without wastage of pesticide. Small targets should be treated from the ground using vehicle-mounted or handheld equipment.

Application technique

Weather conditions

ULV spraying requires a steady wind of at least 2 m/s at 2 m height from the ground otherwise the spray will not be carried far enough across the swath to give an even cover. It also requires the relatively cool weather of morning or late afternoon spraying because upward currents of hot air (convection) can remove the spray from the target area. In practice this usually means that ULV spraying can only be carried out between 0800 and 1100 hours and possibly between 1600 and 1800 hours, although these times may vary according to country and weather conditions. In the absence of a ground team to give the go-ahead, the pilot must use his own judgement.

Flight pattern

Always start at the downwind edge of the target area, fly crosswind, i.e. at 90 degrees to the wind direction, and move upwind at the end of every spray pass. Use a track spacing of 100 m as standard. If the wind is very light, this can be reduced to half i.e. 50 m, but the flow rate must then also be adjusted to half the standard figure to keep the same volume application rate and dosage. If the aircraft is not fitted with a suitable GPS track guidance system, a ground party with flags and/or materials for making smoke should be used to help the pilot locate the target and to mark the correct track spacing. Even if the aircraft has GPS track guidance, a ground party should be present to help delimit the target and check on spray performance and efficacy.

Flying height

Unless otherwise instructed, fly at a height of between 5 and 15 m. At less than 5 m the pesticide is not carried over a wide enough swath and over 15 m it may be carried out of the target area as drift. Higher flying may be required for some specialized treatments such as barrier or swarm spraying, but in these cases specific instructions will be given.

Speed

Flying speed should be around 100 mph (160 km/h) where possible.

Equipment settings

Blade angles

Micronair atomizers should be set to give a volume median diameter droplet size of around 75-100 µm. This means that an AU4000 should spin at around 7 000 rpm and an AU5000 at around 8 000 rpm. Assuming an air speed of around 100 mph and standard blades, this means setting the blade angles to 35 degrees for the AU4000 and 40 degrees for the AU5000. If it is not possible to achieve an air speed of 100 mph, consult the manufacturer's Operator's Handbook, copies of which are with the PPD Director, and arrange for a supply of longer blades designed for slower fixed-wing aircraft and helicopters. If airspeed is greater than 100 mph consult the manufacturer's handbook to determine how much blade angles should be increased to achieve the right droplet size.

Flow rate

Flow rate must be set so that at the chosen track spacing and speed, the FAO recommended dose of insecticide for Desert Locusts is applied. To calculate this, use the formulae on the next page.

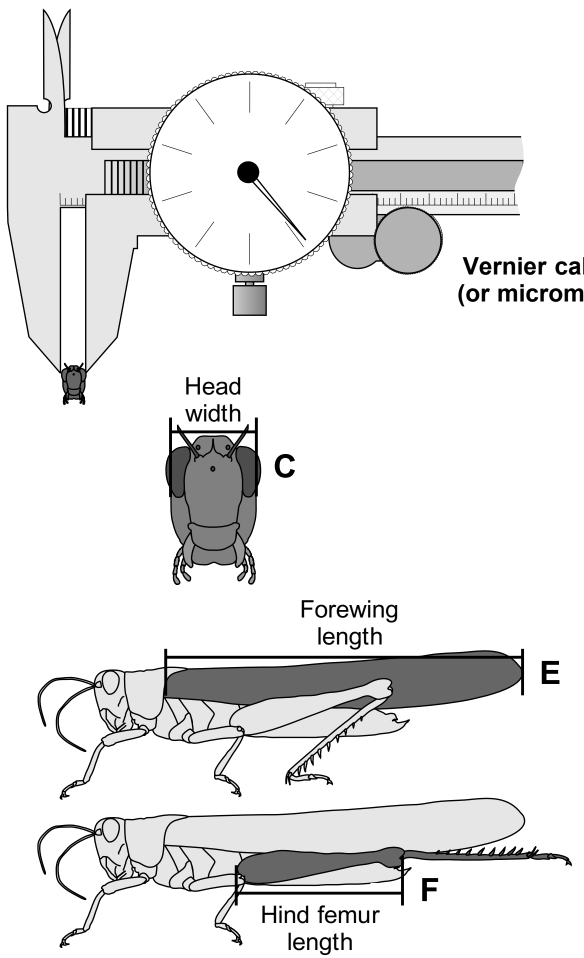
$$\text{Required VAR (l/ha)} = \frac{\text{recommended dose (g a.i./ha)}}{\text{formulation concentration (g a.i./l)}} \qquad \textit{Formula 1}$$

$$\text{Flow rate (l/min)} = \frac{\text{VAR (l/ha) x speed (km/h) x track (m)}}{600} \qquad \textit{Formula 2}$$

Monitoring/reporting

Complete a copy of the FAO Spray Monitoring Form at the end of every spraying and submit to the Locust Unit ground staff so that there is a record of how the control was carried out (see Appendix 4.2 for the form).

Figure 48. Use an accurate tool to measure the width of the head, the length of the forewing, and the length of the hind femur of the rear leg.



! **The value of such measurements is limited because of the influence of factors other than density, such as environmental conditions. Morphometrics can demonstrate the development of an upsurge if samples are available from each generation. A gregariform individual may suggest the recent presence of swarms in the area.**

2.8 MEASURING DESERT LOCUSTS

There is a progressive difference in shape from the extreme solitariform to the extreme gregariform in the Desert Locust. Phase characteristics can be determined by measuring different parts of the locust: the width of the head (or caput), the forewing (elytron), and the femur of the rear leg (see Fig. 48). The ratios are different for males and females and can be influenced by temperature.

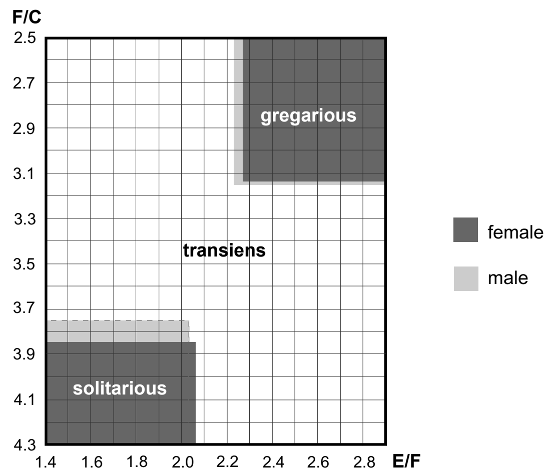
Methods for determining phase characteristics of the Desert Locust

1. Measure the elytron, femur and caput of an adult male and female locust with a micrometer.
2. Use the resulting values in any one of the following ratios to determine the phase of the locust:

Ratio 1	**Solitarious**		**Gregarious**	
	males	**females**	**males**	**females**
F / C	>3.750	>3.850	<3.150	<3.150
E / F	<2.025	<2.075	>2.225	>2.272

Ratio 2	**Solitarious**	**Gregarious**
female E / male E	1.17 – 1.24	1.07 – 1.12

< indicates less than, > indicates greater than
E = elytron (forewing)   C = caput (head)   F = femur (third segment of rear leg)



2.9 SUGGESTED DUTIES OF LOCUST STAFF

Headquarters posts

Locust Unit Head

- overall responsibility for the national locust programme including monitoring, control and training
- maintains regular contact with neighbouring affected countries, regional organizations, FAO and donors
- advises government regarding current locust situation and possible developments

Senior Field Officer / Campaign Officer-in-Charge

- overall technical supervision and management of survey and control
- responsible for control campaigns during upsurges and plagues
- deploys equipment and staff to the field based on advice from the Locust Information Officer
- attends daily radio schedules to review the progress of survey and control

Locust Information Officer

- manages locust and environmental data received from the field and other sources
- registers, corrects and enters data into a database and plot on maps
- analyses locust and environmental information
- summarizes the current situation and forecasts locust breeding and migration
- advises Locust Unit Head about areas that require survey and control
- prepares regular summaries and reports
- keeps FAO informed of the situation in a timely manner and on a regular basis
- stores and archives all data received
- during campaigns: maintains records of pesticide and fuel stocks, positions of aircraft and vehicles and maps of infestations and targets treated

Field posts

Officer-in-Charge of field base (survey and control)

- maintains a map of locust reports and infestations treated
- deploys survey and control teams to the most important areas
- ensures supply of fuel, pesticide, spares and protective clothing for teams
- monitors all spraying operations by collation of data from spray monitoring forms
- prepares regular summary reports on control operations for headquarters
- during upsurges and plagues:
  - is answerable to the Officer-in-Charge of the campaign
  - holds daily briefings with field staff and pilots
  - supervises aircraft reloading operations
  - keeps in close contact with headquarters by radio, fax or telephone at least once a day

Field Supervisor (control)

- supervises calibration of equipment
- directs control operations
- ensures safety of staff, environment and equipment
- communicates with pilots by radio
- communicates with Locust Base by regular radio schedules
- organises disposal of empty pesticide containers
- completes spray monitoring forms and submits them to the Officer-in-Charge of the field base
- transmits information by radio at least once a day

Locust Field Officer (survey and control)

- undertakes surveys to assess locust and habitat conditions
- gathers information from local sources
- completes the FAO Desert Locust Survey and Control Form and the FAO Spray Monitoring Form
- identifies possible control targets and advises on suitable control method
- operates ground sprayers according to instructions
- cleans the sprayer after use and checks if any spares/repairs are required
- transmits information by radio at least once a day

Driver and Aircraft Pilot (control)

- checks that sprayer is in good working order
- fills the sprayer
- calibrates the sprayer (with supervision)
- operates the sprayer according to instructions
- cleans the sprayer after use and checks if any spares/repairs are required

Driver (survey)

- assists officers in ground surveys
- ensures the vehicle is in good operating condition
- checks if any spares/repairs are required

Workshop Mechanic/Engineer (ground or aircraft)

- prepares radios, GPS and spraying equipment for use
- assists with calibration where possible
- checks, maintains and repairs equipment as required

Appendix 3

Locust pesticides

3.1 LOCUST PESTICIDE DOSE RATES

Dose rates and speed of action of different insecticides for which verified dose rates have been established for the Desert Locust

		Dose (g a.i./ha) treatment				Speed of action [3]
		overall (blanket)		barrier (hoppers)		
Insecticide	**Class [1]**	**hoppers**	**adults**	**within**	**overall [2]**	
bendiocarb	CA	100	100			F
chlorpyrifos	OP	225	225			M
deltamethrin	PY	12.5 [4]	12.5			F
diflubenzuron	BU	60	n.a. [5]	100	5	S
fenitrothion	OP	450	450			M
fipronil	PP	4	4	12.5	0.6	M
lambda-cyhalothrin [6]	PY	20 [4]	20			F
malathion	OP	925	925			M
***Metarhizium anisopliae* [7]**	fungus	100	100			S
teflubenzuron	BU	30	n.a.	n.d. [8]		S
triflumuron	BU	25	n.a.	75	3.7	S

(Source: 8th meeting of Pesticide Referee Group, 1999)

Notes:

1. *BU: benzoylurea, CA: carbamate, OP: organophosphate, PY: pyrethroid, PP: phenyl pyrazole.*
2. *Calculated dose rate applied over the total protected area based on an average barrier width of 50 m and a track spacing of 1 000 m.*
3. *F = fast (1-2 hours), M = moderate (3-48 hours), S = slow (> 48 hours).*
4. *A higher rate may be required for the last instar.*
5. *n.a. = not applicable*
6. *Where the "lambda" isomer is not registered in a country, cyhalothrin is applied at 40 g a.i./ha.*
7. *IMI 330189.*
8. *n.d. = not determined.*

3.2 RISK TO NON-TARGET ORGANISMS

(at verified dose rates against Desert Locusts)

	Environmental risk [a]								
	Aquatic organisms		Terrestrial vertebrates			Terrestrial non-target arthropods			WHO [b]
	fish	arthropods	mammals	birds	reptiles	bees	antagonists	soil insects	
bendiocarb	M[2]	L[3]	M[1]	L[3]	-	H[1]	H[2]	M[3]	II
chlorpyrifos	M[3]	H[2]	L[3]	M[3]	M[3]	H[1]	H[3]	-	II
deltamethrin	L[3]	H[3]	L[1]	L[3]	L[3]	M[1]	M[3]	M[3]	II
diflubenzuron (blanket)	L[3]	H[3]	L[1]	L[1]	-	L[1c]	M[2]	M[3]	U
diflubenzuron (barrier) [d]	L	(H)	L	L	-	L[c]	L[3]	(M)	U
fenitrothion	L[3]	M[3]	L[3]	M[3]	-	H[1]	H[3]	H[3]	II
fipronil (blanket)	L[2]	L[2]	L[1]	L[1]	-	H[1]	H[3]	H[3]	U
fipronil (barrier) [d]	L	L	L	L	-	(H)	(H)	(H)	U
imidacloprid [e]	L[1]	L[1]	L[1]	L[1]	-	H[1]	L[3]	L[3]	II
lambda-cyhalothrin	L[2]	H[2]	L[1]	L[1]	-	M[1]	M[3]	H[2]	II
malathion	L[2]	M[2]	L[3]	L[3]	-	H[3]	H[3]	H[3]	III
Metarhizium anisopliae [g]	L[2]	L[2]	L[1]	L[1]	L[2]	L[3]	L[3]	L[3]	U
teflubenzuron (blanket)	L[1]	H[2]	L[1]	L[1]	-	L[1f]	M[1]	-	U
triflumuron (blanket)	L[1]	H[2]	L[1]	L[1]	L[3]	L[1f]	L[3]	L[3]	U
triflumuron (barrier) [d]	L	(H)	L	L	-	L[1f]	L	L	U

(Source: 8th meeting of Pesticide Referee Group, 1999)

Notes:

a. Environmental risk classification (L=low, M=medium, H=high) describes the level of availability of data based on:
1. Laboratory and registration data with species that do not occur in locust areas.
2. Laboratory data or small-scale field trials with indigenous species from locust areas.
3. Large scale field trials and operational data from locust areas (mainly Desert Locust, but also Migratory and Brown Locust).

b. WHO toxicity class (human) for active ingredient: II = moderately hazardous, III = slightly hazardous, U = unlikely to present acute hazard in normal use. The actual WHO toxicity class of the formulated insecticide may differ slightly from the one given here due to the effect of the solvents, or when lower formulation concentrations are used.

c. At normal use, diflubenzuron is not harmful to the brood of honey bee.

d. Extrapolated from blanket treatments but is expected to be considerably lower if at least 50 percent of the area remains uncontaminated and if barriers are not sprayed over surface water. Risk classes are shown in brackets unless the blanket treatment was already considered to pose low risk, and no reference is made to the level of data availability. More field data are needed to confirm that products posing a medium or high risk as blanket sprays can be downgraded to low when applied as barrier sprays.

e. Field data only available from the Madagascar Migratory Locust area.

f. Benzoylureas are safe to adult worker bees but some may cause damage to the brood of exposed colonies.

g. IMI330189.

Figure 49. FAO pictograms.

3.3 WHO HAZARD CLASSES AND PICTOGRAMS

World Health Organization Classification of Pesticides by Hazard

Class		LD50 for rat (mg/kg body weight)			
		Oral		Dermal	
		Solids [1]	Liquids [1]	Solids [1]	Liquids [1]
Ia	Extremely hazardous	5 or less	20 or less	10 or less	40 or less
Ib	Highly hazardous	5-50	20-200	10-100	40-400
II	Moderately hazardous	50-500	200-2 000	100-1 000	400-4 000
III	Slightly hazardous	over 500	over 2 000	over 1 000	over 4 000
IV	Unlikely to cause acute hazard [2]	over 2 000	over 3 000		

[1] *The terms “solids” and “liquids” refer to the physical state of the product or formulation being classified.*

[2] *Although the active ingredients falling into this category present a negligible hazard, it should not be forgotten that the solvents or other non-pesticidal components of the formulation may present a greater hazard than the pesticide itself. It may be necessary to classify the formulation in a higher hazard class.*

The above table deals only with active ingredients, but the concentration of the formulation plays a big part in the hazard the product presents. For example, some moderately hazardous pesticides are used in very low concentrations and the hazard classification of their formulation is reduced to slightly hazardous. The formula below can be used to calculate hazard classification of formulations:

$$\text{Formulation LD50} = \frac{\text{LD50 of active ingredient x 100}}{\text{Percentage of active ingredient in formulation}}$$

Pictograms are symbols that convey a message without the use of words. You may see these on pesticide drums. Their meanings are given in Fig. 49. They can help to convey messages about the toxicity of products and the precautions that must be taken and they can be assembled into a series of instructions. For example, for a product that is relatively safe, the pictograms on the label might be as below:

If you feel ill

1. If you have a headache, blurred vision, or you feel dizzy or sick, stop working and see a doctor as soon as possible.

If someone's skin is contaminated

1. Remove clothing wet with pesticide.

2. Thoroughly wash pesticide off skin with soap and water. Eyes need gentle washing for a long time with clean water.

If pesticide has been swallowed

1. Do not induce vomiting – some pesticides are caustic and can burn the lungs.

What to do next

1. If someone is affected by pesticide poisoning, keep them calm and cool while you immediately call a doctor or take them to a doctor. If they feel well enough, they should drink water.

2. If they are not conscious lie them on their side with their head back until the doctor comes. Do not induce vomiting. Artificial respiration will be needed if they stop breathing, but make sure you do not become contaminated yourself from any pesticide on their face.

3. Show doctors the pesticide label so that they can give the correct medical treatment.

Tip: learn artificial respiration first aid technique but be careful when using it on people who have ingested pesticide.

3.4 PREVENTION AND TREATMENT OF PESTICIDE POISONING

Pesticides can be dangerous. They can cause immediate sickness from a large dose (acute effects) or can cause slow sickness resulting from small doses over a long period (chronic effects).

Avoid problems

1. Wear appropriate protective clothing.

2. Avoid all skin contact with pesticide and do not breath the vapour.

3. Have soap and water ready in case you are splashed.

4. When filling or spraying, stand upwind, so drops are carried away from you.

5. If nozzles block, do not blow through them with your mouth. Use a needle or a plant stem to clear the blockage (wear protective gloves).

6. Do not eat, drink or smoke when using pesticides.

7. Keep clearly labelled pesticide containers away from children – they may play with them or drink from them.

8. Never pour pesticide into drinks bottles – someone may drink them accidentally.

9. Always wash hands and face after spraying, and wash protective clothing regularly to prevent build up of pesticide residues that might be transferred to the skin.

! **Many spills occur while the sprayer is being filled.**

Appendix 4

FAO forms

Always carry this form with you when making Desert Locust surveys. Results from survey and control operations should be entered on the form, even if no locusts were found. Use a separate column for each survey stop; the first stop in the first column and so on. There are enough columns on this form for six stops. Use more forms as necessary.

FAO DESERT LOCUST SURVEY AND CONTROL FORM INSTRUCTIONS

1	**SURVEY STOP**	
1-1	date	write the day / month / year of the survey
1-2	name	write the local name of where you have stopped (? = name unknown)
1-3	latitude (N)	degrees / minutes / seconds North; use a GPS
1-4	longitude (E or W)	degrees / minutes / seconds West or East; use a GPS
2	**ECOLOGY**	
2-1	area (ha) of survey	estimated area of survey at the stop in ha (this can be based on the estimated area of green vegetation at the site)
2-2	habitat (wadi, plains, dunes, crops)	describe the site of the survey stop (wadi, plains, dunes, crops, etc.)
2-3	date of last rain	write day / month / year (if known), or estimate (i.e. 2 days, 3 months, etc), or ? if unknown
2-4	rain amount (mm, Low Moderate High, ?)	exact (mm), or circle L for low (1-20 mm), M for moderate (21-50 mm), H for heavy (50+ mm), ? if unknown
2-5	vegetation (dry, greening, green, drying)	write **dry**, **greening** (becoming green), **green** (already green), **drying** (becoming dry)
2-6	vegetation density (Low Medium Dense)	circle L for low (more bare ground than vegetation), M for medium (same amount of bare ground and vegetation), D for dense (more vegetation than bare ground)
2-7	soil moisture (wet/dry)	circle W for wet (if the soil is moist to about 10-15 cm), D for dry
3	**LOCUSTS**	
3-1	present or absent	cirlce P if any stage of locusts are present or A if locusts are absent
3-2	area infested (ha)	write the estimated number of hectares that contain locusts at the survey stop
4	**HOPPERS**	**(if individual hoppers or groups are present, indicate the details)**
4-1	hopper stages (H123456F)	circle which instars (**1,2,3,4,5,6**), hatchlings (H) or fledglings (F) are present
4-2	appearance (solitary, transiens, gregarious)	circle S for solitary (green colour), T for transiens (green/black), G for gregarious (black or yellow/black)
4-3	behaviour (isolated, scattered, groups)	circle I for isolated (individual hoppers), S for scattered (several hoppers), G for groups (clumping together)
4-4	hopper density (/site, $/m^2$, Low Med High)	examine at least 10 samples of 1 m^2 each (or 10 bushes), record the lowest & highest number seen in one sample; or if you make a rough estimate, circle L for low, M for medium, H for high
5	**BANDS**	**(if hopper bands are present, indicate the details)**
5-1	band stage (H12345F)	circle which instars (**1,2,3,4,5**), hatchlings (H) or fledglings (F) are present
5-2	band density ($/m^2$ or Low Medium High)	number of hoppers per bush or m^2, or write L for low (more bare ground or vegetation visible than band), M for medium (same amount of bare ground and band), D for dense (more band than bare ground); (EX: $30/m^2$)
5-3	band sizes (m^2 or ha)	write the estimated size of band in m^2, or indicate the minimum and maximum sizes
5-4	number of bands	write the number of bands present at the survey site
6	**ADULTS**	**(if individual adults or groups are present, indicate the details)**
6-1	maturity (immature, mature)	circle I for immature, M for mature, or both; estimate the percent of each maturity & note in the Comments
6-2	appearance (solitary, transiens, gregarious)	circle S for solitary (brown), T for transiens (brown/pink or brown/yellow), G for gregarious (pink or yellow)
6-3	behaviour (isolated, scattered, groups)	circle I for isolated (individual hoppers), S for scattered (several hoppers), G for groups (clumping together)
6-4	adult density (/transect, /ha, L M H)	count the number of adults when walking 250-400 m (and indicate the length and width of the foot transect); or estimate adult numbers per ha (EX: $4/1000m^2$ or 20/ha); or circle L for low, M for medium, H for high
6-5	breeding (copulating, laying)	circle C for copulating, L for laying
7	**SWARMS**	**(if swarms are present, indicate the details)**
7-1	maturity (immature, mature)	circle I for immature, M for mature, or both; estimate the percent of each maturity & note in the Comments
7-2	swarm density ($/m^2$ or Low Medium High)	number of adults per bush or m^2, or write L for low (more bare ground or vegetation visible than swarm), M for medium (same amount of bare ground and swarm), D for dense (more swarm than bare ground)
7-3	swarm size (km^2 or ha)	write the estimated size of the swarm in km^2 or ha
7-4	number of swarms	write the number of swarms present at the survey site
7-5	breeding (copulating, laying)	circle C for copulating, L for laying
7-6	flying (direction, time passing)	the direction swarms are flying FROM and TO, the time (hours, minutes) that they took to pass overhead
7-7	flying height (Low Medium High)	estimate height of flight, or write L for low (1-100 m), M for medium (100-500 m), H for high (500+ m)
8	**CONTROL**	**(if control was carried out, indicate the details)**
8-1	pesticide name & formulation	write for example MAL for Malathion, FEN for fenitrothion, etc., and formulation (ULV, EC, dust, bait)
8-2	application rate (l/ha or kg/ha))	write the number of litres or kg used per hectare
8-3	quantity (l)	write the total number of litres or kg used
8-4	area treated (ha)	write the total number of hectares sprayed
8-5	ground or air	circle G for ground of A for aerial control
8-6	estimated % kill	estimate the number of locusts killed out of 100. Examine several 1 m^2 samples
9	**COMMENTS**	**(write any other information that is not indicated above)**
		Write important information that could not be indicated above. For example, if there were more of one type of locusts present than another type (e.g. more transiens than solitary or more 5th instar hoppers than 2nd), or if you tried to estimate the percent of immature and mature adults present, or if crops are present, or what the ecology between survey stops, or unconfirmed reports from nomads, etc., or if you know the time of swarm departure or arrival, or if it was a ground or aerial survey.

lce 99.03

Was a GPS used to determine locations? Circle: Yes or No Is a brief interpretation or analysis of the results included? Circle: Yes or No

Country: Your Country Name Locust Officer : Name of person who made survey date : completed

cleared by : Name of authorizing person date : approved

FAO DESERT LOCUST SURVEY AND CONTROL FORM

page ______ of ______

please send to FAO HQ by fax (+39-06-57055271) or email (eclo@fao.org)

(indicate appropriate information as required)

1	**SURVEY STOP**	**1**	**2**	**3**	**4**	**5**	**6**
1-1	date						
1-2	name						
1-3	latitude (N)						
1-4	longitude (E or W)						
2	**ECOLOGY**						
2-1	area (ha) of survey						
2-2	habitat (wadi, plains, dunes, crops)						
2-3	date of last rain						
2-4	rain amount (mm, Low Moderate High, ?)	L M H ?	L M H ?	L M H ?	L M H ?	L M H ?	L M H ?
2-5	vegetation (dry, greening, green, drying)						
2-6	vegetation density (Low Medium Dense)	L M D	L M D	L M D	L M D	L M D	L M D
2-7	soil moisture (wet/dry)	W D	W D	W D	W D	W D	W D
3	**LOCUSTS**						
3-1	present or absent	P A	P A	P A	P A	P A	P A
3-2	area infested (ha)						
4	**HOPPERS**						
4-1	hopper stages (H123456F)	H 1 2 3 4 5 6 F	H 1 2 3 4 5 6 F	H 1 2 3 4 5 6 F	H 1 2 3 4 5 6 F	H 1 2 3 4 5 6 F	H 1 2 3 4 5 6 F
4-2	appearance (solitary, transiens, gregarious)	S T G	S T G	S T G	S T G	S T G	S T G
4-3	behaviour (isolated, scattered, groups)	I S G	I S G	I S G	I S G	I S G	I S G
4-4	hopper density (/site, /m2, Low Med High)						
5	**BANDS**						
5-1	band stage (H12345F)	H 1 2 3 4 5 F	H 1 2 3 4 5 F	H 1 2 3 4 5 F	H 1 2 3 4 5 F	H 1 2 3 4 5 F	H 1 2 3 4 5 F
5-2	band density (/m2 or Low Medium High)						
5-3	band sizes (m2 or ha)						
5-4	number of bands						
6	**ADULTS**						
6-1	maturity (immature, mature)	I M	I M	I M	I M	I M	I M
6-2	appearance (solitary, transiens, gregarious)	S T G	S T G	S T G	S T G	S T G	S T G
6-3	behaviour (isolated, scattered, groups)	I S G	I S G	I S G	I S G	I S G	I S G
6-4	adult density (/transect, /ha, L M H)						
6-5	breeding (copulating, laying)	C L	C L	C L	C L	C L	C L
7	**SWARMS**						
7-1	maturity (immature, mature)	I M	I M	I M	I M	I M	I M
7-2	swarm density (/m2 or Low Medium High)						
7-3	swarm size (km2 or ha)						
7-4	number of swarms						
7-5	breeding (copulating, laying)	C L	C L	C L	C L	C L	C L
7-6	flying (direction, time passing)						
7-7	flying height (Low Medium High)	L M H	L M H	L M H	L M H	L M H	L M H
8	**CONTROL**						
8-1	pesticide name & formulation						
8-2	application rate (l/ha or kg/ha))						
8-3	quantity (l)						
8-4	area treated (ha)						
8-5	ground or air	G A	G A	G A	G A	G A	G A
8-6	estimated % kill						
9	**COMMENTS**						

lce 99.03

Was a GPS used to determine locations? yes no Is a brief interpretation or analysis of the results included? yes no

Country: ________________ Locust Officer : ________________ date : ________

cleared by : ________________ date : ________

Send completed forms to FAO DLIS by e-mail (eclo@fao.org) or fax (+39 06 570 55271) **within 48 hours** of the end of the survey. A short paragraph should be attached indicating what the results mean.

Always carry this form with you to record control details. Use this form in combination with the FAO Survey and Control Form. Each column represents a control location and should match the information in the same column on the survey form. Submit both forms to the National Locust Unit headquarters.

FAO SPRAY MONITORING FORM INSTRUCTIONS

1	CONTROL LOCATION	
1-1	date	Write the day / month / year of the control operation
1-2	name (from DL Survey Form)	Write the local name of where you made the control (**?** = name unknown). This should match the name in the same column on the Survey and Control Form.
2	**VEGETATION DATA**	
2-1	vegetation type (Grass, Bushes, Trees, Crop)	Circle **G** if grass, **B** if bushes, **T** if trees or **C** if crop
2-2	height (m)	Write the approximate or average height (in metres) of the vegetation
2-3	crop names and damage (%)	Write the names of the crops and estimate the percentage of damage; if there are no crops and it is natural vegetation, write Natural.
3	**INSECTICIDE DATA**	
3-1	trade name	Write, for example, SUM for Sumithion and DUR for Dursban, etc.
3-2	concentration (g a.i./l or%)	Write the concentration of the active ingredient in grams/litre or as a percentage
3-3	formulation (EC, ULV, Dust)	Circle **E** if Emulsion Concentrate, **U** if Ultra Low Volume or **D** if Dust formulation was used
3-4	expiry data	Write the expiry date of the insecticide found on the label of the drum
3-5	is insecticide mixed with water or solvent?	Circle **Y** if the insecticide is mixed with water or solvent or **N** if not mixed
3-6	if yes, what solvent and mixing ratio	Write the name of the solvent used for mixing and what ratio was used (insecticde:solvent)
4	**WEATHER CONDITIONS**	
	start and end of control operations:	Write the required weather conditions at the start and the end of the control operations as indicated below
4-1	time	Write the time operations started and the time operations ended
4-2	temperature (°C)	Write the temperature at the time operations started and the temperature at the end of operations, in centigrade (use the dry-bulb reading on a whirling hygrometer)
4-3	relative humidity (%)	Write the relative humidity in percentage at the start and end of operations (use a whirling hygrometer)
4-4	wind speed (m/s)	Write the speed of the wind in meter/second at the start and the end of operations (use a anemometer)
4-5	wind direction (degree from N)	Write the wind direction in degrees from the north at the start and the end of operations (use a compass)
4-6	spray direction (degree from N)	Write the spray direction in degrees from the north at the start and the end of operations (use a compass)
5	**SPRAY APPLICATION**	
5-1	sprayer type	Circle **R** for rotary, **A** for airblast, **E** for exhaust nozzle sprayer (ENS), **H** for hydraulic or **O** for other
5-2	sprayer operator	Circle **P** for pilot, **D** for driver, **L** for locust officer, **H** for hired labor or **O** for other operator
5-3	sprayer manufacturer	Write the name of the sprayer manufacturer or company
5-4	sprayer model	Write the model of the sprayer, for example, Micronair AU8000 or Micronair AU7010
5-5	sprayer platform	Circle **A** for aerial spraying, **V** for vehicle spraying or **H** for handheld sprayer
5-6	date of last calibration	Write the date of the last calibration done on the sprayer used in the control operation
5-7	atomizer height above ground (m)	Write the height (in metres) of the atomizer above the ground
5-8	ROTARY SPRAYERS: speed setting	Write the degree of blade angle for Micronair, pully setting for Ulvamast or no. of batteries for Microulva
5-9	speed of atomizer (rpm)	Write the speed of the atomizer per minute using a vibrating tachometer
5-10	flow rate setting	Write the colour or size of the nozzle, or what orifice or restrictor was used
5-11	flow rate/atomizer (l/min)	Write the flow rate (in litre/minute) for each atomizer used in the control operation
5-12	number of atomizers	Specify the number of atomizers used in the control operation (i.e. the number of atomizers on the aircraft used for control)
5-13	track spacing (m)	Write the track spacing (in metres) used during spraying
5-14	BARRIERS ONLY: width and spacing (m)	Write the spraying width of a barrier and the width in between each barrier not sprayed (in metres)
5-15	forward speed (km/h)	Write the sprayer speed (in km/h). This will be the speed of aircraft, vehicle or walking operator.
5-16	AERIAL SPRAYING: support supplied	Circle **GP** for ground party, **RC** for radio communication or **TG** for DGPS if it is used
5-17	ground marking (GPS, flag, Mirror, smoke, Vehicle, None)	Circle **G** for GPS, **F** for flag, **M** for mirror, **S** for smoke, **V** for vehicle or **N** if no ground marking was used during the control operation
6	**CONTROL EFFICACY**	
6-1	locust mortality (% dead)	Write in figures the estimated percentage of damage caused by locust
6-2	timer after treatment (hours)	Write the time (in hours) after treatment when the mortality estimate was carried out
6-3	method of mortality estimation	Circle **Q** for quadrats, **T** for target size, **V** for visual, **C** for cages or **O** for other methods
7	**SAFETY AND ENVIRONMENT**	
7-1	protective clothing: what did the operator wear	Circle **G** for goggles, **M** for mask, **L** for gloves, **O** for overalls and **B** boots
7-2	was soap and water available?	Circle **Y** if soap and water were available or **N** if they were not available during operations
7-3	who was informed of spraying?	Circle **F** for farmer, **N** for nomad, **V** for village, **O** for officials and **B** for beekeepers
7-4	effect on non-target organisms	Circle **Y** if you noticed an effect on non-locusts in the field after operations or **N** if none
7-5	if yes, what	Write what insects, animals, wildlife etc were affected (killed or sick) by the control operation
7-6	detail if anyone felt unwell or if other problems were encountered:	Write the details if any operators, ground teams or nearby inhabitants felt sick or unwell (i.e. headache, eye or skin irritation, dizziness, vomiting) after control. Write any other problems that were encountered during or after the spraying operations (i.e. broken vehicles, sudden rainfall during or shortly after control).

Equipment required for monitoring spraying: gloves, clipboard, blank copies of this form, pen, anemometer (for wind speed), tachometer (for speed of rotary atomizers), whirling hygrometer (for temperature/humidity), measuring cylinder, bucket, funnel, stop watch, tape measure, compass and GPS.

FAO SPRAY MONITORING FORM

Attach this form to the DL Survey and Control Form and send it to the National Locust Unit in your country whenever control operations are carried out

(indicate appropriate information as required)

1	CONTROL LOCATION	1	2	3	4	5	6
1-1	date						
1-2	name *(from DL Survey Form)*						
2	**VEGETATION DATA**						
2-1	vegetation type (Grass, Bushes, Trees, Crop)	G B T C	G B T C	G B T C	G B T C	G B T C	G B T C
2-2	height (m)						
2-3	crop names and damage (%)						
3	**INSECTICIDE DATA**						
3-1	trade name						
3-2	concentration (g a.i./l or %)						
3-3	formulation (EC, ULV, Dust)	E U D	E U D	E U D	E U D	E U D	E U D
3-4	expiry date						
3-5	is insecticide mixed with water or solvent?	Y N	Y N	Y N	Y N	Y N	Y N
3-6	if yes, what solvent and mixing ratio						
4	**WEATHER CONDITIONS**						
	start and end of control operations:	start end	start end	start end	start end	start end	start end
4-1	time						
4-2	temperature (°C)						
4-3	relative humidity (%)						
4-4	wind speed (m/s)						
4-5	wind direction (degrees from N)						
4-6	spray direction (degrees from N)						
5	**SPRAY APPLICATION**						
5-1	sprayer type (Rotary, Airblast, ENS, Hydraulic, Other)	R A E H O	R A E H O	R A E H O	R A E H O	R A E H O	R A E H O
5-2	sprayer operator (Pilot, Driver, Locust officer, Hired, Other)	P D L H O	P D L H O	P D L H O	P D L H O	P D L H O	P D L H O
5-3	sprayer manufacturer						
5-4	sprayer model						
5-5	sprayer platform (Aerial, Vehicle, Handheld)	A V H	A V H	A V H	A V H	A V H	A V H
5-6	date of last calibration						
5-7	atomizer height above ground (m)						
5-8	ROTARY SPRAYERS: speed setting (blade angle, pulley setting, no. batteries)						
5-9	speed of atomizer (rpm)						
5-10	flow rate setting (which nozzle or restictor used)						
5-11	flow rate/atomizer (l/min)						
5-12	number of atomizers						
5-13	track spacing (m)						
5-14	BARRIERS ONLY: width and spacing (m)						
5-15	forward speed (km/h)						
5-16	AERIAL SPRAYING:	GP = ground party available RC = radio communication with aircraft TG = DGPS track guidance					
	support supplied	GP RC TS	GP RC TS	GP RC TS	GP RC TS	GP RC TS	GP RC TS
5-17	ground marking (GPS, Flag, Mirror, Smoke, Vehicle, None)	G F M S V N	G F M S V N	G F M S V N	G F M S V N	G F M S V N	G F M S V N
6	**CONTROL EFFICACY**						
6-1	locust mortality (% dead)						
6-2	time after treatment (hours)						
6-3	method of mortality estimation (Quadrats, Target size, Visual, Cages, Other)	Q T V C O	Q T V C O	Q T V C O	Q T V C O	Q T V C O	Q T V C O
7	**SAFETY AND ENVIRONMENT**						
7-1	protective clothing:	G = googles M = mask L = gloves O = overalls B = boots					
	what did the operator wear?	G M L O B	G M L O B	G M L O B	G M L O B	G M L O B	G M L O B
7-2	was soap and water available?	Y N	Y N	Y N	Y N	Y N	Y N
7-3	who was informed of spraying? (Farmer, Nomad, Villager, Officials, Beekeeper)	F N V O B	F N V O B	F N V O B	F N V O B	F N V O B	F N V O B
7-4	effect on non-target organisms	Y N	Y N	Y N	Y N	Y N	Y N
7-5	if yes, what						
7-6	details of anyone who felt unwell or if other problems were encountered:						

mb/hd/kc 08.01

The latest versions of the FAO Survey and Control Form and the Spray Monitoring Form are available on the Internet:

www.fao.org/news/global/locusts/pubs1.htm

Appendix 5

Reference

5.1 EGG AND HOPPER DEVELOPMENT TABLES

The following tables have been derived from a computer program developed by FAO in which egg and hopper development are a function of the mean daily temperature. The program takes the long-term monthly values at the weather stations listed in the tables and calculates expected daily values by double quadratic interpolation. For example, if laying is thought (or known) to have taken place on 7 January 2000 at a certain place, the computer will calculate the expected temperature for 7 January and the percentage development. The program does the same for 8 January, accumulating the percentages until they reach 100, which will occur on the predicted date of hatching. The procedure is the same for hopper development.

The predictions will be unreliable for long development periods that occur when temperatures are close to those where development ceases. If the actual temperature is only slightly less than the long-term average, the model will predict slow development when in fact the eggs will not develop at all. Over a substantial time, this will result in a large error. A similar difference at high temperatures will produce only a small error.

These tables should prove adequate for most practical purposes. However, these are only estimates of hatching and fledging. Actual hatching and fledging typically occur over two to three days, even when laying occurred within 24 hours.

Using the egg and hopper development tables

To calculate the number of days from laying to hatching or fledging

1. Choose one of the following tables:

Hatching to laying:	Tables 1a and 1b
Laying to fledging:	Tables 2a and 2b
Hatching to fledging:	Tables 3a and 3b

2. Look up the period for laying on the 1st of the month in the appropriate table.
3. Look up the period for laying on the 1st of the next month.
4. Find the difference between the two values.
5. Divide the date in the month of laying by the total number of days in that month and multiply this answer by the difference found in (4).
6. Add or subtract this answer from the figure for laying in the first month (2); add if the figure for the second month (3) is greater, or subtract if it is smaller.

Note: The answer for (6) must always lie between the successive monthly values.

To calculate the fledging date for hoppers at given stages of development

1. Calculate fledging date as for hatching (see Example 3).
2. Multiply the result by the percentage remaining for that instar:

1st instar	10% developed to fledge (90% remaining)
2nd instar	30% developed to fledge (70% remaining)
3rd instar	50% developed to fledge (50% remaining)
4th instar	80% developed to fledge (20% remaining)
5th instar	90% developed to fledge (10% remaining)

EXAMPLES

EXAMPLE 1: Laying to hatching

If laying has taken place on 25 March, when will hatching occur?

Use Table 1a for Adrar, Algeria:

(a) Laying on 1 March will result in hatching after 24 days
(b) Laying on 1 April will result in hatching after 17 days
(c) The difference between the two values: 24 – 17 = 7
(d) (Date of actual laying) / (No. of days in month) x difference: 25/31 x 7 = 6
(e) Therefore, (a) – (d): 24 – 6 = 18

Result: For laying on 25 March, hatching should occur after 18 days on about 12 April.

EXAMPLE 2: Laying to fledging

If laying has taken place on 2 September, when will fledging occur?

Use Table 2a for Adrar, Algeria:

(a) Laying on 1 September will result in fledging after 41 days
(b) Laying on 1 October will result in fledging after 155 days
(c) The difference between the two values: 155 – 41 = 114
(d) (Date of actual laying) / (No. of days in month) x difference: 2/30 x 114 = 8
(e) Therefore, (a) + (d): 41 + 8 = 49

Result: For laying on 2 September, fledging should occur after 49 days on about 21 October.

EXAMPLE 3: Hatching to fledging

If hatching took place on 12 April, when will the hoppers fledge?

Use Table 3a for Adrar, Algeria:

(a) Hatching on 1 April will result in fledging after 42 days
(b) Hatching on 1 May will result in fledging after 32 days
(c) The difference between the two values: 42 – 32 = 10
(d) (Date of actual hatching) / (No. of days in month) x difference: 12/30 x 10 = 4
(e) Therefore, (a) – (d): 42 – 4 = 38

Result: For hatching on 12 April, the hoppers should fledge after 38 days on about 20 May.

EXAMPLE 4: 2nd instar hoppers to fledging

If second instar hoppers are present on 20 May, when will they fledge?

Use Table 3a for Adrar, Algeria:

(a) Hatching on 1 May will result in fledging after 32 days
(b) Hatching on 1 June will result in fledging after 24 days
(c) The difference between the two values: 32 – 24 = 8
(d) (Date of actual hatching) / (No. of days in month) x difference: 20/31 x 8 = 5

Result: For hatching on 20 May, fledging should occur 27 (32 – 5) days later on 16 June.

(e) Second instar hoppers present on 20 May should fledge after 19 days on 8 June:
% remaining for 2nd instar x No. days to fledging if hatch 20 May: 70/100 x 27 = 19 days

Notice that the second instar hoppers hatched 8 days earlier on 12 May: 27 – 19 = 8 days

Table 1. Hatching to laying

		J	F	M	A	M	J	J	A	S	O	N	D
ALGERIA	**Adrar** *(2753N/0017W)*	**56**	**37**	**24**	17	14	11	11	11	11	**14**	**32**	**71**
	Bechar *(3137N/0214W)*	**83**	**52**	35	26	19	14	12	11	13	21	**116**	**110**
CHAD	**Abeche** *(1351N/2051E)*	15	14	12	11	11	11	12	14	14	13	13	14
	Faya-Largeau *(1800N/1910E)*	23	20	14	12	11	11	11	11	11	12	14	21
DJIBOUTI	**Djibouti** *(1136N/4309E)*	15	15	13	13	12	11	11	11	11	12	13	14
EGYPT	**Aswan** *(2402N/3253E)*	**34**	**28**	19	14	12	11	11	11	11	12	**15**	**24**
	Shalatyn *(2308N/3536E)*	21	19	17	15	13	12	11	11	12	14	16	19
ERITREA	**Massawa** *(1537N/3927E)*	15	15	14	13	12	11	11	11	11	12	13	14
ETHIOPIA	**Jijiga** *(0920N/4243E)*	**35**	**30**	25	23	22	22	24	24	24	**29**	**34**	**36**
INDIA	**Bikaner** *(2800N/7318E)*	**43**	27	16	12	11	11	11	11	12	12	**19**	**40**
IRAN	**Chahbahar** *(2525N/6045E)*	25	22	17	15	13	12	12	12	13	13	15	21
LIBYAN A. J.	**Ghadames** *(3008N/0930E)*	**66**	**45**	29	20	15	12	11	11	12	16	**38**	**80**
	Kufra *(2413N/2318E)*	**50**	35	23	17	13	12	12	12	12	15	21	**44**
MALI	**Menaka** *(1552N/0213E)*	18	16	12	11	11	11	11	12	12	12	12	15
	Tessalit *(2012N/0059E)*	24	20	15	13	11	11	11	11	11	12	14	22
MAURITANIA	**Aioun** *(1642N/0936W)*	19	16	13	12	11	11	11	12	12	12	12	17
	Atar *(2031N/1304W)*	25	21	16	14	12	11	11	11	11	12	14	23
	Bir Moghrein *(2514N/1137W)*	**36**	28	22	20	16	14	12	11	12	14	**22**	**38**
MOROCCO	**Ouarzazate** *(3056N/0654W)*	**86**	**55**	**39**	**29**	21	15	13	12	**15**	**24**	**118**	**113**
	Dakhla *(2342N/1552W)*	**31**	**29**	**26**	26	24	23	21	19	18	19	**22**	**27**
NIGER	**Agadez** *(1658N/0759E)*	**24**	**20**	14	12	11	11	12	12	12	12	**15**	**22**

		J	F	M	A	M	J	J	A	S	O	N	D
OMAN	**Salalah** *(1702N/5405E)*	18	18	15	14	13	13	14	15	15	15	15	17
	Sohar-Majis *(2428N/5638E)*	29	27	19	15	12	11	11	11	12	13	17	**24**
PAKISTAN	**Karachi** (2448N/6659E)	27	22	16	14	13	12	12	13	13	14	15	20
	Dalbandin *(2853N/6424E)*	**74**	**44**	28	19	14	12	11	11	13	20	99	99
SAUDI ARABIA	**Gizan** *(1654N/4235E)*	15	14	13	12	11	11	11	11	11	11	13	14
	Nejran *(1737N/4426E)*	**35**	**28**	19	16	14	12	12	12	12	18	**26**	**31**
	Hail *(2726N/4141E)*	**73**	**45**	30	21	15	12	12	12	12	**16**	**42**	**93**
SENEGAL	**St. Louis** *(1603N/1627W)*	18	20	19	18	17	15	14	13	13	13	14	17
SOMALIA	**Berbera** *(1025N/4501E)*	16	16	14	13	12	11	11	11	11	12	14	16
	Hargeisa *(0930N/4405E)*	30	25	20	18	17	16	18	18	17	**20**	**25**	**30**
SUDAN	**El Obeid** *(1310N/3014E)*	20	19	14	12	12	12	13	14	14	13	14	18
	Tokar *(1826N/3744E)*	16	16	15	13	12	11	11	11	11	11	13	15
TUNISIA	**Gafsa** *(3425N/0849E)*	**90**	**59**	**42**	**31**	**22**	15	13	12	14	21	**112**	**114**
YEMEN	**Hodeidah** *(1445N/4259E)*	16	15	14	13	12	12	11	11	11	12	13	15
	Lahaj *(1310N/4500E)*	17	16	15	14	13	12	12	12	12	13	15	17

*Note: Figures in **bold** should be treated with considerable caution as average temperatures during the period of calculation fell below 20°C, and estimates are unreliable.*

Table 2. Laying to fledging

		J	F	M	A	M	J	J	A	S	O	N	D
ALGERIA	**Adrar** *(2753N/0017W)*	**114**	**88**	**68**	53	41	33	32	33	41	**155**	**163**	**140**
	Bechar *(3137N/0214W)*	**147**	**116**	93	71	55	42	37	39	83	**215**	**200**	**177**
CHAD	**Abeche** *(1351N/2051E)*	52	43	38	36	37	39	47	51	47	44	49	55
	Faya-Largeau *(1800N/1910E)*	72	56	45	39	35	35	36	36	37	44	74	86
DJIBOUTI	**Djibouti** *(1136N/4309E)*	53	49	45	43	38	34	33	34	37	43	49	53
EGYPT	**Aswan** *(2402N/3253E)*	**93**	**73**	57	44	37	35	34	35	38	48	**99**	**108**
	Shalatyn *(2308N/3536E)*	74	65	57	48	42	39	36	38	45	55	72	79
ERITREA	**Massawa** *(1537N/3927E)*	56	52	47	43	39	35	34	34	36	41	48	53
ETHIOPIA	**Jijiga** *(0920N/4243E)*	**118**	**105**	96	92	95	99	**104**	**114**	**131**	**142**	**139**	**129**
INDIA	**Bikaner** (2800N/7318E)	88	63	46	37	32	33	36	37	40	59	**126**	**111**
IRAN	**Chahbahar** *(2525N/6045E)*	81	67	56	48	42	39	41	43	46	53	79	92
LIBYAN A. J.	**Ghadames** *(3008N/0930E)*	**128**	**100**	78	58	45	38	36	38	51	**181**	**180**	**154**
	Kufra *(2413N/2318E)*	**111**	86	67	51	41	39	39	41	49	92	**143**	**133**
MALI	**Menaka** *(1552N/0213E)*	60	47	38	35	33	34	38	41	39	40	49	64
	Tessalit *(2012N/0059E)*	74	58	47	41	34	33	34	36	36	43	78	89
MAURITANIA	**Aioun** *(1642N/0936W)*	62	50	42	37	33	35	39	41	40	40	55	70
	Atar *(2031N/1304W)*	**79**	64	53	45	38	34	34	35	37	46	83	93
	Bir Moghrein *(2514N/1137W)*	**106**	88	75	63	53	44	37	38	47	89	**128**	**123**
MOROCCO	**Ouarzazate** *(3056N/0654W)*	**156**	**125**	**101**	**79**	60	47	43	47	**197**	**225**	**208**	**185**
	Dakhla *(2342N/1552W)*	**118**	**112**	**105**	99	90	82	75	72	74	93	**115**	**120**
NIGER	**Agadez** *(1658N/0759E)*	**72**	**55**	44	39	35	36	40	41	41	48	**82**	**88**

		J	F	M	A	M	J	J	A	S	O	N	D
OMAN	**Salalah** *(1702N/5405E)*	67	59	51	47	44	47	54	55	54	55	61	70
	Sohar-Majis *(2428N/5638E)*	92	74	58	46	38	36	36	38	43	59	97	**105**
PAKISTAN	**Karachi** (2448N/6659E)	81	64	54	47	42	41	43	47	48	53	78	93
	Dalbandin *(2853N/6424E)*	**127**	**96**	74	55	43	37	35	40	76	**194**	**179**	**156**
SAUDI ARABIA	**Gizan** *(1654N/4235E)*	52	47	43	39	35	35	35	36	36	39	48	52
	Nejran *(1737N/4426E)*	**95**	**76**	62	52	44	41	41	41	56	109	**124**	**112**
	Hail *(2726N/4141E)*	**132**	**102**	79	60	47	12	39	40	50	**185**	**183**	**159**
SENEGAL	**St. Louis** *(1603N/1627W)*	75	74	69	64	57	51	48	46	45	48	60	71
SOMALIA	**Berbera** *(1025N/4501E)*	58	54	48	43	37	32	32	33	36	47	56	61
	Hargeisa *(0930N/4405E)*	95	80	71	65	62	65	68	68	81	**108**	**117**	**109**
SUDAN	**El Obeid** *(1310N/3014E)*	68	55	45	40	39	42	48	50	47	48	65	76
	Tokar *(1826N/3744E)*	59	55	50	43	38	33	32	32	35	40	51	60
TUNISIA	**Gafsa** *(3425N/0849E)*	**159**	**128**	**104**	**81**	**62**	48	44	46	**176**	**225**	**211**	**188**
YEMEN	**Hodeidah** *(1445N/4259E)*	57	52	47	42	39	37	36	36	38	44	53	59
	Lahaj *(1310N/4500E)*	61	57	52	46	42	39	39	40	43	51	61	64

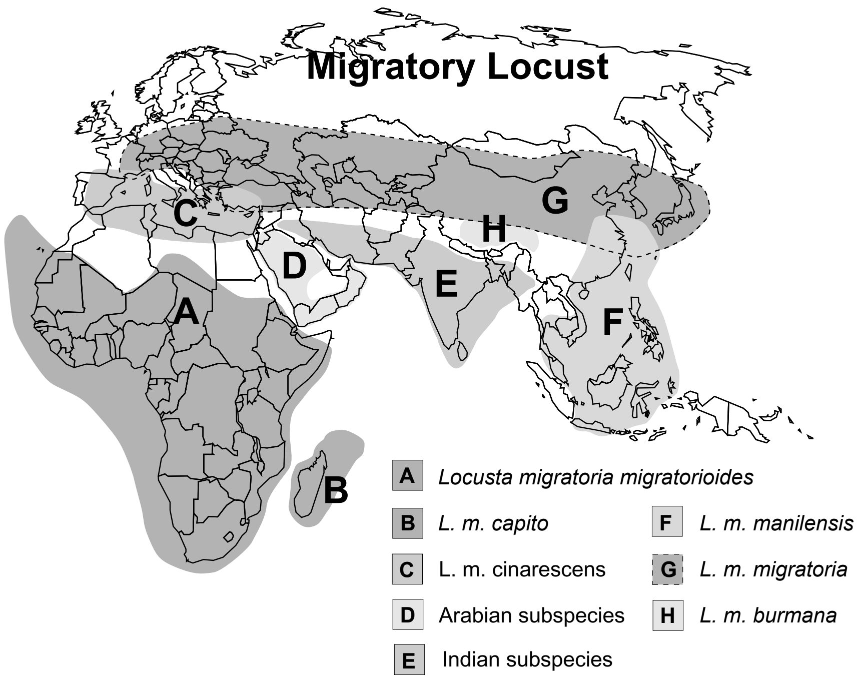
*Note: Figures in **bold** should be treated with considerable caution as average temperatures during the period of calculation fell below 20°C, and estimates are unreliable.*

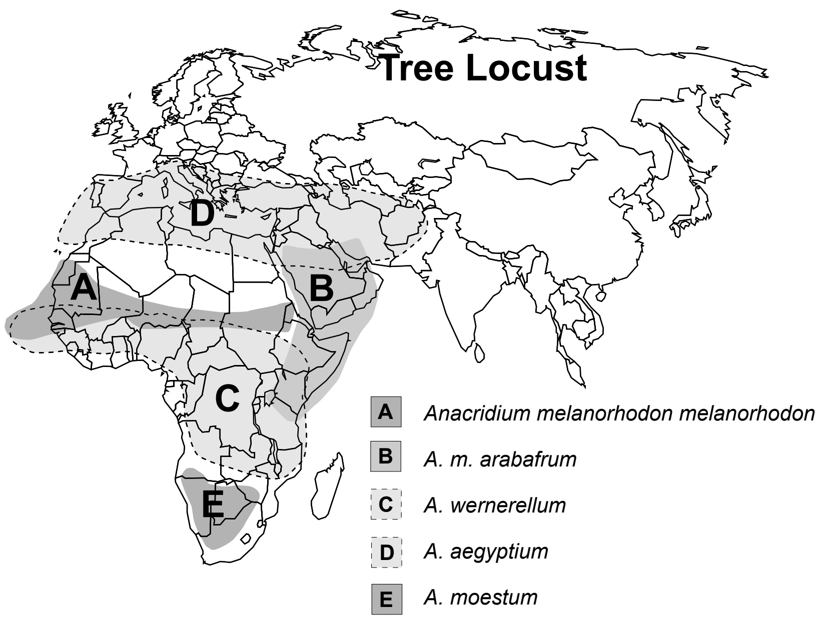
Table 3. Hatching to fledging

		J	F	M	A	M	J	J	A	S	O	N	D
ALGERIA	**Adrar** *(2753N/0017W)*	**104**	**76**	**56**	42	32	24	21	21	25	**55**	**148**	**133**
	Bechar *(3137N/0214W)*	**137**	**106**	**80**	60	43	32	26	26	38	**190**	**189**	**167**
CHAD	**Abeche** *(1351N/2051E)*	40	33	26	25	26	27	32	38	35	31	33	39
	Faya-Largeau *(1800N/1910E)*	61	45	33	28	24	23	24	25	25	28	45	68
DJIBOUTI	**Djibouti** *(1136N/4309E)*	39	36	33	31	28	24	22	22	25	29	34	39
EGYPT	**Aswan** *(2402N/3253E)*	**80**	**61**	45	34	27	24	23	23	26	31	**58**	**92**
	Shalatyn *(2308N/3536E)*	58	51	44	37	31	27	26	26	31	37	48	60
ERITREA	**Massawa** *(1537N/3927E)*	41	39	35	32	28	25	23	23	24	27	33	38
ETHIOPIA	**Jijiga** *(0920N/4243E)*	**95**	**84**	76	70	69	74	78	**82**	**94**	**109**	**113**	**106**
INDIA	**Bikaner** *(2800N/7318E)*	**79**	54	36	27	22	21	24	26	27	34	**103**	**101**
IRAN	**Chahbahar** *(2525N/6045E)*	67	53	43	37	31	28	28	30	32	36	51	72
LIBYAN A. J.	**Ghadames** *(3008N/0930E)*	**120**	**90**	66	48	34	27	25	26	32	**143**	**165**	**148**
	Kufra *(2413N/2318E)*	**99**	**74**	55	40	30	27	27	28	33	48	**119**	**119**
MALI	**Menaka** *(1552N/0213E)*	47	37	28	25	23	23	26	29	28	27	32	47
	Tessalit *(2012N/0059E)*	62	46	30	30	25	22	23	24	25	28	46	72
MAURITANIA	**Aioun** *(1642N/0936W)*	49	38	31	26	23	23	27	29	28	27	35	52
	Atar *(2031N/1304W)*	66	51	41	34	28	24	23	24	25	30	51	76
	Bir Moghrein *(2514N/1137W)*	**88**	72	60	50	41	34	26	26	31	48	**101**	**104**
MOROCCO	**Ouarzazate** *(3056N/0654W)*	**144**	**113**	**88**	**67**	49	36	30	31	**52**	**201**	**197**	**175**
	Dakhla *(2342N/1552W)*	**92**	**87**	**83**	**78**	72	64	58	54	53	61	**83**	**94**
NIGER	**Agadez** *(1658N/0759E)*	**61**	**44**	33	28	25	25	27	29	28	32	**53**	**72**
OMAN	**Salalah** *(1702N/5405E)*	53	46	38	34	31	32	38	41	39	39	42	50
	Sohar-Majis *(2428N/5638E)*	78	62	46	35	28	25	25	26	29	38	64	86
PAKISTAN	**Karachi** *(2448N/6659E)*	68	52	41	35	31	29	30	33	34	36	48	74
	Dalbandin *(2853N/6424E)*	**117**	**86**	62	44	32	26	24	26	39	**173**	**169**	**147**
SAUDI ARABIA	**Gizan** *(1654N/4235E)*	38	35	31	28	25	24	24	24	25	26	33	37
	Nejran *(1737N/4426E)*	**81**	62	48	40	33	29	30	28	34	69	**100**	**97**
	Hail *(2726N/4141E)*	**122**	**91**	68	49	36	29	27	27	31	**148**	**169**	**151**
SENEGAL	**St. Louis** *(1603N/1627W)*	56	56	52	49	43	38	35	33	33	33	40	50
SOMALIA	**Berbera** *(1025N/4501E)*	44	40	36	32	27	22	21	21	23	31	39	44
Hargeisa	**78** *(0930N/4405E)*	64	55	50	46	47	51	49	53	74	**92**	**91**	
SUDAN	**El Obeid** *(1310N/3014E)*	56	44	33	29	27	28	33	36	34	33	43	56
	Tokar *(1826N/3744E)*	44	42	37	32	28	23	21	21	22	27	33	43
TUNISIA	**Gafsa** *(3425N/0849E)*	**149**	**118**	**92**	**69**	**50**	37	31	32	**46**	**199**	**200**	**179**
YEMEN	**Hodeidah** *(1445N/4259E)*	43	39	35	31	28	26	25	25	26	30	36	43
	Lahaj *(1310N/4500E)*	45	42	39	34	30	28	27	28	29	35	42	48

Note: Figures in bold should be treated with considerable caution as average temperatures during the period of calculation fell below 20°C; such estimates are unreliable.

Figure 50. Distribution of Migratory Locusts and Tree Locusts in Africa.





5.2 OTHER LOCUSTS

There are several other important species of locusts, in addition to the Desert Locust, that are known to form swarms in Africa, Asia, Australia and South America.

Africa (see Figs. 50-51)

Migratory Locust (*Locusta migratoria*)

Distribution

Subspecies are present throughout Africa (*L. m. migratorioides*), Madagascar (*L. m. capito*), Asia (northern: *L. m. migratoria*; southeast: *L. m. manilensis;* southwest: Indian subspecies; Tibet: *L. m. burmana*), Australia and Europe (southern: *L. m. cinerascens*; northern: *L. m. migratoria*). The distribution area of the Desert Locust overlaps with that of the African Migratory Locust.

Life cycle

Similar to Desert Locust. Usually two generations per year but, depending on location and subspecies, up to five (i.e. *L. m. manilensis*).

Appearance

Solitary hoppers are first grey then vary; gregarious hoppers are brown with black markings. Gregarious adults are grey when immature, turning brownish when mature. Although similar to Desert Locust, African Migratory Locusts are stouter. They can be yellow but not pink. Adults have a yellowish underwing.

Behaviour

Bands occur most often in flood plain grasslands, move slowly and are much denser than Desert Locust. Rapid and direct flight which usually ends in a dive. Swarms fly very low as a rule and at very high densities. The formation of swarms occurs less often in the Near East and southwest Asia.

Tree Locust (*Anacridium* spp.)

Distribution

Subspecies are present throughout Africa, the Near East, southern Europe and southwest Asia. The distribution area of the Desert Locust overlaps with that of the Tree Locust.

Lifecycle

Similar to Desert Locust, except hoppers have six to nine instars. Usually one generation per year.

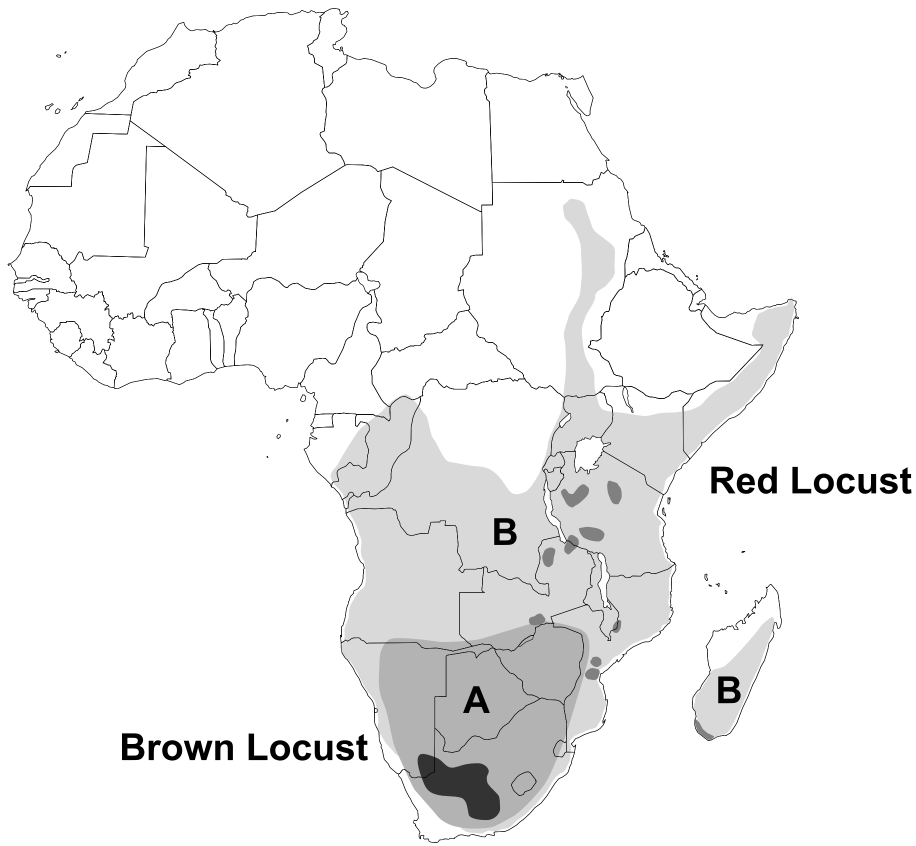
Appearance

Tree Locusts are grey or brown and have a transparent or purplish hind wing with a dark arc of varying size depending on the species. Stout and solid body appearance.

Behaviour

Present in arid savannah areas on trees and shrubs. Ponderous and slow flying adults. Rarely form bands. Swarms are smaller and less mobile than those of Desert Locust.

Figure 51. Distribution of Red Locust and Brown Locust in Africa.



Brown Locust (*Locustana pardalina*)

recession area — A invasion area

Red Locust (*Nomadacris septemfasciata)*

outbreak area — B invasion area

Red Locust (*Nomadacris septemfasciata*)

Distribution

Southern Africa and, to a lesser extent, Madagascar, Mauritius, Cape Verde, Lake Chad Basin and the Niger delta flood plains, preferably in flood plain habitats.

Life cycle

Hoppers have six to eight instars, lasting about two months. Remain immature for 10-11 months. One generation per year.

Appearance

The body shape is similar to Desert Locust but longer. Immature adult is brown and becomes redder with age, with a distinctive yellow stripe along the head, a series of distinct dark bands across the forewing and a reddish inner hindwing.

Behaviour

Soaring flight which usually ends with a vertical plunge into the grass.

Brown Locust (*Locustana pardalina*)

Distribution

Southern Africa during plagues; South Africa and Namibia during recessions.

Life cycle

Drought resistant egg stage; egg pods can remain viable for more than 30 months. A one to three month diapause in the solitary phase egg, absent in the gregarious phase. Five hopper instars, completing their development in one month during the summer. Two to four generations per year.

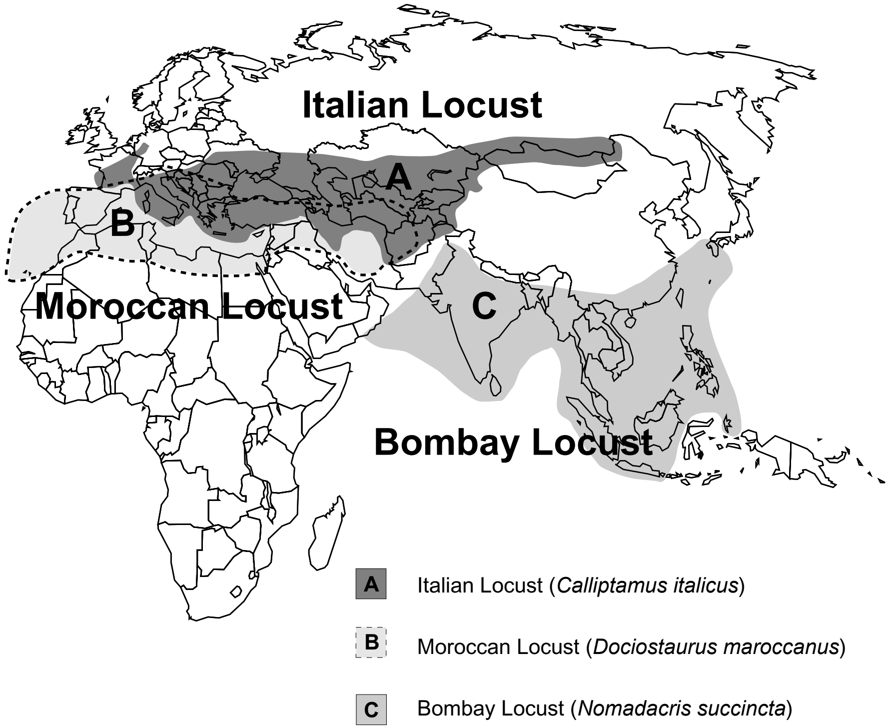
Appearance

Adults are green to grey (solitary) or brown to yellow/brown (gregarious), medium-sized with a bluish tinge to the underwing. Hoppers take on the background coloration but are uniformly black and orange as bands.

Behaviour

Swarms fly 80-100 km per day. Mass migration during summer evenings is common. Bands roost in dense compact masses on the tops of shrubs and can be spotted several kilometres away.

Figure 52. Distribution of Italian Locust, Moroccan Locust and Bombay Locust in Europe, North Africa and Asia.



Europe, North Africa and Asia (see Fig. 52)

Migratory Locust (*Locusta migratoria* ssp.)

See Africa section.

Italian Locust (*Calliptamus italicus*)

Distribution

From western Europe and North Africa through the central Asian republics.

Life cycle

Hatching occurs from April to June. There are five hopper instars in the male and six in the female. Adults appear from May to June. Egg laying occurs from June to September. One generation per year with egg diapause in the autumn and winter.

Appearance

A short, stout shape that is smaller than the Desert Locust.

Behaviour

Often found in field borders and fallow areas. Adults subject to phase change but do not become completely gregarious. Hoppers can form bands.

Moroccan Locust (*Dociostaurus maroccanus*)

Distribution

From northwest Africa and southwestern Europe to central Asia.

Life cycle

Eggs are laid about one month after adults appear, from June onwards. They overwinter and hatch in the following March or April. Hoppers have five to six instars. One generation per year.

Appearance

Hoppers are usually black with brown markings. Swarms are usually brown.

Behaviour

Bands tend to move in long, narrow streams. Swarms rarely migrate.

Bombay Locust (*Nomadacris succincta*)

Distribution

Southwest and southeast Asia.

Life cycle

Adults remain immature during the dry cool season. One generation per year.

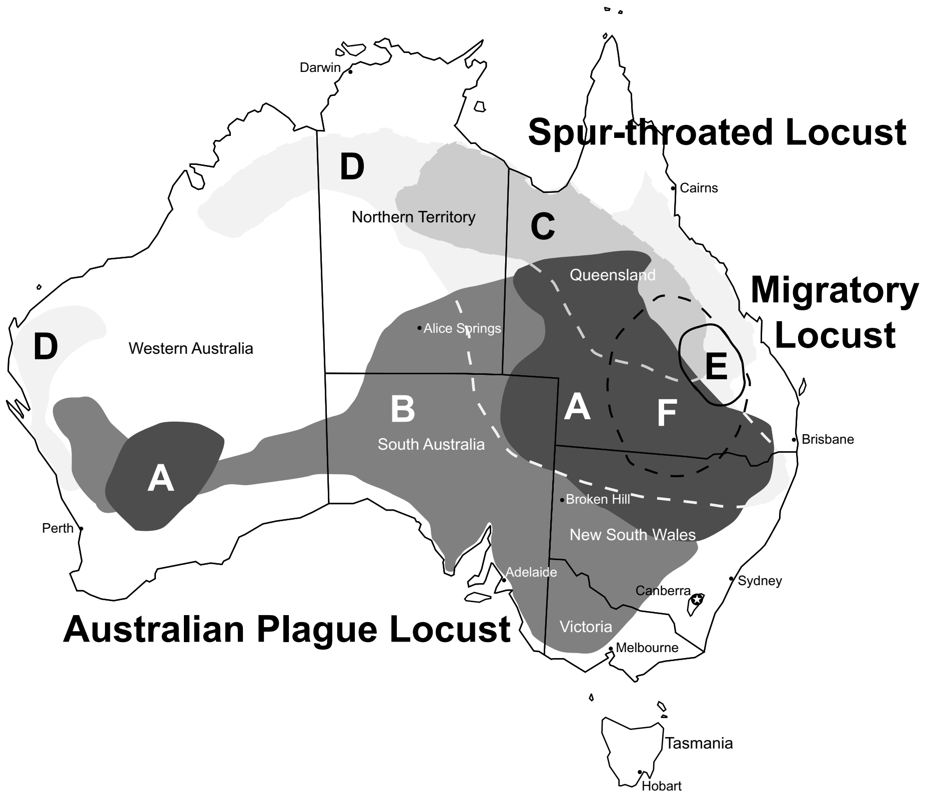
Appearance

Hoppers are green with black spots, becoming more variable in later stages. Look and behave like Red Locust. The body shape is similar to Desert Locust but longer.

Behaviour

Similar to Red Locust.

Figure 53. Distribution of important locust species in Australia.



Australian Plague Locust (*Chortoicetes terminifera*)	Spur-throated Locust (*Austracris guttulosa*)	Migratory Locust (*Locusta migratoria* ssp.)
A persistent	C persistent	E persistent
B intermittent	D intermittent	F intermittent

Australia (see Fig. 53)

Australian Plague Locust (*Chortoicetes terminifera*)

Distribution

Australia.

Life cycle

Eggs overwinter (May to September). Hoppers have five to six instars and they develop in about four to six weeks. Adults start to appear by December. This is followed by a second generation of laying and hatching in January/February. A third generation may occur from March to May. Two to four generations per year, depending on conditions.

Appearance

The smallest of Australian locusts and can be confused with grasshoppers. Adults can be different shades of brown, grey or green with dark tips on hindwings. Hoppers are brownish.

Behaviour

Adults group together when laying. Hoppers form dense bands. Swarms can migrate up to 600 km in one night. Given good conditions, plagues can develop in one year.

Spur-throated Locust (*Austracris guttulosa*)

Distribution

Australia, Indonesia, South Pacific.

Life cycle

Egg laying occurs from October to January, sometimes to April. Hoppers have six to eight instars, taking ten weeks to complete development. Adults start appearing in about March, overwinter and live 10-12 months. One generation per year.

Appearance

Large size with a spur between the front legs. Adults are pale brown with white stripes and dark markings. Hoppers change from bright green to pale brown.

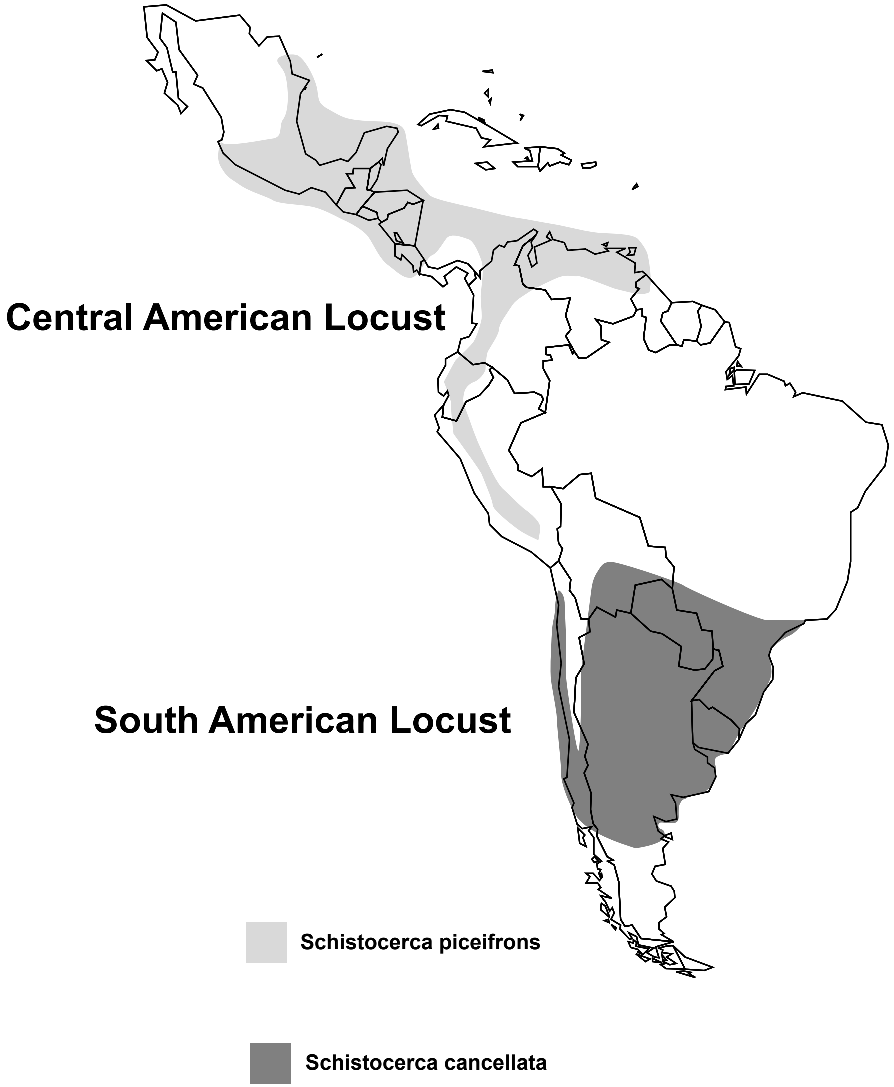
Behaviour

Hoppers remain solitary and do not form bands. Takes three to four years to develop into plague proportions.

Migratory Locust (*Locusta migratoria* ssp.)

See Africa section.

Figure 54. Distribution of important locust species in South America.



South America (see Fig. 54)

Central American Locust (*Schistocerca piceifrons*)

Distribution

Mexico south of the Tropic of Cancer and below 2 000 m in Central America (*S. p. piceifrons*); Peru and Ecuador 1 200-2 200 m (*S. p. peruviana*).

Life cycle

Breeding occurs with the onset of the rains. Overwinters as an adult. Two generations during the summer rains.

Appearance

Solitary hoppers are green, gregarious are black and pink. Mature gregarious adults are bright yellow.

Behaviour

Populations are always present on the Pacific coast of Central America, in northern Honduras, and the Yucatan Peninsula (*S. p. piceifrons*), and central Peru (*S. p. peruviana*). Plagues can occur when swarms migrate from the permanent breeding areas.

South American Locust (*Schistocerca cancellata*)

Distribution

Southern portion of South America.

Life cycle

Similar to Desert Locust.

Appearance

Similar to solitary and gregarious Desert Locusts.

Behaviour

Populations are always present in parts of northwest Argentina and adjacent areas of Bolivia and Paraguay. Behaviour is similar to the Desert Locust. Plagues can occur when swarms migrate from the permanent breeding areas.

5.3 ULV SPRAYER SETTINGS

Sprayer	Emission height (m)	VMD (μm)	Track spacing (m)	Flow rate
All settled targets (bands, blocks of bands or settled swarms)				
Handheld spinning disc	0.5-2.0	50-75	10	Full
Knapsack mistblower	0.5-1.5	50-75	25	Full
Vehicle passive drift	fixed	50-75	30	Full
Vehicle airblast	directed up	50-75	50	Full
Aircraft	5-10 m	75-100	100	Full
Milling swarms at roost				
Aircraft	5-15 m	75-100	100	Full or half x 2
Stratiform swarms				
Aircraft	above swarm	75-100	100	Full or half x 2
Cumuliform swarms				
Aircraft	wherever dense but towards rear	75-100	n.a.	Half

Tip: for the Micron Ulvamast, the fast atomizer speed is usually recommended unless it is very windy or very hot, in which case the medium speed can be used to make slightly larger droplets.

! The settings required to produce the drop sizes listed vary greatly especially for aircraft spraying. They can vary with length of blade (there are two different lengths), the speed of the aircraft and whether the atomizers are mounted on pods or on a boom. It is necessary to consult the manufacturer's handbook in order to be sure of correct blade angle settings for each different situation.

5.4 EVALUATION OF GROUND SPRAYERS

	Vehicle – Passive		Vehicle – Airblast				
	Micron MKII Ulva-mast	MAT Airbi Drift Air	Francome MKII ENS [6]	Berthoud Puma	Micronair AU8110	Micronair AU0110	Tifa 100E
Pesticide efficiency							
droplet size[1]	****	**	***	****	***	****	*
spectrum width	*****	*	**	*	**	***	**
flow rate	*****	*****	*	*****	*****	*****	*****
calibration ease[2]	****	****	*	**	****	****	***
Sustainability							
filling/spraying/cleaning	****	****	**	**	**	***	*
durability/maintenance	***	***	***	*	**	**	*
Socio-economics							
safety[3]	****	****	*	*	***	***	*
cost[4]	****	***	****	***	**	****	*
work rate[5]	***	***	****	***	****	***	****
Total	****	***	**	**	***	***	**

Notes

[1] Results from an FAO workshop (Cairo, 1994). The full report is available on the Internet (www.fao.org/news/global/locusts/pubs1.htm) or from FAO.
[2] As measured at the workshop.
[3] Includes operator and environmental safety.
[4] Based on suggested manufacturer's retail cost.
[5] Based on assumed track spacing and forward speed; vehicle-mounted and portable sprayers assessed separately.
[6] Not tested.

Key:

Star ratings	*****	****	***	**	*
Technical assessment	excellent	good	average	poor	inappropriate
Cost (US$) – vehicle	0-1 000	1 000-2 000	2 000-5 000	5 000-10 000	10 000-25 000

	Knapsack		Handheld		
	Jacto PL 50	Micronair AU8000	Berthoud C5	Micron Ulva +	Micron MicroUlva
Pesticide efficiency					
droplet size[1]	**	***	***	*****	****
spectrum width	**	**	****	****	*****
flow rate	****	****	*****	*****	*****
calibration ease[2]	****	***	*****	*****	****
Sustainability					
filling/spraying/cleaning	****	****	*****	*****	*****
durability/maintenance	****	****	****	*****	***
Socio-economics					
safety[3]	***	***	***	***	****
cost[4]	***	**	*****	****	****
work rate[5]	***	****	***	***	***
Total	***	***	****	****	****

Notes

[1] Results from an FAO workshop (Cairo, 1994). The full report is available on the Internet (www.fao.org/news/global/locusts/pubs1.htm) or from FAO.
[2] As measured at the workshop.
[3] Includes operator and environmental safety.
[4] Based on suggested manufacturer's retail cost.
[5] Based on assumed track spacing and forward speed; vehicle-mounted and portable sprayers assessed separately.
[6] Includes knapsack and handheld sprayers.

Key:

Star ratings	*****	****	***	**	*
Technical assessment	excellent	good	average	poor	inappropriate
Cost (US$) – portable [6]	0-50	50-100	100-500	500-1 000	1 000-2 500

5.5 CONVERSION TABLES

Area

	ft²	m²	acre	ha	km²	mi²
1 ft² =	1.00	0.0929	0.000023	0.0000093	0.000000093	0.000000036
1 m² =	10.764	1.00	0.000247	0.0001	0.000001	0.000000386
1 acre =	43560	4046.85	1.00	0.4047	0.004047	0.001563
1 ha =	107639	10000	2.471	1.00	0.01	0.003861
1 km² =	10763910	1000000	247.11	100.00	1.00	0.3861
1 mi² =	27878400	2589998	640.00	259.00	2.590	1.00

Volume

	ml	litre	Imp gal	US gal	m³	ft³	US fl oz
1 ml =	1.00	0.001	0.000220	0.000264	0.000001	0.0000353	0.033814
1 l =	1000	1.00	0.220	0.264	0.001	0.0353	33.814
1 Imp gal =	4546	4.546	1.00	1.200	0.00455	0.160	153.721
1 US gal =	3785	3.785	0.833	1.00	0.00379	0.134	127.999
1 m³ =	1000000	1000	219.97	264.17	1.00	35.31	33814
1 ft³ =	28317	28.317	6.229	7.481	0.0283	1.00	957.51
1 US fl oz =	29.57	0.0296	0.00651	0.007813	0.0000296	0.001044	1.00

Distance

	cm	in	ft	m	km	mi	naut mi
1 cm =	1.00	0.394	0.0328	0.01	0.00001	0.000006	0.000005
1 in =	2.54	1.00	0.0832	0.0254	0.0000254	0.000016	0.000014
1 ft =	30.48	12.0	1.00	0.3048	0.0003048	0.000189	0.000165
1 m =	100	39.37	3.281	1.00	0.001	0.000621	0.000540
1 km =	100000	39370	3281	1000	1.00	0.621371	0.539610
1 mi =	160934	63360	5280	1609	1.609	1.00	0.868976
1 naut mi =	185200	72913	6076	1852	1.852	1.151	1.00

Speed

	km/h	mph	m/s	m/min	knots
1 km/h =	1	0.621	0.278	16.67	0.540
1 mph =	1.610	1.00	0.447	26.82	0.869
1 m/s =	3.60	2.24	1.00	60.00	1.942
1 m/min =	0.06	0.0373	0.017	1.00	0.032
1 knot =	1.853	1.151	0.515	30.89	1.00

Weight

	g	oz	lb	kg	tonne
1 g =	1.00	0.0353	0.0022	0.001	0.000001
1 oz =	28.35	1.00	0.0625	0.0283	0.0000283
1 lb =	453.59	16.00	1.00	0.4536	0.000454
1 kg =	1000	35.27	2.205	1.00	0.001
1 mt =	1000000	35274	2205	1000	1.00

Water weight

	lb	kg	litre	US gal	ft³
1 lb =	1.00	0.454	0.454	0.1198	0.0160
1 kg =	2.205	1.00	1.00	0.2642	0.0353
1 l =	2.205	1.00	1.00	0.2642	0.0353
1 US gal =	8.378	3.785	3.785	1.00	0.1337
1 ft³ =	62.41	28.31	28.31	0.7494	1.00

Dose (solids)

	oz/acre	g/ha	kg/ha	lb/acre
1 oz/acre =	1.00	70.05	0.07005	0.0625
1 g/ha =	0.01427	1.00	0.0010	0.0008922
1 kg/ha =	14.28	1000.0	1.00	0.8924
1 lb/acre =	16.0	1120.8	1.121	1.00

Dose (liquids)

	US fl oz/acre	ml/ha	l/ha	US gal/acre
1 US fl oz/acre =	1.00	73.08	0.07307	0.007813
1 ml/ha =	0.01369	1.00	0.001	0.0001068
1 l/ha =	13.69	1000	1.00	0.1068
1 US gal/acre=	128	9363	9.363	1.00

Pressure

	kg/cm²	lb/in²	bar
1 kg/cm² =	1.00	14.22	0.980
1 lb/in² =	0.0703	1.00	0.069
1 bar =	1.02	14.50	1.00

Terminology and definitions for describing Desert Locust populations

Non-gregarious hoppers and adults

Term and behaviour (other terms)		/ site	/ FT (1)	/ VT (2)	/ bush	/m²	/ ha	/ km²
Isolated:	very few present and no mutual reaction occurring (few)							
	adults:	1	1	3	-	-	6	< 100
	hoppers:	1-10	-	-	-	-	-	-
Scattered:	enough present for mutual reaction to be possible but no groups (some, low numbers)							
	adults:	-	1-75	4-250	1-3	-	7-500	100-5 000
	hoppers:	10+	-	-	-	-	-	-
Group:	forming ground or basking groups							
	adults:	-	75+	250+	3+	-	500+	5 000+
	hoppers:	-	-	-	10+	5-100	-	-

(1) *About 300 m long by up to 5 m wide. Actual transect will vary depending on habitat and weather at the survey location.*

(2) *1 km long by 2 m wide in low gear.*

Hopper bands and adult swarms

		bands (1)	swarms (2)
Density	Low	4-10 hoppers / m²	4-10 adults / m²
	Medium	10-50 hoppers / m²	10-50 adults / m²
	High	50+ hoppers / m²	50+ adults / m²
Size	Very small	1-25 m²	less than 1 km²
	Small	25-2 500 m²	1-10 km²
	Medium	2 500 m² -10 ha	10-100 km²
	Large	10-50 ha	100-500 km²
	Very large	50+ ha	500+ km²
Flying height	Low		<100 m
	Medium		100-500 m
	High		500+ m

(1) *Densities will vary with hopper instar and band size; band sizes vary with instar.*

(2) *Densities will vary depending whether swarms are settled, milling or flying.*

5.6 DESERT LOCUST TERMINOLOGY

The monthly FAO Desert Locust Bulletin uses special terms when reporting locusts. Countries are encouraged to use similar terminology to avoid confusion and make it easier for others to understand the locust situation.

To determine which term to use for non-gregarious adult and hopper populations, you should observe their behaviour as well as try to estimate their density; that is, the number of locusts in a given unit of area such as a square metre or hectare.

It is very difficult to determine accurately the density and size of adult swarms and hopper bands. In the case of swarms, density will vary according to the size of the swarm as well as to its behaviour – whether it is settled, milling or flying. In the case of hoppers, band densities will differ according to the hopper instar and band size. If you cannot estimate numbers, than it may be important to use relative terms such as low (more ground or bush visible than locusts), medium (about equal portions of locust and ground or bush are visible), and high (more locusts visible than ground or bush).

The terms summer, winter and spring are not precisely fixed according to the calendar. They are only indicative and may vary from region to region.

The terms describing rainfall are used to estimate the quantity of rainfall, not the intensity or duration.

For more terminology, see the Glossary section.

Terminology describing rainfall and Desert Locust breeding

Rainfall quantity

Light	1-20 mm
Moderate	20-50 mm
Heavy	more than 50 mm

Breeding seasons

Summer	July – September/October	Sahel of West Africa/Sudan Indo-Pakistan desert
Winter	October – January/February	Red Sea coasts Northwest Africa
Spring	February – June/July	Northwest Africa Arabian interior Baluchistan

5.7 USEFUL ADDRESSES

Organizations and manufacturers are kindly requested to keep FAO informed of their current contact information.

Organizations

Australian Plague Locust Commission (APLC)

Agriculture, Fisheries and Forestry – Australia
GPO Box 858
Canberra ACT 2601
AUSTRALIA
Tel.: +61 2 62725076
Fax: +61 2 6272 5074
E-mail: aplc@affa.gov.au
Internet: www.affa.gov.au

CABI Biosciece

UK Centre (Egham)
Bakeham Lane
Egham
Surrey TW20 9TY
Tel: +44 1491 829000
Fax: +44 1491 829100

Canadian International Development Agency (CIDA)

200 Promenade du Portage
Hull, Quebec
K1A 0G4
CANADA
Tel.: +1 819 9975006
Fax: +1 819 9536088
E-mail: info@acdi-cida.qc.ca
Internet: w3.acdi-cida.qc.ca

Department for International Development (DFID)

94 Victoria Street
London SW1E 5JL
UNITED KINGDOM
Tel.: +44 20 79177000
Fax: +44 20 79170019
E-mail: enquiry@dfid.gov.uk
Internet: www.dfid.gov.uk

Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH

Dag-Hammarskjöld-Weg 1-5
65760 Eschborn
GERMANY
Tel.: +49 619679-0
Fax: +49 619679-1115
Internet: www.gtz.de

Food and Agriculture Organization of the United Nations (FAO)

Viale delle Terme di Caracalla
00100 Rome
ITALY
Tel.: +39 06 57052420
Fax: +39 06 57055271
E-mail: eclo@fao.org
Internet: www.fao.org

The International Centre of Insect Physiology and Ecology (ICIPE)

PO Box 30772
Nyayo Stadium
KENYA
Tel.: +254 2 861680-4/802501
Fax: +254 2 860110/803360
E-mail: icipe@icipe.org
Internet: www.icipe.org

International Institute of Tropical Agriculture (IITA)

c/o Lambourn & Co.
Carolyn House, 26 Dingwall Road
Croydon CR9 3EE
UNITED KINGDOM
Internet: www.iita.org

Locustox

FAO Locustox Project
POB 3300
Dakar
SENEGAL
Tel.: +221 8344294
Fax: +221 8344290
E-mail: cereslocustox@sentoo.sn
Internet:
www.fao.org/news/global/locusts/locustox/ltoxhome.htm

Natural Resources Institute (NRI)

University of Greenwich
Chatham Maritime
Kent ME4 4TB
UNITED KINGDOM
Tel.: +44 1634 880088
Fax: +44 1634 880077/66
Internet: www.nri.org

PRIFAS

Acridologie Operationnelle
CIRAD-AMIS/Protection des Cultures
TA 40/PS2
Boulevard de la Lironde
34398 Montpellier Cedex 5
FRANCE
Tel.: +33 4 67615800
Fax: +33 4 67410958
Internet: www.cirad.fr

Swedish International Development Cooperation Agency (SIDA)

105 25 Stockholm
SWEDEN
Tel.: +46 8 6985000
Fax: +46 8 208864
E-mail: info@sida.se
Internet: www.sida.se

United States Agency for International Development (USAID)

Ronald Reagan Building
Washington, DC 20523-1000
USA
Tel.: +1 202 7124810
Fax: +1 202 2163524
Internet: www.usaid.gov

World Health Organization (WHO)

Avenue Appia 20
1211 Geneva 27
SWITZERLAND
Tel.: +41 22 7912111
Fax: +41 22 7913111
E-mail: info@who.int
Internet: www.who.int

World Meteorological Organization (WMO)

7 bis Avenue de la Paix
CP 2300
1211 Geneva 2
SWITZERLAND
Tel.: +41 22 7308111
Fax: +41 22 7308181
E-mail: ipa@www.wmo.ch
Internet: www.wmo.ch

Manufacturers

Beecomist Systems (sprayers)

33 Meeting House Road
Telford, PA 18969
USA
Tel.: +1 630 8942028

Berthoud / EXEL GSA (sprayers)

B.P 424
69653 Villefanche s/Saône Cedex
FRANCE
Tel.: +33 4 74624848
Fax : +33 4 746251
Internet: www.berthoud.fr

Codan Pty Ltd (radios)

81 Graves Street
Newton SA 5074
AUSTRALIA
Tel.: +61 8 83050311
Fax: +61 8 83050411
E-mail: info@codan.com.au
Internet: www.codan.com.au

Del Norte Technology, Inc (GPS spray)

1100 Pamela Drive
Euless, TX 76040
USA
Tel.: +1 817 2673541
Fax: +1 817 3545762
E-mail: dnti@delnorte.com
Internet: www.delnorte.co

GARMIN International Inc. (GPS)

1200 E. 151st Street
Olathe, KS 66062
USA
Tel.: +1 913 3978200
Fax: +1 913 3978282
E-mail: europe@garmin.com
Internet: www.garmin.com

ICOM Inc. (radios)

6-9-16, Kamihigashi, Hirano-ku
Osaka 547-0002
JAPAN
Tel.: +81 6 67935302
Fax: +81 6 67930013
E-mail: support_center@icom.co.jp
Internet: www.icom.co.jp

K&L Technologies (GPS navigation)

16800 Pella Road
Adams, NE 68301
USA
Tel.: +1 402 7882572
Fax: +1 402 7882766
E-mail: info@klasi.com
Internet: www.klasi.com

Magellan (GPS)

Internet: www.magellangps.com

Markus Technology (sprayers)

320 Rue du Mont Descats
59270 Godwaersvelde
FRANCE
Tel.: +33 3 28425298
Fax: +33 3 2842 5556

Micron Sprayers Ltd (sprayers)

Bromyard Industrial Estate
Bromyard, Herefordshire HR7 4HS
UNITED KINGDOM
Tel.: +44 885 482397
Fax: +44 885 483043
E-mail: micron@micron.co.uk
Internet: www.micron.co.uk

Picodas Group (differential GPS)

100 W Beaver Creek Rd., Unit 6
Richmond Hill, Ontario L4B 1H4
CANADA
Tel.: +1 905 7643744
Fax: +1 905 7643792
E-mail: general@picodas.com
Internet: www.ag-aviation-online.com/agnav2.htm

Psion PLC (handheld computers)

12 Park Crescent
London W1B 1PH
UNITED KINGDOM
Tel.: +44 870 6080680
E-mail: uk.support@psion.com
Internet: www.psion.com

Racal Landstar (differential GPS)

Racal LandStar USA
7313A Grove Rd.
Frederick, MD 21704
USA
Tel.: +1 301 6245505
Fax: +1 301 6245848
E-mail: racalgps@cs.com
Internet: www.racal-landstar.com

Satloc Inc (GPS spraying systems)

15990 North Greenway Hayden Loop,
Suite 800
Scottsdale, AZ 85260
USA
Tel.: +1 480 3489919
Fax: +1 480 3486364
E-mail: info@satloc.com
Internet: www.satloc.com

Spraying Systems Co. (sprayer nozzles and oil-sensitive paper)

PO Box 7900
Wheaton, IL 60189-7900
USA
Tel.: +1 630 6655000
Fax: +1 630 2600842
E-mail: info@spray.com
Internet: www.spray.com

Trimble Navigation (differential GPS)

645 North Mary Ave.
POB 3642
Sunnyvale, CA 94088
USA
Tel.: +1 408 4818000
Fax: +1 408 4812000
E-mail: salesinfo@trimble.com
Internet: www.trimble.com

WAG Corporation (differential GPS)

386 Highway 6 West
Tupelo, MS 38801
USA
Tel.: +1 662 8448478
Fax: +1 662 8447247
E-mail: info@wagcorp.com
Internet: www.wagcorp.com

Yaesu UK Ltd (radios)

Unit 12
Sun Valley Business Park,
Winnall Close, Winchester
SO23 0LB Hampshire
UNITED KINGDOM
Tel.: +44 1962 866667
Fax: +44 1962 856801
E-mail: Service_Dept@yaesu.co.uk
Internet: www.yaesu.com

The inclusion of the manufacturers mentioned in this section does not imply the expression of any opinion or an endorsement whatsoever on the part of the Food and Agriculture Organization of the United Nations concerning their products.

5.8 GLOSSARY

Adult: The winged and final stage of the Desert Locust.
Aerial spraying: Spraying from aircraft, either fixed wing or helicopter.
Aircraft-mounted sprayer: A sprayer that is fitted to an aircraft, either fixed wing or helicopter.
Airblast: A blast of air created by a fan or exhaust gases.
Air-shear nozzle: An atomizer that relies on an airblast to break the spray liquid up as it is emerging at low pressure from a nozzle.
Anemometer: Device for measuring wind speed.
Anti-feedant: Property of a spray product that prevents locust feeding on it.
Atomization: The process of making spray, i.e. breaking liquid up into droplets.
Active ingredient (a. i.) concentration: The amount of the actual pesticide in grams in a given amount (usually a volume) of the commercial product. This is usually expressed as a %wt/vol; for example, 96% fenitrothion usually means 960 grams a.i. in 1 litre (1 000 cc) of product.
Baiting: Mixing insecticide with a material that locusts will eat and scattering it in front of them.
Band (or **hopper band**): A gregarious group of locust hoppers marching together, which can vary in size.
Barrier: A strip of vegetation sprayed with pesticide. When dieldrin was used against hoppers, it was usually applied in barriers so that the hopper bands would march through a barrier, feeding as they went, and be killed by the pesticide ingested with the vegetation.
Bearing: The number of degrees by which a direction differs from magnetic north. North is 0, east is 90, south is 180 and west is 270. Compass bearings can be any figure between 0 and 360 degrees.
Biopesticide: A micro-organism that can be sprayed on to locusts to infect and kill them.
Blanket spraying: Spraying the whole of a target surface, as opposed to barrier spraying.
Block: An area that contains sufficient bands to justify spraying the whole of it. Obviously much of the pesticide will be wasted in between the bands, but this is considered preferable to the difficulty of finding and spraying each individual band in the block.
Botanical: A plant extract that can be sprayed to kill or deter locusts.
Breeding: The process of reproduction from copulation to fledging.
Broad-spectrum: The property of a pesticide that kills a wide range of different organisms.
Calibration: The process of setting up a sprayer to apply the right dose of insecticide in the right-sized droplets to the right place.
Buffer zone: The region close to an ecologically sensitive area or habitation where no spraying is carried out, to avoid the zone being affected by drift.
Cannibalism: Locusts feeding on other locusts.
Chemical and **brand name** (also called **trade name**): The chemical name has the first letter in lower case; the brand name has the first letter in upper case. For example, fenitrothion and Sumithion. Where there is registration, it is the brand not the chemical that is registered. It may be legal to apply Sumithion but not Brand X fenitrothion.

Cocktails: This term is sometimes applied to pesticide formulations that contain a mixture of active ingredients.
Compass: A handheld device with a needle that always points to magnetic north. Used for navigation.
Concentration: An increase in population density as a result of convergent movement of hoppers and adults caused by their independent reactions to external environmental factors. Large-scale concentration may result from convergent wind flow; small-scale concentration may occur as locusts move into preferred microhabitats, for example, to bask, feed or lay.
Contact action: A pesticide that can pass through the locust skin and kill it. The efficacy may also be assisted by secondary contact action, i.e. where locusts touch insecticide drops that are on vegetation or other surfaces. This compares with stomach action products that have to be eaten by the locust to be effective.
Controlled droplet application (CDA): This is the technique of applying droplets in a narrow size range believed to be most effective for the particular target and conditions.
Control method: The equipment, pesticide and technique used for killing locusts.
Convection: The phenomenon of air being heated up by the ground and rising.
Copulation: The process by which males fertilize females.
Crosswind: At 90 degrees to the wind direction.
Cumuliform swarm: A swarm that is carried upwards, sometimes thousands of metres, by convection.
Decline: A period characterized by breeding failure and/or successful control leading to the dissociation of swarming populations and the onset of recessions; can be regional or major.
Delimit: To determine the boundaries of a locust target or infestation.
Density: Often used to mean the number of locusts in a given area, e.g. number per m^2.
Deposition: The term used to describe a droplet hitting any surface, vertical or horizontal, by impaction or sedimentation.
Deposition profile: The shape of the graph of deposition over distance downwind from a spray pass.
Dissociation: The portion of phase transformation in which locusts are changing from gregarious to solitarious.
Dose: The amount of active ingredient (a. i.) in grams applied to a given unit of area (usually 1 ha).
Downwind edge: The edge of a spray block that is furthest from the direction that the wind is coming from.
Droplet size: Droplet size refers to the diameter of a droplet, i.e. the size across it. It is usually measured in micrometers (also called microns) – written µm. A micrometer is 1 millionth of a metre. A 100 µm diameter dot can be seen by the naked eye; smaller droplets are difficult to see.
Droplet spectrum: All sprayers produce a range of droplet sizes. This range is called the droplet spectrum.
Dusting: Mixing insecticide with an inert dust such as chalk or talc and sprinkling it on to locusts.
Efficacy: Usually referring to the extent of the locust kill.
Efficiency: The comparison of efficacy and cost, both in terms of money and effort.

Egg pod: A cluster of eggs typically laid by the Desert Locust female, containing about 100 eggs.
Emission height: The height at which the spray is released into the air.
Emulsifiable concentrate (EC): This is pesticide that is applied diluted with water.
Environmental impact: An effect on non-target organisms. Environmental impact is usually negative, i.e. organisms other than the target are killed.
Ferry time: The time an aircraft spends flying backwards and forwards between the airstrip and the target for refuelling or refilling with insecticide.
Few (adults or hoppers): Very few non-gregarious adults or hoppers present and no mutual reaction occurring; 0-1 locust per 400 m foot transect or less than 25 locusts/hectare. See also **Isolated**.
First in-First out: The strategy in a pesticide store where the oldest stock is always used before newer stock to avoid the problem of accumulation of out-of-date pesticides.
Fixed-wing aircraft: The type of aircraft referred to as an aeroplane.
Fledge: To develop to winged adult stage from a fifth or sixth instar nymph.
Fledging: The final moult where the hopper stage ends and the adult stage begins.
Fledgling: A newly emerged adult after completing its final moult as a hopper. Its skin and wings are soft and must harden before it can fly.
Formation spraying: Two or more sprayer operators spraying at the same time, but in a way which avoids one contaminating the other.
Formulation: This is the product supplied by the manufacturer, i.e. the active ingredient mixed with solvents, stabilizers carriers and other inert materials that make up the rest of the volume.
Flag person: Person using a flag to mark the end of the spray passes for a sprayer operator.
Full-coverage spraying: See **Blanket spraying**.
Gregarious: The phase of the Desert Locust when large numbers of individuals gather together. Colours are bright – hoppers are black and yellow and adults are pink when immature and yellow when mature.
Gregarization: An acquisition of behavioural and other characteristics of the gregarious phase.
Group (of adults or hoppers): Forming ground or basking groups; 20+ adults or hoppers per 400 m foot transect or 500+ per hectare.
Hazard: A source of danger. Risk from pesticides is hazard x level of exposure to the product.
Headwind: A wind that is against the flying direction of an aircraft.
Heavy (rainfall): Rainfall of more than 50 mm.
Helicopter: A rotary wing aircraft with a horizontal rotor that allows it to hover.
Hydraulic nozzle: A simple device that atomizes the liquid by forcing it out of a small hole under pressure.
Insect growth regulators (IGRs): Products that interfere with the growth of the locust, usually the moulting process.
Impaction: This occurs when a droplet carried sideways by the wind lands on a vertical surface such as a plant or insect. The droplet hits the surface because of the horizontal momentum it has been given by the wind.

Incremental spraying: Spraying in a crosswind so that deposit is built up from overlapping swaths. Note that incremental spraying uses ULV pesticides and attempts CDA.
Instar: The five or six stages that Desert Locust nymphs pass through before becoming adults.
Invasion: The appearance or arrival of locust swarms from another source such as another country, region or continent.
Isolated (adults or hoppers): Very few non-gregarious adults or hoppers present and no mutual reaction occurring; 0-1 locust per 400 m foot transect or less than 25 locusts/hectare. See also **Few**.
Large (swarm or hopper band size): A hopper band with a size of 10-50 ha or a swarm with a size of 100-500 km^2.
LD50: The dose which will kill 50 percent of a test population, i.e. lethal dose for 50 percent.
Light (rainfall): Rainfall of 1-20 mm.
Low numbers (adults or hoppers): Enough non-gregarious adults or hoppers present for mutual reaction to be possible but no ground basking groups seen; 1-20 locusts per 400 m foot transect or 25-500 locusts/ha). See also **Scattered**, **Low numbers**.
Knock down: The property of some insecticides, notably pyrethroids, to make insects drop very quickly after spraying. They may not be dead, and if the dose was not sufficient, in some circumstances can recover.
Mammalian toxicity: The measure of how poisonous a product is to mammals – usually tested in the laboratory on rats, and expressed as the LD50.
Marching: The behaviour of locust hopper bands that are moving together.
Mark: To place flags or other markers such as vehicles, people or smoky fires at the corners of a spray block.
Maturation: The sequence of changes that occur when sexually immature locusts become mature, including colour, behaviour and reproductive organs.
Maturity: Adults are immature at first and then their sexual organs develop, when they are ready to copulate, i.e. they are mature. Mature adults are either pale yellow (solitarious) or bright yellow (gregarious).
Mechanical control: Using physical methods such as beating, burning or burying locusts. Egg beds are also sometimes dug up or ploughed.
Medium (swarm or hopper band size): A hopper band with a size of 2 500 m^2 – 10 ha or a swarm with a size of 10-100 km^2.
Milling: Locusts making short flights above a population that is mostly settled. This can occur in the evening when settling at the roost, or in the morning when preparing for swarm departure.
Moderate (rainfall): Rainfall of 20-50 mm.
Monitor: To observe and record details of control operations such as the spraying techniques and the percentage mortality of the locusts.
Mortality: Usually used to mean the percentage kill of the locusts.
Moulting: Locust nymphs shedding their skins and becoming the next instar.
Multiplication: An increase in locust numbers as a result of breeding.
Neurotoxic: Products that interfere with the locusts' nervous systems.
Nitrile rubber: A synthetic rubber that is more resistant to pesticide and solvents.

Number median diameter (NMD): The diameter such that half the total number of droplets are smaller and half are larger.
Nymphs (also called **hoppers**): Young locusts before they have developed wings.
Odometer: A device on the speedometer of a vehicle that can be used to measure distances.
Operator: The person using the sprayer – can be locust staff on foot, driver in a vehicle or pilot in an aircraft.
Outbreak: A marked increase in locust numbers due to concentration, multiplication and gregarization which, unless checked, can lead to the formation of hopper bands and swarms.
Overdose/underdose: Where more/less than the recommended dose of an insecticide has been used.
Passive-drift sprayer: A sprayer that releases the spray droplets passively into the crosswind. This compares with airblast sprayers that give the droplets an initial throw in the jet of air.
Persistence: The property of a pesticide that remains effective for a long time in the field.
Plague: A period of one or more years of widespread and heavy locust infestations, the majority of which occur as bands or swarms. A major plague exists when two or more regions are affected simultaneously.
Portable sprayer: A sprayer that is carried by a person during spraying.
Pheromone: A chemical released by one insect that produces an effect in another insect of the same species.
Predation: Animals feeding on other locusts.
Protective clothing: Garments worn by sprayer operators to protect them from pesticides.
Quadrat: A small sampling area (usually 1 m^2) in which the number of locusts are counted.
Recession: A period without widespread and heavy infestations by swarms.
Recommended dose: The amount of insecticide active ingredient that has been found to kill Desert Locusts reliably, but without waste.
Remission: A period of deep recession marked by the complete absence of gregarious populations.
Roosting: The resting behaviour of solitarious and gregarious hoppers and adults usually by clinging to vegetation.
Rotary atomizer: An atomizer that spins at high speed and that throws pesticide off its surface to make small droplets.
Route of entry: The route by which an insecticide enters a living organism. This can be dermal, i.e. through the skin, oral, i.e. through the mouth and stomach, or inhalation, i.e. being breathed in.
Rpm: Revolutions per minute – the standard measure of rotational speed of an atomizer, motor engine etc.
Scattered (adults or hoppers): Enough non-gregarious adults or hoppers present for mutual reaction to be possible but no ground basking groups seen; 1-20 locusts per 400 m foot transect or 25-500 locusts/ha). See also **Some**, **Low numbers**.
Settled: This applies to adults and means resting on vegetation or the ground rather than flying.

Sedimentation: This occurs when a droplet falls downwards and lands on a horizontal surface. The droplet hits the surface because of the force of gravity.
Sensitive ecological area: A region where there is a risk of environmental damage from the control operations. There may be rare or sensitive species of plant or animal which must be protected.
Shelf life: How long a pesticide in storage remains effective.
Small (swarm or hopper band size): A hopper band with a size of 25-2 500 m^2 or a swarm with a size of 1-10 km^2.
Solitarious: The phase of the Desert Locust where individuals live mostly separately from each other. They are usually drab coloured, brown or grey as immature adults and pale yellow as mature adults.
Some (adults or hoppers): Enough non-gregarious adults or hoppers present for mutual reaction to be possible but no ground basking groups seen; 1-20 locusts per 400 m foot transect or 25-500 locusts/ha). See also **Scattered**, **Low numbers**.
Specificity: The property of a pesticide that acts only on a narrow range of organisms.
Speed of action: How fast an insecticide kills the insect after exposure.
Spray pass: One passage of the sprayer along its spray track.
Spraying: Breaking insecticide liquid into small drops that are applied to the locusts or their food.
Spring (rains and breeding): From February to June/July.
Stomach action: A pesticide product that kills locusts after they eat it, rather than being touched by it (contact action).
Stratiform swarm: A swarm that is flying fairly near to the ground – usually found during the cooler parts of the day.
Summer (rains and breeding): From July to September/October.
Suspension concentrate (called SC): A pesticide that is formulated as a suspension which is mixed with water before application.
Swarm: A large group of gregarious adults, that can fly large distances as a single mass of individuals.
Swarmlet: A small swarm.
Swath width: This is the width of the strip at right angles to the sprayer's track where there is *significant* deposit .
Tailwind: A wind that is in the same direction as the flying direction of an aircraft.
Threshold number: The number of locusts per square metre (or per hectare or per km^2) when it is judged that control operations are worthwhile. This number varies from country to country.
Track spacing: The distance between the tracks or passes of the sprayer.
Transect: A line through a locust population on which several quadrat counts of locust density are made.
Transiens (or **Transient phase**): The phase when locusts are grouping and starting to act as a single mass and are either changing from solitarious to gregarious (gregarization) or from gregarious to solitarious (dissociation).
Turbulence: The mixing of air caused by the action of wind over rough ground.
Uniform deposit: A deposit with equal amounts at different distances downwind from a spray pass – this cannot be achieved from a single pass of a ULV sprayer.

Ultra low volume spraying (ULV): The application of small volumes (usually 0.5-1.0 l/ha for locusts) in very small droplets of concentrated pesticide. ULV pesticides are sprayed undiluted; they are oil-based to reduce evaporation, so they cannot be diluted with water.
Upsurge: A period following a recession marked initially by a very large increase in locust numbers and contemporaneous outbreaks followed by the production of two or more successive seasons of transient-to-gregarious breeding in complimentary seasonal breeding areas in the same or neighbouring regions.
Upwind edge: The edge of the block nearest to the direction that the wind is coming from.
Vehicle-mounted sprayer: A sprayer that is mounted on a four-wheel drive pick-up vehicle.
Very large (swarm or hopper band size): A hopper band with a size greater than 50 ha or a swarm with a size greater than 500 km^2.
Very small (swarm or hopper band size): A hopper band with a size of 1-25 m^2 or a swarm with a size of less than one km^2.
Volatile: Tending to evaporate.
Volume application rate (VAR): The volume of liquid (with ULV, the volume of product) in litres or ml applied to a given unit of area (1 ha).
Volume median diameter (VMD): The diameter of the droplet such that half the spray volume is in smaller droplets and half in larger ones.
VMD:NMD ratio (called R): The value of the VMD divided by the value of the NMD and gives a measure of the width of the droplet spectrum. If R is larger than 2, the spectrum is wide, if it is less than 2 it is relatively narrow and more suitable for ULV spraying. A value of 1 would mean that all of the droplets were the same size, but no sprayer can produce such a spectrum.
Water-based spraying: Using an insecticide formulation that can be mixed with water – usually emulsifiable concentrate (EC) or wettable powder (WP). The mixture is usually applied in large volumes (hundreds or even thousands of l/ha) which means it is not very suitable for Desert Locust control.
Wettable granule (called WG): A pesticide that is formulated as granules which is mixed with water before application.
Whirling hygrometer: A small handheld device for measuring the temperature and relative humidity.
Winter (rains and breeding): From October to January/February.
Work rate: The area that can be treated in a given time, usually expressed as hectares per hour (ha/h).

5.9 LITERATURE

Abdallahi, Ould M. Sidia, Skaf, R., Castel, J. N. & Ndiaye, A. 1979. OCLALAV and its environment: a regional international organization for the control of migrant pests. *Phil. Trans. R. Ent. Soc. Lond.,* B287: 269-276.

Aelion, E. 1958. A report on weather types causing marked storms in Israel during the cold season. *Israel Met. Service, Miscellaneous Papers,* Series C, No. 10.

Ahmad, T. 1950. Department of Plant Protection: its work on locust control. *Agriculture Pakist.,* 1: 133-135.

Albrecht, F. O. 1962. Some physiological and ecological aspects of locust phases. *Trans. R. Ent. Soc. Lond.,* 114: 335-375.

Ashall, C. & Chaney, I. 1982. Operational analysis of the role of DLCO-EA. COPR Project 42.06.1. London, Centre for Overseas Pest Research.

Ashall, C. & Ellis, P. E. 1962. Studies on numbers and mortality in field populations of the Desert Locust *(Schistocerca gregaria* Forskål). *Anti-Locust Bull.,* London, 38. 59 pp.

Aspliden, C. I. 1974. The low level windfield and associated perturbations over tropical Africa during northern summer. *Proc. International Tropical Meteorology Meeting, Nairobi:* 218-223.

Balança, G. & de Visscher, M. 1992. *Glossaire des termes élémentaires d'acridologie et de lutte anti-acridienne en Afrique Sahélienne.* Paris, GTZ & CIRAD. 157 pp.

Bateman, R. 1997. Methods of application of microbial pesticide formulations for the control of grasshoppers and locusts. *Mem. Ent. Soc. Canada*, 171: 69-81.

Batten, A. 1966. The course of the last major plague of the African Migratory Locust, 1928 to 1941. *Pl. Prot. Bull.,* FAO, Rome, 14: 1-16.

Batten, A. 1967. Seasonal movements of swarms of *Locusta migratoria migratorioides* (R. & F.) in western Africa in 1928 to 1931. *Bull. Ent. Res.,* 57: 357-380.

Batten, A. 1969. The Senegalese grasshopper, *Oedaleus senegalensis* Krauss. *J. Appl. Ecol.,* 6: 27 45.

Bennett, L. V. 1975. Factors affecting the upsurge and decline of populations of the Desert Locust *(Schistocerca gregaria* Forskål) in 1966-1969. Vol. 1: Text + 40 appendices, c. 450 pp. Vol. 2: Maps and figures. (Unpublished typescript, Ph.D. thesis, University of London).

Bennett, L. V. 1976. The development and termination of the 1968 plague of the Desert Locust. *Bull. Ent. Res.,* 66: 511-552.

Bennett, L. V. & Symmons, P. M. 1972. A review of estimates of numbers in some types of Desert Locust *(Schistocerca gregaria* [Forsk.]) populations. *Bull. Ent. Res.,* 61: 637-649.

Bérenger, M. 1963. Contribution a l'étude des lithométéores. *La Météorologie,* 72: 347-374.

Betts, E. 1961. Outbreaks of the African Migratory Locust *(Locusta migratoria migratorioides* R. & F.) since 1871. *Anti-Locust Mem.,* London, 6. 25 pp.

Betts, E. 1976. Forecasting infestations of tropical migrant pests: the Desert Locust and the African armyworm. *In* Rainey, R. C., ed. *Insect Flight: Syrnp. R. Ent. Soc. Lond.,* 7: 113-134.

Bhatia, G. N. 1961. Observations on concentrated solitary breeding of Desert Locust *(Schistocerca gregaria* Forsk.) in Rajasthan (India) during 1956. *Indian J. Ent.,* 21: 77-81.

Bhatia, D. R. & Mital, V. P. 1962. Displacement of invading Desert Locust swarms during 1959 in India in relation to wind movements. *Indian J. Ent.,* 23: 225-229.

Bodenheimer, F. S. 1929. Studien zur Epidemiologie, Oekologie und Physiologie der afrikanischen Wanderheuschrecke *(Schistocerca gregaria* Forsk.). *Z. Angew. Ent.,* Berlin, 15: 435-557.

Bouaichi, A. 1992. The use of diflubenzuron in locust and grasshopper control. Rome, FAO.

Bouaichi, A., Roessingh, P. & Simpson, S. J. 1995. An analysis of the behavioural effects of crowding and re-isolation on solitary-reared adult desert locusts (*Schistocerca gregaria)* and their offspring. *Physiol. Entomol.*, 20: 199-208.

Bugaev, V. A., Dzordzio, V. A., Kozik, E. M., Petrosjanc, M. A., Psenicnyi, A. J., Romanov, N. N. & Cernyseva, O. N. 1962. *Synoptic processes of Central Asia.* Wld Met. Org. [Translation of Trans. Acad. Sci. Uzbek S.S.R., 1957.]

Bullen, F. T. 1966. Locusts and grasshoppers as pests of crops and pasture – a preliminary economic approach. *J. Appl. Ecol.,* 3: 147-168.

Bullen, F. T. 1969. The distribution of the damage potential of the Desert Locust *(Schistocerca gregaria* Forsk.). *Anti-Locust Mem.,* London, 10. 44 pp.

Burt, P. J. A., Larkin, A. D. & Magor, J. I. 2000. *Bibliography on upsurges and decline of Desert Locust plagues 1925-1998*. Chatham, UK, Natural Resources Institute. 71 pp.

CAB. 1988. *Biological control of locusts: the potential for the exploitation of pathogens and proposals for research*. CAB Int. Inst. of Biological Control. 13 pp.

Carlisle, D. B., Ellis, P. E. & Betts, E. 1965. The influence of aromatic shrubs on sexual maturation in the Desert Locust *Schistocerca gregaria. J. Insect Physiol.,* 11: 1541-1558.

Carlson, T. N. 1971. A detailed analysis of some African disturbances. USA, NOAA Tech. Mem. ERL-NHRL-90.

Casanova, H. 1967. Principaux types de temps en Afrique occidentale, illustrés par des situations météorologique réelles. *Bull. Inst. Fond. Afr. Noire,* 29A: 383-408.

Chandra, S. 1984. Field observations on plant association of solitarious adult Desert Locust (*Schistocerca gregaria* Forsk.) in western Rajasthan. *Plant Prot. Bull.,* 36 (4): 23-28.

Chandra, S. 1985a. Feeding behaviour of the Desert Locust (*Schistocerca gregaria* F.) in relation to nutritional values of some food plants. *Plant Prot. Bull.,* 37 (2): 25-30.

Chandra, S. 1985b. Screening of some common desert plants for feeding preference in non-gregarious adults of *Schistocerca gregaria* Forsk. *Plant Prot. Bull.,* 37 (2): 1-3.

Chandra, S. 1985c. Some field observations on the plant association of Solitary living Desert Locust hoppers in western Rajasthan. *Plant. Prot. Bull.,* 37 (1): 1-2.

Chandra, S. 1987a. Food selection behaviour of the Desert Locust *Schistocerca gregaria*, Forsk. in relation to increasing abundance of food plant(s). *Plant Prot. Bull.,* 39: 32-34.

Chandra, S. 1987b. Relative feeding deterrency of some plant alkaloids to the Desert Locust, *Schistocerca gregaria* (Forsk). *Plant Prot. Bull.,* 39: 17-19.

Chandra, S. 1988. Development of Desert Locust situation in Thar Desert of India during 1987 – a case study with special reference to timing and quantity of rainfall. *Plant Prot. Bull.,* 40 (384): 14-19.

Chandra, S., Sinha, P. P. & Singh, R. P. 1988. The Desert Locust build-up in western Rajasthan during monsoon season of 1986. *Plant Prot. Bull.,* 40 (384): 21-28.

Cheke, R. A. & Holt, J. 1993. Complex dynamics of Desert Locust plagues. *Ecol. Entomol.,* 18: 109-115.

Cherlet, M. & Di Gregorio, A. 1993. Calibration and integrated modelling of remote sensing data for Desert Locust habitat monitoring. *RSC Series No. 64*. Plant Protection Service, FAO, Rome.

Christophe, L. A. 1966. Pluies nubiennes avant la construction du haut-barrage. *Bull. Soc. Géog. D'Egypte,* 39: 155-160.

Cochemé, J. 1966a. Wind opportunities for locust transport and concentration in India and West Pakistan, June 1961. FAO Progress Report No. UNSF/DL/RFS/6. 59 pp.

Cochemé, J. 1966b. Isotherms of monthly mean effective night temperatures. Study No. 2. Anti-Locust Climatic Manual. Section B. Temperatures. FAO Progress Report No. UNSF/DL/RFS/7-B.2. 216 pp.

Colon, J. A., Raman, C. R. V. & Srinivasan, V. 1970. On some aspects of the tropical cyclone of *20-29* May 1963 over the Arabian Sea. *Ind. J. Met. Geophys.,* 21: 1-22.

COPR. 1982. *The locust and grasshopper agricultural manual*. London, Centre for Overseas Pest Research. 690 pp.

Cooper, J. F., Coppen, G. D. A., Dobson, H. M., Rakotonandrasana, A. & Scherer, R. 1995. Sprayed barriers of diflubenzuron (ULV) as a control technique against marching hopper bands of migratory locust, *Locusta migratoria capito* (Sauss.) (Orthoptera: Acrididae), in southern Madagascar. *Crop Protection*, 14 (2): 137-143.

Courshee, R. J. 1990. Desert locusts and their control. *International Pest Control*, 32(1): 16-18.

Cressman, K. 1996. Current methods of desert locust forecasting at FAO. *Bulletin OEPP/EPPO,* 26: 577-585.

Cressman, K. 1997a. Monitoring Desert Locusts in the Middle East: a review. *In* Albert, J., Bernhardsson, M., & Kenna, R., eds., *Transformations of Middle Eastern natural environments: legacies and lessons*: 123-140. New Haven, CT (USA), Yale University.

Cressman, K. 1997b. SWARMS: A geographic information system for desert locust forecasting., p. 522, *In* Krall, S., Peveling, R., & Ba Diallo, D., eds. *New strategies in locust control*: 27-35. Birkhauser Verlag, Basel.

Davey, P. M. 1954. Quantities of food eaten by the Desert Locust, *Schistocerca gregaria* (Forsk.), in relation to growth. *Bull. Ent. Res.,* 45: 539-551.

Davey, J. T. 1959. The African Migratory Locust *(Locusta migratoria migratorioides* Rch. & Frm., Orth.) in the Central Niger Delta. Part two: the ecology of *Locusta* in the semi-arid lands and seasonal movements of populations. *Locusta,* Nogent-sur-Marne, 7. 180 pp.

Davies, D. E. 1952. Seasonal breeding and migrations of the Desert Locust *(Schistocerca gregaria* Forskål) in north-eastern Africa and the Middle East. *Anti-Locust Mem.,* London, 4. 56 pp.

Dent, L. & Mason, D. C. 1972. A study of rapid cyclonic development over the central Mediterranean in September 1969. *Met. Mag.,* 101: 78-85.

Desai, B. N. 1967. On the formation, direction of movement and structure of the Arabian Sea cyclone of 20-29 May 1963. *Ind. J. Met. Geophys.,* 18-68.
Desai, B. N. 1970. Synoptic climatology of the Indian subcontinent. *India Met. Dept., Met. Geophys. Rev.,* 2.
Dhonneur, G., Finaud, L., Gamier, R., Gaucher, L. & Rossignol, D. 1973 Analyse de deux pertrubations ayant évolvé en dépressions tropicales. *A. Sec. N.A., Publ. Dir. Expl. Mét.,* 27.
Dirsch, V. M. 1953. Morphometrical studies on phases of the Desert Locust *(Schistocerca gregaria* Forskål*). Anti-Locust Bull.,* London, 16. 34 pp.
Dobson, H. M. 1999. Advances in locust spraying technology. *Insect Science and its Application*, 19 (4): 335-368.
Dobson, H. M., Cooper, J. & Scherer, R. 1995. Economics and practicalities of migratory locust hopper band control using barriers of insect growth regulator. *In* Krall, S., Peveling, R., & Ba Diallo, D., eds. *New strategies in locust control*: 433-442. Birkhauser Verlag, Basel.
Dobson, H. M. & Magor J. I. 1999. Ancient plagues and modern solutions: locust management in the new millennium. BCPC pre-conference symposium, Brighton (in press).
Donnelly, U. 1974. Seasonal breeding and migrations of the Desert Locust *(Schistocerca gregaria* Forskål*)* in western and north-western Africa. *Anti-Locust Mem.,* London, 3. 43 pp.
Dubief, J. 1953. *Essai sur l'hydrologie superficielle au Sahara.* Algiers, Gouvernement Général de l'Algérie. 457 pp.
Dudley, B. A. C. 1961. Studies on the biology of locusts when reared under controlled conditions. 149 pp. (Unpublished typescript, Ph.D. thesis, Cardiff).
Duranton, J. F., Launois, M., Launois-Luong, M. H., & Lecoq, M. 1982. *Manuel de prospection acridienne en zone tropical sèche (Tomes I & II).* Paris, Ministère des Relations extérieures – Coopération et Dévelopement – et G.E.R.D.A.T. 1496 pp.
Duranton, J. F., Launois, M., Launois-Luong, H., Lecoq, M., & Rachadi, T. 1987. *Guide antiacridien du Sahel*. Paris, Ministère de la Coopération. 344 pp.
Duranton, J. F. & Lecoq, M. 1990. Le Criquet pèlerin au Sahel. *Collection Acridologie Opérationelle 6.* Paris, Ministère des Affaires Etrangères des Pays-Bas et CIRAD-PRIFAS.
Ebdon, R. A. & Oxley, W. J. 1975. A note on tropical storms in the Arabian Sea, October to December 1972. *Met. Mag.,* 104: 227-230.
Ellis, P. E. 1959. Learning and social aggregation in locust hoppers. *Anim. Behav.,* 7: 91-106.
Ellis, P. E. & Ashall, C. 1957. Field studies on diurnal behaviour, movement and aggregation in the Desert Locust *(Schistocerca gregaria* Forskål). *Anti-Locust Bull.,* London, 25. 94 pp.
FAO 1975. Manuel du prospecteur. FAO Report No. NWA/DL/SS2. 69 pp.
FAO 1980. Trilingual glossary of terms used in acridology. FAO Report No. FAO/AGP/DL/TS/2. 171 pp.
FAO 1988. *Meeting on Desert Locust research – Defining future research priorities. 18-20 October 1988,* Rome.
FAO 1995. *Report of the workshop on evaluation of spray equipment used in Desert Locust control, 21-23 August 1994 (Cairo, Egypt)*. Cairo, FAO Commission for Controlling the Desert Locust in the Central Region.

Farrow, R. A. 1974. Comparative plague dynamics of tropical *Locusta* (Orthoptera, Acrididae). *Bull. Ent. Res.,* 64: 401-411.
Farrow, R. A. & Longstaff, B. C. 1986. Comparison of the annual rates of increase of locusts in relation to the incidence of plagues. *Oikos*, 46: 207-222.
Fortescue-Foulkes, J. 1953. Seasonal breeding and migrations of the Desert Locust *(Schistocerca gregaria* Forskål) in south-western Asia. *Anti-Locust Mem.,* London, 5. 36 pp.
Gadallah, A. I., El-Gammel, A. M., Eissa, I. S., El-Hossini Abdel Monim, A. & Abdel Karim, I. A. 1986. Effect of anti-juvenile hormone (precocene II) on cuticle development and its contents of protein and chitin in *Schistocerca gregaria* (Forsk). *Al-Azhar J. Agric. Res.,* 5: 144-156.
Gerbier, N. E. 1965. Analysis of the relationship between meteorology and the movements of gregarious Desert Locust swarms in the western invasion area. A. Text. B. Figures. FAO Progress Report No. UNSF/DL/RFS/4: A. 106 pp., B. 289 Figs.
Germain, H. 1959. Situation typique de petit hivernage (heug.) *Mét. Nat., Not. Inst. Tech.,* Section VII, No. 13. Paris.
Ghosh, S. K. & Veeraraghavan, K. 1975. Severe floods in Jammu and Kashmir in August 1973. *Ind. J. Met. Geophys.,* 26: 203-207.
Gland, H. 1964. Un cas de brouillard au Sahara central. *La Météorologie,* 74: 153-156.
Greathead, D. J. 1966. A brief survey of the effects of biotic factors on populations of the Desert Locust. *J. Appl. Ecol.,* 3: 239-250.
Guichard, K. M. 1955. Habitats of the Desert Locust *(Schistocerca gregaria* Forskål) in western Libya and Tibesti. *Anti-Locust Bull.,* London, 21. 33 pp.
Gunn, D. L., Perry, F. C., Seymour, W. G., Telford, T. M., Wright, E. N. & Yeo, D. 1948. Behaviour of the Desert Locust *(Schistocerca gregaria* Forskål) in Kenya in relation to aircraft spraying. *Anti-Locust Bull.,* London, 3. 70 pp.
Gupta, G. R., Misra, D. K. & Yadav, B. R. 1977. The Porbandar cyclone of October 1975. *Ind. J. Met. Geophys.,* 28: 177-188.
Habtemichael, A. & Pedgley, D. E. 1974. Synoptic case-study of spring rains in Eritrea. *Arch. Met. Geoph. Biokl.,* A 23: 285-296.
Healey, R. G., Robertson, S. G., Magor, J. I., Pender, J., & Cressman, K. 1996. A GIS for desert locust forecasting and monitoring. *Int. J. Geographical Information Systems,* 10: 117-136.
Hemming, C. F., Popov, G. B., Roffey, J. & Waloff, Z. 1979. Characteristics of Desert Locust plague upsurges. *Phil. Trans. R. Ent. Soc. Lond.,* B287: 375-386.
Herok, C. A. & Krall, S. 1995. *Economics of desert locust control*. Eschborn, Germany, GTZ.
Hielkema, J. U. & Howard, F. A. 1976. Pilot project on the application of remote sensing techniques for improving Desert Locust survey and control. FAO Working Paper AGP: LCC/76/4. 55 pp.
Hielkema, J. U. 1990. Satellite environmental monitoring for migrant pest forecasting by FAO: the ARTEMIS system. *Phil. Trans. R. Ent. Soc. Lond.,* B328: 705-717.
Holt, J. & Cheke, R. A. 1996. Models of desert locust phase changes. *Ecological Modelling,* 91: 131-137.

Hudleston, J. A. 1958. Some notes on the effects of bird predators on hopper lands of the Desert Locust *(Schistocerca gregaria* Forskål). *Ent. Mon. Mag.,* London, 94: 210-214.
Hunter-Jones, P. 1964. Egg development in the Desert Locust *(Schistocerca gregaria* Forsk.) in relation to the availability of water. *Proc. R. Ent. Soc. Lond.,* A39: 25-33.
Hunter-Jones, P. 1966. Studies on the genus *Schistocerca* with special reference to development. 171 pp. (Unpublished typescript, Ph.D. thesis, University of London).
Husein, M. 1941. A note on the breeding and movements of the Desert Locust *Schistocerca gregaria* Forskål, in Egypt during 1941 (Orthoptera: Acrididae). *Bull. Soc. Fouad I. Ent.,* 25: 203-206.
Islam, M. S., Roessingh, P., Simpson, S. J. & McCaffery, A. R. 1994a. Effects of population density experienced by parents during mating and oviposition on the phase of hatchling desert locusts, *Schistocerca gregaria*. *Proc. R. Ent. Soc. Lond.,* B257: 93-98.
Islam, M. S., Roessingh, P., Simpson, S. J. & McCaffery, A. R. 1994b. Parental effects on the behaviour and colouration of nymphs of the Desert Locust *Schistocerca gregaria. J. Insect Physiol.,* 40(2): 173-181.
Jalu, R., Bocquillon, —, & Bonnefous, —. 1965. Tempéte de sable sur le Sahara. *La Météorologie,* 6: 105-112.
Jalu, R. & Darnote, P. 1967. Précipitations importantes sur le Hoggar le 16 Juin 1965. *Acta Géog., 68:* 16-21.
Joffe, S. 1998. Economic and policy issues in Desert Locust Management: a preliminary analysis. FAO/EMPRES Workshop on Economics in Desert Locust Management. FAO Desert Locust Technical Series, AGP/DL/TS/27. Rome.
Johnson, D. H. 1962. Rain in East Africa. *Quart. J. R. Met. Soc.,* 88: 1-19.
Johnson, D. H. 1964. Forecasting weather in East Africa. *Wld Met. Org. Tech. Note,* 64: 83-94.
Johnson, D. H. 1965. African synoptic meteorology. *Wld Met. Org. Tech. Note,* 69: 48-90.
Johnson, D. H. & Mörth, H. T. 1963. Forecasting research in East Africa. *Proc. Symp. Tropical Meteorology Africa, Nairobi 1959:* 56-137.
Johnston, H. B. 1926. A further contribution to our knowledge of the bionomics and control of the Migratory Locust., *Schistocerca gregaria* Forsk. *(peregrina* Oily.), in the Sudan. *Bull. Wellcome Trop. Res. Labs (Ent. Sect.),* 22. 14 pp.
Johnston, H. B. 1956. *Annotated catalogue of African grasshoppers.* Cambridge, Cambridge University Press. 833 pp.
Johnston, H. B. 1968. *Annotated catalogue of African grasshoppers: supplement.* Cambridge, Cambridge University Press. 488 pp.
Joyce, R. J. V. 1952. The ecology of grasshoppers in East Central Sudan. *Anti-Locust Bull.,* London, 11. 97 pp.
Joyce, R. J. V. 1961. The behaviour and control of a Desert Locust swarm in the Northern Region of the Somali Republic, 1960. Desert Locust Survey, Nairobi. (Unpublished typescript).
Joyce, R. J. V. 1962. Report of the Desert Locust Survey 1st June 1955 – 31st May 1961. Nairobi, East African Common Services Organization. 112 pp.
Jurcec, V. 1970. On the problem of forecasting in subtropical Africa and the Middle East. *UAR Met. Dept., Met. Res. Bull.,* 2: 63-96.

Kassas, M. 1966. Plant life in deserts. *In* Hills, E. S., ed. *Arid lands: a geographical appraisal:* 145-180. London, Methuen: Paris, UNESCO.
Kennedy J. S. 1939. The behaviour of the Desert Locust (*Schistocerca gregaria* (Forskål)) (Orthopt.) in an outbreak centre. *Trans. R. Ent. Soc. Lond.,* 89: 385-542.
Kennedy, J. S. 1951. The migration of the Desert Locust (*Schistocerca gregaria* Forsk.) I. The behaviour of swarms. *Phil. Trans. R. Ent. Soc. Lond.,* 235: 163-260.
Kevan, D. K. 1989. Transatlantic travellers. *Antenna,* 13: 12-15.
Krall, S. & Wilps, H., eds. 1994. *New trends in locust control: ecotoxicology, botanicals, pathogenes, attractants, hormones, pheromones, remote sensing.* Eschborn, Germany, GTZ.
Krall, S. 1996. Towards the development of integrated pest management in desert locust control. *Plant Research and Development,* 42: 1-10.
Krall, S., Peveling, R., & Ba Diallo, D., eds. 1997. *New strategies in locust control.* Birkhauser Verlag, Basel. 522 pp.
Kulshrestha, S. M. & Gupta, M. G. 1964. Satellite study of an inland monsoon depression. *Ind. J. Met. Geophys.,* 15: 175-182.
Kumar, S. & Saxena, R. K. S. 1969. Spells of heavy rainfall in association with western disturbances over northwest India during the monsoon of 1966 – a quantitative approach. *Ind. J. Met. Geophys.,* 20: 257-262.
Lahr, J. 1998. An ecological assessment of the hazard of eight insecticides used in Desert Locust control to invertebrates in temporary ponds in the Sahel. *Aquatic Ecology,* 32: 153-162.
Latchininsky, A. V. & Launois-Luong, M. H. 1997. *Le criquet pèlerin (Schistocerca gregaria Forskal, 1775) dans la partie nord orientale de son aire d'invasion.* Montpellier, France, CIRAD-PRIFAS. 192 pp.
Launois-Luong, M. H., Launois, M. & Rachadi, T. 1988. La lutte chimique contre les criquets du Sahel. *Collection Acridologie Opérationelle No. 3,* Paris, Ministère des Affaires Etrangères des Pays-Bas et CIRAD-PRIFAS.
Launois-Luong, M. H. & Lecoq, M. 1989. Vade-mecum des criquets du Sahel. *Collection Acridologie Opérationelle No. 5,* Paris, Ministère des Affaires Etrangères des Pays-Bas et CIRAD-PRIFAS.
Launois-Luong, M. H. & Lecoq, M. 1993. Reference manual of WMO codes for transmission of pest locust data. Geneva, WMO and Islamic Educational, Scientific and Cultural Organization.
Lecoq, M. 1988. Les criquets du Sahel. *Collection Acridologie Opérationelle No. 1,* Paris, Ministère des Affaires Etrangères des Pays-Bas et CIRAD-PRIFAS. 130 pp.
Lecoq, M. & Mestre, J. 1988. La surveillance des sauteriaux du Sahel. *Collection Acridologie Opérationelle No. 2,* Paris, Ministère des Affaires Etrangères des Pays-Bas et CIRAD-PRIFAS. 62 pp.
Lomer, C. J., Bateman, R. P., Johnson, D. L., Langewald, J., & Thomas, M. 2001. Biological control of locusts and grasshoppers. *Ann. Rev. Entomol. 2001,* 46: 667-702.
Magor, J. I. 1962. Rainfall as a factor in the geographical distribution of the Desert Locust breeding areas, with particular reference to summer breeding areas of India and Pakistan. 118 pp. (Unpublished typescript, Ph.D. thesis, University of Edinburgh).

Magor, J. I. 1992. Forecasting migrant insect pests. *In* Drake, V. A. & Gatehouse, A. G., eds. *Insect migration: tracking resources through time and space*, p. 399-426. Cambridge, Cambridge University Press.

Magor, J. I. 2001. The Desert Locust upsurge 1992-1994: a control-free simulation. FAO Desert Locust Technical Series, AGP/DL/TS/31. Rome. (in press)

Mason, J. B. 1973. A revision of the genera *Hieroglyphus* Krauss, *Parahieroglyphus* Carl and *Hieroglyphodes* Uvarov (Orthoptera: Acridoidea). *Bull. Br. Mus. Nat. Hist. (Ent.),* 28: 509-560.

Matthews, L. S. 1961. The unusual storms of Christmas week 1960 in Nigeria. *Brit. W. Afr. Meteorological Service, Tech. Note,* 15.

Mayencon, R. 1958. La prévision des pluies diluviennes en Algerie. *Mét. Nat. Not. Inst. Tech.,* Section XV, No. 13. Paris.

Mayencon, R. 1961a. Conditions météorologiques synoptiques propices aux chutes de gréle importantes en Algerie. *La Météorologie,* 4: 41-54.

Mayencon, R. 1961b. Conditions synoptiques dormant lieu a des précipitations torrentielles au Sahara. *La Météorologie,* 4: 171-180.

Meinzingen, W. F., ed. 1993. *A guide to migrant pest management in Africa.* Rome, FAO. 184 pp.

Mestre, J. 1988. *Les acridiens des formations herbeuses d'Afrique de l'Ouest.* Paris, CIRAD-PRIFAS. 331 pp.

Milford, J. R. 1988. Potential and limits of rainfall estimates using cold cloud statistics. University of Reading, UK, Dept Meteorology. (Unpublished typescript).

Milford, J. R. 1989. Satellite Monitoring of the Sahel. *Weather,* 44: 77-82.

Morant, V. 1947. Migrations and breeding of the Red Locust *(Nomadacris septemfasciata* Serville) in Africa, 1927-1945. *Anti-Locust Mem.,* London, 2. 59 pp.

Morell, M. 1973. Notes sur les situations météorologiques remarquables observées au Tchad. *A. Sec. N. A., Dir. Expl. Mét.,* Publ., 30.

Mörth, H. T. 1964. Five years of pressure analysis over tropical Africa. *Proc. Symp. Tropical Meteorology, Rotorua 1963:* 329-338.

Naguib, M. K. 1970. Precipitation in the UAR in relation to different synoptic patterns. *UAR Met. Dept. Bull. Met. Res.,* 2: 207-221.

Nahas, M. M. 1969. Desert Locust invasion to UAR during June-July, 1968. *UAR Minist. Agric., Tech. Bull.,* No. 16. 18 pp.

Nakamura, K. 1967. Climate of East Africa as related to equatorial westerlies. *Tokyo Metr. Univ., Geog. Reps.,* No. 2: 49-69.

Nakamura, K. 1968. Equatorial westerlies over East Africa and their climatological significance. *Tokyo Metr. Univ., Geog. Reps.,* 3: 43-61.

Neave, C. F. 1967. Tropical storm "Lilly", 19th April – 3rd May 1966: an account of its history and behaviour. *East Afr. Met. Dept., Memoirs,* 4.

Norris, M. J. 1954. Sexual maturation in the Desert Locust *Schistocerca gregaria* (Forskål) with special reference to the effects of grouping. *Anti-Locust Bull.,* London, 18. 44 pp.

NRI. 1990a. *Locust handbook*. Chatham, UK, Natural Resources Institute. 204 pp.

NRI. 1990b. *The Desert Locust pocket book*. Chatham, UK, Natural Resources Institute. 46 pp.

Otteson, P. S., Butrous, M., Corbett, M., Fossland, S., Jaffar, M., Johannessen, B., & Sander, T. 1999. Field tests on an integrated differential GPS navigation and spray monitoring system for aerial Desert Locust control operations. FAO Desert Locust Technical Series, AGP/DL/TS/29. Rome.

Papillon, M. 1960. Etude préliminaire de la répercussion du groupement des parents sur les larves nouveau – nées de *Schistocerca gregaria* Forsk. *Bull. Biol. Fr. Belg.,* 93: 203-263.

Pasquier, R. 1946. Les étapes de la vie de la sauterelle pèlerine. *Bull. Sem. Office Nat. Anti-Acridien,* Algér, 1: 7-13. Pasquier, R. 1952. Quelques propositions de terminologie acridologique. Premiére Note. Terminologie concernant le cornportement et l'aspect des Acrididae grégariaptes. *Arms. Inst. Agric. AIgér.,* 6. 16 pp.

Payne, S. W. & McGarry, M. M. 1977. The relationship of satellite inferred convective activity to easterly waves over West Africa and the adjacent ocean during phase III of GATE. *Mon. Wea. Rev.,* 105: 413-420.

Pédelaborde, P. & Delannoy, H., 1958. Recherches sur les types de temps et la mécanisme des pluies en Algerie. *Ann. Geog.,* 67: 216-244.

Pedgley, D. E. 1966. The Red Sea convergence zone. *Weather,* 21: 350-358, 394-406.

Pedgley, D. E. 1969. Cyclones along the Arabian coast. *Weather,* 24: 456-469.

Pedgley, D. E. 1970a. A heavy rainstorm over north-western Arabia. *Proc. Symp. Tropical Meteorology, Honolulu 1970,* E VII: 1-6. Amer. Met. Soc.

Pedgley, D. E. 1970b. An unusual monsoon disturbance over southern Arabia. *Proc. Symp. Tropical Meteorology, Honolulu 1970,* E VI: 1-6. Amer. Met. Soc.

Pedgley, D. E. 1970c. The climate of interior Oman. *Met. Mag.,* 99: 29-37.

Pedgley. D. E. 1972. Desert depressions over north-east Africa. *Met. Mag.,* 101: 228-244.

Pedgley, D. E. 1974a. An exceptional desert rainstorm at Kufra, Libya. *Weather,* 29: 64-71.

Pedgley, D. E. 1974b. Winter and spring weather at Riyadh, Saudi Arabia. *Met. Mag.,* 103: 225-236.

Pedgley, D. E. 1974c. ERTS surveys a 500 km^2 locust breeding site in Saudi Arabia. *In* Friden, S. C., Mercanti, E. P. & Becker, M. A., eds. *Third Earth Resources Technology Satellite – Symposium December 1973,* 1: 233-246. Maryland, National Aeronautics and Space Administration.

Pedgley, D. E. 1979. Weather during Desert Locust plague upsurges. *Phil. Trans. R. Soc. Lond.,* B287: 387-391.

Pedgley, D. E. & Krishnamurti, T. N. 1976. Structure and behavior of a monsoon cyclone over West Africa. *Mon. Wea. Rev.,* 104: 149-167.

Pedgley, D. E. & Symmons, P. M., 1968. Weather and the locust upsurge. *Weather,* 23: 484-492.

Pedgley, D. E. 1981a. *Desert Locust Forecasting Manual.* London, Centre for Overseas Pest Research. Vol I. viii + 268 pp.

Pedgley, D. E. 1981b. *Desert Locust Forecasting Manual.* London, Centre for Overseas Pest Research. Vol II 142 pp.

Phipps, J. 1949. The structure and maturation of the ovaries in British Acrididae (Orthoptera). *Trans. R. Ent. Soc. Lond.,* 100: 233-247.

Popov, G. [B.] 1948. Desert Locust in the Saudi-Arabian Tihama in 1947-1948. 30 pp. Centre for Overseas Pest Research. (Unpublished mimeograph).
Popov, G. B. 1954a. Notes on the behaviour of swarms of the Desert Locust *(Schistocerca gregaria* Forskål) during oviposition in Iran. *Trans. R. Ent. Soc. Lond.,* 105: 65-77.
Popov, G. [B.] 1954b. Investigations of suspected outbreak areas of the Desert Locust *(Schistocerca gregaria* Forskål) in Iran. *Anti-Locust Bull.,* London, 14. 30 pp.
Popov, G. B. 1958a. Ecological studies on oviposition by swarms of the Desert Locust *(Schistocerca gregaria* Forskål) in Eastern Africa. *Anti-Locust Bull.,* London, 31. 70 pp.
Popov, G. B. 1958b. Note on the frequency and rate of oviposition in swarms of the Desert Locust *(Schistocerca gregaria* Forskål). *Ent. Mon. Mag.,* London, 94: 167-180.
Popov, G. B. 1959. The Desert Locust *(Schistocerca gregaria* Forskål) in the island of Socotra. *J. Anim. Scol,* 28: 89-95.
Popov, G. [B.] 1965. Review of the work of the Desert Locust Ecological Survey June 1958 – March 1964. FAO Progress Report No. UNSF/DL/ES/8. 80 pp.
Popov, G. B. 1968. Report on the Niger Mission, 1965. FAO Progress Report No. UNDP (SF) DL/TS/2. 102 pp.
Popov, G. B. 1972. Outbreak of the African Migratory Locust in the Bornu Province of NE Nigeria, October-November 1970. *Centre for Overseas Pest Research, Misc. Rep.* No. 3. 7 pp.
Popov, G. B. 1988a. Sahelian grasshoppers. *Overseas Development Natural Resources Institute Bulletin,* No. 5.
Popov, G. [B.] 1988b. The locusts and grasshoppers of the Wahiba Sands. *J. Oman Studies Special Report,* 3.
Popov, G. B. 1989. *Nymphs of the Sahelian grasshoppers – an illustrated guide.* Chatham, Overseas Development Natural Resources Institute. 158 pp.
Popov, G. B., Duranton, J. F., & Gigault, J. 1991. *Etude écologique des biotopes du criquet pèlerin* Schistocerca gregaria *(Forskål, 1775) en Afrique nord-occidentale. Mise en évidence et description des unités territoriales écologiquement homogènes.* Montpellier, France, CIRAD/PRIFAS. 744 pp.
Popov, G. [B.] & Ratcliffe, M. 1968. The Sahelian Tree Locust, *Anacridium melanorhodon* (Walker). *Anti-Locust Mem.,* London, 9. 48 pp.
Pradhan, S. 1945. Rate of insect development under variable temperatures of the field. *Proc. Nat. Inst. Sci. India,* 11: 73-80.
Predtechenskii, S. A. 1935. Studies on the Desert Locust *(Schistocerca gregaria* Forsk.) in Central Asia and Transcaucasus in 1929-1930. [In Russian with English summary]. *Trudy Zashch. Rast.,* ser. Ent., 11. 92 pp.
Predtechenskii, S. A. 1938. The annual cycle of the Desert Locust *(Schistocerca gregaria* Forsk.) – its migrations and periodicity in Persia and adjacent countries of tropical and sub-tropical Asia. [English translation from] *Bull Pi. Prot.,* Leningrad, ser. 1, 12. 124 pp.
Rachadi, T. 1991. *Précis de lutte antiacrideienne – les pulvérsations d'insecticides.* Paris, CIRAD. Montpellier, PRIFAS. 312 pp.
Rainey, R. C. 1951. Weather and the movements of locust swarms: a new hypothesis. *Nature,* London, 168: 1057-1060.
Rainey, R. C. 1954. Recent arrival of Desert Locusts in the British Isles. *Proc. R. Ent. Soc. Lond.,* 19: 45-46.
Rainey, R. C. 1955. Observation of Desert Locust swarms by radar. *Nature,* London, 176: 77.
Rainey, R. C. 1958. The use of insecticides against the Desert Locust. *J. Sci. Fd. Agric.,* 9: 677-692.
Rainey, R. C. 1958b. Some observations on flying locusts and atmospheric turbulence in eastern Africa. *Quart J. R. Met. Soc.,* 84: 334-354.
Rainey, R. C. 1962. Some effects of environmental factors on movements and phase-change of locust populations in the field. *Colloques Int. Cent. Nat. Tech. Scient.,* 114: 175-199.
Rainey, R. C. 1963. Meteorology and the migration of Desert Locusts. *Anti-Locust Mem.,* London, 7. 115 pp. (Also as *Wld Met. Org. Tech. Note,* 54)
Rainey, R. C. 1965a. Seasonal and longer-period changes in the Desert Locust situation (with a note on a tropical cyclone affecting southern Arabia in 1948). *Wld Met. Org. Tech. Note,* 69: 255-264.
Rainey, R. C. 1955b. Report on advisory visits to Pakistan and India, July-August 1963. FAO Progress Report No. UNSF/DLP/RFS/3. 21 pp.
Rainey, R. C. 1967. Radar observations of locust swarms, *Science,* NY, 157: 98-99.
Rainey, R. C. 1988. Meteorology and the migration of Desert Locusts. *Wld Met. Org. Tech. Note,* 54.
Rainey, R. C. & Betts, E. 1979. Continuity in major populations of migrant pests: the Desert Locust and the African armyworm. *Phil. Trans. R. Ent. Soc. Lond.,* B287: 359-374.
Rainey, R. C., Betts, E., & Lumley, A. 1979. The decline of the Desert Locust plague in the 1960s: control operations or natural causes? *Phil. Trans. R. Ent. Soc. Lond.,* B287: 315-344.
Rainey, R. C. & Waloff, Z. 1948. Desert Locust migrations and synoptic meteorology in the Gulf of Aden area. *J. Anim. Ecol.,* 17: 101-112.
Raj Sircar, N. C. & Datar, S. V. 1963. Cold waves in northwest India. *Ind. J. Met. Geophys.,* 14: 315-319.
Ramamurthy, K. 1969. Some aspects of the "break" in the Indian southwest monsoon during July and August. *Forecasting Manual,* Part IV, Section 18.3. India Met. Dept.
Ramana Murty, B. H., Roy, A. K., Biswas, K. R, & Khemani, L. T. 1964. Observations on flying locusts by radar. *J. Sci. Ind. Res.,* 23: 289-296.
Ramaswamy, C. 1965. On a remarkable case of dynamical and physical interaction between middle and low latitude weather systems over Iran. *Ind. J. Met. Geophys.,* 16: 177-200.
Ramaswamy, C. & Kailasanathan, K. 1971. Prolonged spells of non-convective sandstorms in the Rajasthan desert during the southwest monsoon period. *Vayu Mandal,* 1: 78-83.
Ramiarasoa, A. 1969. Les pluies exceptionnelles de décembre 1964 sur la Haute Volta. *A. Sec. N. A., Div. Expl. Mét.,* Publ. No. 11.
Rao, M. S. V., Srinivasan, V. & Raman, S. 1970. Southwest monsoon – typical situations over northwest India. *Forecasting Manual,* Part III, Section 3.3. India Met. Dept.

Rao, Y. P. 1976. Southwest monsoon. *India Met. Dept., Met. Monog. Synop,* Met. No. 1.
Rao, Y. P. & Srinivasan, V. 1989. Winter western disturbances and their associated features. *Forecasting Manual,* Part III, Section 1.1. India Met. Dept.
Rao, Y. P., Srinivasan, V. & Raman, S. 1970. Effect of middle latitude westerly systems on Indian monsoon. *Proc. Symp, Tropical Meteorology, Honolulu 1970,* N IV: 1-4. Amer. Met. Soc.
Rao, Y. Ramchandra 1937. Some outbreak centres of *Schistocerca* in Mekran. *Proc. 4th Inst. Locust Conf., Cairo,* App. 30. 9 pp.
Rao, Y. Ramchandra 1942. Some results of studies on the Desert Locust *(Schistocerca gregaria* Forsk.) in India. *Bull. Ent. Res.,* 33: 241-265.
Rao, Y. Ramchandra 1954. An unusual appearance of Desert Locust swarms on the Malabar Coast in October 1962. *Current Sci.,* 23: 248-251.
Rao, Y. Ramchandra 1960. The Desert Locust in India, *Monogr, Ind. Coun. Agric. Res.,* 21. 721 pp.
Reed, R. J., Norquist, D. C. & Racker, E. E. 1977. The structure and properties of African wave disturbances as observed during Phase III of GATE. *Mon. Wea. Rev.,* 105: 317-333.
Régnier, P. R. 1931. Les invasions d'acridiens au Maroc de 1927 à 1931. *Dir. Gén. Agric. Comm. Colonis, Déf. des Cult.,* Rabat, 3. 139 pp.
Reus, J. A. W. A. & Symmons, P. M. 1992. A model to predict the incubation and nymphal development periods of the desert locust, *Schistocerca gregaria* (Orthoptera: Acrididae). *Bull. Ent. Res.,* 82: 517-520.
Ritchie, M. & Pedgley, D. 1989. Desert locust across the Atlantic. *Antenna*, 13: 10-12.
Ritchie, M. & Dobson, H. 1995. Desert locust control operations and their environmental impacts. NRI Bulletin, No. 67. Chatham, ODA/NRI.
Roessingh, P., Simpson, S. J. & James, S. 1993. Analysis of phase-related changes in behaviour of desert locust nymphs. *Proc. R. Ent. Soc. Lond.,* B252: 43-49.
Roessingh, P. & Simpson, S. J. 1994. The time-course of behavioural phase change in nymphs of the desert locust, *Schistocerca gregaria*. *Physiol. Entomol.,* 19: 191-197.
Roffey, J. 1963. Observations on night flight in the Desert Locust *(Schistocerca gregaria* Forskål). *Anti-Locust Bull.,* London, 39. 32 pp.
Roffey, J. 1965. Part III. Locust Surveys *In* FAO Final Report of the Operational Research Team of the United Nations Special Fund Desert Locust Project. UNSF/DL/OP/5-5bis. Rome.
Roffey, J. 1969. Radar studies on the Desert Locust, *Schistocerca gregaria* (Forskål), in the Niger Republic September-October 1969, *Anti-Locust Res. Cent., Occ. Rep.,* 17. 14 pp.
Roffey, J. 1979. Developments in the Desert Locust situation during 1976-9. *Phil. Trans. R. Ent. Soc. Lond.,* B287: 479-488.
Roffey, J. 1982. The Desert Locust upsurge and its termination 1977-79. *In* FAO Desert Locust Technical Series, AGP/DL/TS/23: 1-74. Rome.
Roffey, J. & Magor, J. I. 2001. Desert Locust population parameters. FAO Desert Locust Technical Series, AGP/DL/TS/30. Rome. (in press)
Roffey, J. & Popov, G. R. 1968. Environmental and behavioural processes in a Desert Locust outbreak. *Nature,* London, 219: 446 450.

Roffey, J., Popov, G. & Hemming, C. F. 1970. Outbreaks and recession populations of the Desert Locust, *Schistocerca gregaria* (Forsk.). *Bull. Ent. Res.,* 59: 675-680.
Roffey, J. & Stower, W. J. 1983. Numerical changes in the Desert Locust, *Schistocerca gregaria* (Forskål), in a seasonal breeding area on the coasts of Eritrea, Ethiopia, with special reference to ecology and behaviour. FAO Desert Locust Technical Series, AGP/DL/TS/24. Rome.
Roonwal, M. L. 1954. Size, sculpturing, weight and moisture content of the developing eggs of the Desert Locust, *Schistocerca gregaria* (Forskål) (Orthoptera, Acrididae). *Proc. Nat. Inst. Sci. India,* 20: 388-398.
Rosenberg, L. J. & Burt, P. J. A. 1999. Windborne displacements of Desert Locusts from Africa to the Caribbean and South America. *Aerobiologia,* 15: 167-175.
Roy, J. 1982. Report on the Operational Research Team's work in Pakistan from 11 July to 12 August, and in India from 13 August to 25 September 1962. FAO Progress Report No. UNSF/DL/OP/1. 21 pp.
Rungs, C. 1946. Rapport sur les essais de lutte contre les adultes de *Schistocerca gregaria* Forsk. au Maroc français, au printemps de 1945. *Bull. Sem. Off. Nat. Anti-acrid.,* Algiers, 2: 41-87.
Rungs, C. 1954. Une nouvelle représentation graphique de la grégariosité des populations de Criquet Pèlerin, *Schistocerca gregaria* Forsk. *C. R. Soc. Sciences Naturelles et Physiques du Maroc,* 6: 130-132.
Rutter, J. & Bullen, F. T. 1997. Distribution of the damage potential of the Desert Locust (*Schistocerca gregaria* Forsk): Crop vulnerability index, geographical information system, guidelines and user manual. Chatham, UK, NRI.
Sayer, H. J. 1956. A photographic method for the study of insect migration. *Nature,* London, 177: 226.
Sayer, H. J, 1962 The Desert Locust and tropical convergence. *Nature,* London, 194: 330-336.
Schaefer, G. W. 1972. Radar detection of individual locusts and swarms. *In* Hemming, C. F. & Taylor, T. H. C., eds. *Proc. Int. Study Conf. Current and Future Problems of Acridology, London 1970:* 379-380. London, Centre for Overseas Pest Research.
Schaefer, G. W. 1976. Radar observations of insect flight. *In* Rainey, R. C., ed. *Insect flight, Sym. R. Ent. Soc. Lond.,* 7: 157-197.
Shenk, W. E. & Curran, R. J. 1974. The detection of dust storms over land and water with satellite visible and infrared measurements. *Mon. Wea. Rev.,* 102: 830-837.
Shulov, A. 1952. The development of eggs of *Schistocerca gregaria* (Forskål) in relation to water. *Bull. Ent. Res., 43:* 469-476.
Shulov, A. & Pener, M. P. 1963. Studies on the development of eggs of the Desert Locust *(Schistocerca gregaria* Forskål) and its interruption under particular conditions of humidity. *Anti-Locust Bull.,* London, 41. 59 pp.
Siddiqi, K. 1965. Influence of meteorological factors on the behaviour of the Desert Locust. *Wld Met. Org. Tech. Note,* 69: 189-193.
Singh, B. & Venkatesh, M. V. 1972. A field guide for determining the period to fledging of hoppers of the Desert Locust, *Schistocerca gregaria* Forsk., in Bikaner region. FAO Progress Report No. AGP/DL/TS/11: 68-79.
Singh, G. 1952. Formation of incipient swarms of the Desert Locust in India in 1949. *Indian J. Ent.,* 13: 109-116.
Singh, G. & Bhatia, K. R. 1952. Population density of hopper bands of the Desert

Locust *(Schistocerca gregaria* Forsk.) in different instars. *Indian J. Ent.,* 14: 161-164.
Singh, M. S. 1963. Upper air circulation associated with western disturbance. *Ind. J. Met. Geophys.,* 14: 156-172.
Sinha, P. P. & Chandra, S. 1985. Monitoring desert locust breeding habitats through satellite imagery. *Plant Prot. Bull.,* 37(3&4): 1-3.
Sinha, P. P. & Chandra, S. 1988. Locust habitat mapping in western part of Rajasthan through satellite imagery. *Plant Prot. Bull.,* 40: 5-9.
Sissons, T. 1966. Some examples of synoptic situations which affect East Africa. *Weather,* 21: 228-231, 260-262, 298-300, 319-320.
Skaf, R. 1978. Etude sur le cas de grégarisation du criquet pèlerin en 1974 dans le sud-ouest mauritanien et au Tamesna rnalien. FAO Report No. AGP/DL/TS/17. 46 pp.
Skaf, R. 1986. Current problems of locust and grasshopper control in developing countries. *Proceedings of 4th triennial meeting, Pan Amer. Acridol. Soc., 28 July - 2 August 1985*: 221-228.
Skaf, R. 1988. A story of a disaster: why locust plagues are still possible. *Disasters*, 12: 122-127.
Skaf, R. 1990. The development of a new plague of the Desert Locust *Schistocerca gregaria* (Forskål) (Orthoptera: Acrididae) 1985-1989. *Bol. San. Veg. Plagas,* 20: 59-66.
Skaf, R., Popov, G. B., & Roffey, J. 1990. The Desert Locust: an international challenge. *Phil. Trans. R. Ent. Soc. Lond.,* B328: 525-538.
Steedman, A., 1977. Movements of swarms of the Desert Locust, *Schistocerca gregaria* (Forsk.), across the northern Red Sea. *Acrida,* 6: 109-140.
Steedman, A., ed. 1988. *Locust Handbook (2nd edition)*. London, ODNRI. 180 pp.
Stolyarov, M. L. 1964. *Schistocerca gregaria* Forsk. (Orthoptera, Acrididae) in Turkmenia, summer 1962. [in Russian] *Ent. Obozr.,* 43: 21-31. [English translation: *Ent. Rev.,* Washington, DC, 43: 9-15.]
Stower, W. J. 1959. The colour patterns of hoppers of the Desert Locust *(Schistocerca gregaria* Forskål). *Anti-Locust Bull.,* London, 32. 75 pp.
Stower, W. J., Davies, D. E. & Jones, I. B. 1960. Morphometric studies of the Desert Locust, *Schistocerca gregaria* (Forskål). *J. Anim. Ecol.,* 29: 309-339.
Stower, W. J. & Greathead, D. J. 1969. Numerical changes in a population of the Desert Locust, with special reference to factors responsible for mortality. *J. Appl. Ecol.,* 6: 203-235.
Stower, W. J. & Griffiths, J. F. 1966. The body temperature of the Desert Locust. *Entomologia Exp. Appl.,* 9: 127-178.
Stower, W. J., Popov, G, B. & Greathead, D. J. 1958. Oviposition behaviour and egg mortality of the Desert Locust *(Schistocerca gregaria* Forskål) on the coast of Eritrea. *Anti-Locust Bull.,* London, 30. 33 pp.
Swaminathan, D. R. 1969. Large-scale convection over central parts of India in relation to “subtropical jet stream wave”. *Ind. J. Met. Geophys.,* 20: 247-252.
Symmons, P. M. 1978. The prevention of plagues of the Red Locust, *Nomadacris septemfasciata* (Sew.). *Acrida,* 7: 55-78.
Symmons, P. M. 1992. Strategies to combat the desert locust. *Crop Protection*, 11: 206-212.
Symmons, P. M., Dobson, H. M. & Sissoko, M. 1991. Pesticide droplet size and efficacy: a series of trials on grasshoppers. *Crop Protection*, 10: 136-144.

Symmons, P. M., Green, S., Robertson, R. A. & Wardhaugh, K. G. 1973. *Incubation and hopper development periods of the Desert Locust.* (156 sheets and 11 pp. guide). London, Centre for Overseas Pest Research.
Symmons, P. M., Green, S. M., Robertson, R. A. & Wardhaugh, K. G. 1974. The production of distribution maps of the incubation and hopper development periods of the Desert Locust *Schistocerca gregaria* (Forsk.) (Orthoptera, Acrididae). *Bull. Ent. Res., 64: 443-451.*
Symmons, P. M. & van Huis, A. 1997. *Desert Locust control campaign studies: operation guidebook.* GTZ and WAU Desert Locust Studies. Wageningen Agriculture University, Dept of Entomology.
Tantawy, A. H. I. 1964a. The role of the jet stream in the formation of desert depressions in the Middle East. *Wld Met. Org. Tech. Note,* 64: 159-171.
Tantavw, A. H. I. 1964b The role of the jet stream in the development of autumn thunderstorms in the Middle East. *Wld Met. Org. Tech. Note,* 64: 172-185.
Tappan, G. G., Moore, D. G. & Knausenberger, W. I. 1991. Monitoring grasshopper and locust habitats in Sahelian Africa using GIS and remote sensing technology. *Int. J. Geographical Information Systems,* 5: 123-135.
Thesiger, W. 1950-1951. Desert borderlands of Oman. *Geographical J.,* 116-117: 137-172.
Toffolon, C. 1960. Report of the FAO mission to Yemen. FAO, Rome.
Tsyplenkov, E. P. 1978. *Harmful acrfdloidea of the USSR.* [Translated from the Russian edition (1970) by R. S. Chakravarthy. New Delhi, Amerind. 208 pp.]
Tucker, C. J., Hielkema, J. U. & Roffey, J. 1985. The potential of satellite remote sensing of ecological conditions of survey and forecasting Desert Locust activity. *Int. J. Remote Sensing,* 6: 127-138.
Tucker, M. R. 1976. Synoptic meteorology and the forecasting of Desert Locust swarm migrations. (Unpublished typescript, M.Sc. thesis, University of Bristol).
Tucker, M. R. & Pedgley, D. E. 1977a. Synoptic disturbances over the Nile valley north of the intertropical convergence zone. *Tellus,* 29: 17-24.
Tucker, M. R, & Pedgley, D. E. 1977b. Summer winds around the southern Red Sea. *Arch. Met. Geoph. Biokl.,* B 25: 221-231.
US Congress, Office of Technical Assessment. 1990. A plague of locusts – Special Report, OTA-F450. Washington, DC, US Government Printing Office.
Uvarov, B. P. 1921. A revision of the genus *Locusta, L. (=Pachytylus,* Fieb.), with a new theory as to the periodicity and migrations of locusts. *Bull. Ent. Res.,* 12: 135-163.
Uvarov, B. P. 1933a. The locust outbreak in Africa and Western Asia, 1925-31. Economic Advisory Council, Committee on Locust Control, London, HMSO, 62-80. 87 pp.
Uvarov, B. P. 1933b. The locust outbreak in Africa and Western Asia in 1932. Economic Advisory Council, Committee on Locust Control, London, HMSO, 63-80-2. 74pp.
Uvarov, B. P. 1934. The locust outbreak in Africa and Western Asia in 1933. Economic Advisory Council, Committee on Locust Control, London, HMSO, 63-80-3. 66 pp.
Uvarov, B. P. 1951 Locust research and control, 1929-1950. *Colon. Res.,* London, 10. 67 pp.

Uvarov, B. [P.] 1966. *Grasshoppers and locusts. A handbook of general acridology.* Vol I. xi + 481 pp. Cambridge, Cambridge University Press.

Uvarov, B. P. 1977. *Grasshoppers and locusts. A handbook of general acridology.* Vol II. ix + 613 pp. London, Centre for Overseas Pest Research.

Van der Valk, H. C. H. G. 1998. The impact of locust and grasshopper control on beneficial arthropods in West Africa. *In* Haskell, P.T. & McEwen, P., eds. *Ecotoxicology: pesticides and beneficial organisms*, p. 372-380. London, Chapman and Hall.

Van der Valk, H. C. H. G., Niassey, A., & Bèye, A. B. 1999. Does grasshopper control create grasshopper problems? Monitoring side-effects of fenitrothion applications in the western Sahel. *Crop Protection,* 18: 139-149.

Van Huis, A., ed. 1994. Desert Locust control with existing techniques – an evaluation of strategies. *Proceedings of the Seminar held in Wageningen, the Netherlands, 6-11 December 1993.* Wageningen Agricultural University.

Van Huis, A. 1995. Desert Locust plagues. *Endeavour,* New Series*,* 19: 118-124.

Venkatesh, M. V., Singh, Brajendra & Singh, Dharampal. 1972. A ready reckoner of Desert Locust egg and hopper development periods in Bikaner region. FAO Progress Report No. AGP/DL/TS/10: 7-14.

Vittal Sarma, V. 1968. On the southerly movement of the Arabian Sea storm, November 1964. *Ind. J. Met. Geophys,* 19: 73-80.

Vittori, A. 1969. Note sur les invasions polaires en altitude sur le Sénégal et la Mauritanie. *A. Sec. N. A., Dir. Expl. Mét.,* Publ. No. 10.

Volkonsky, M. 1938. Possibilité de changement de phase à l'état imaginal chez le criquet pèlerin *(Schistocerca gregaria* Forsk.). *C. R. Soc. Biol.,* 127: 583-585.

Volkonsky, M. A. & Volkonsky, M. T. 1939. Rapport préliminaire sur une mission d'étude des acridiens dans le Mouydir et le Tademait (mai-juillet 1939). *Archs. Inst. Pasteur Algér.,* 17: 634-649.

Waloff, N. & Popov, G. B. 1990. Sir Boris Uvarov (1889-1970). *Ann. Rev. Entomol.,* 35: 1-24.

Waloff, Z. 1946a. A long-range migration of the Desert Locust from southern Morocco to Portugal, with an analysis of concurrent weather conditions. *Proc. R. Ent. Soc. London.,* A 21: 81-84.

Waloff, Z. 1946b. Seasonal breeding and migrations of the Desert Locust *(Schistocerca gregaria* Forskål) in eastern Africa. *Anti-Locust Mem.,* London, 1. 74 pp.

Waloff, Z. 1958. The behaviour of locusts in migrating swarms. (Abstr.) *10th Int. Congr. Ent., Montreal 1956,* 2: 587-569.

Waloff, Z. 1960. Some notes on the Desert Locust and its occurrence at sea. *Mar. Obsr.,* London, 30: 40-45.

Waloff, Z. 1963. Field studies on solitary and *transiens* Desert Locusts in the Red Sea area*, Anti-Locust Bull.,* London, 40. 93 pp.

Waloff, Z. 1966. The upsurges and recessions of the desert locust plague: an historical survey. *Anti-Locust Mem.,* London, 8. 111 pp.

Waloff, Z. 1972a. The plague dynamics of the Desert Locust, *Schistocerca gregaria* (Forsk.) *In* Hemming, C. F. & Taylor, T. H. C., eds. *Proc. Int. Study Conf. Current and Future Problems of Acridology, London 1970: 343-349.* London, Centre for Overseas Pest Research.

Waloff, Z. 1972b. Orientation of flying locusts, *Schistocerca gregaria* (Forsk.), in migrating swarms. *Bull. Ent. Res.,* 62: 1-72.

Waloff, Z. 1972c. Observations on the airspeeds of freely flying locusts. *Anirn. Beh.,* 20: 367-372.

Waloff, Z. 1976. Some temporal characteristics of Desert Locust plagues, with a statistical analysis by S. M. Green, *Anti-Loc. Mem.,* London, 13. 36 pp.

Waloff, Z. & Rainey, R. C. 1951. Field studies on factors affecting the displacements of Desert Locust swarms in eastern Africa. *Anti-Locust Bull.,* London, 9: 1-50.

Ward, M. N., Folland, C. K., Maskell, K., Owen, J. A., & Rowell, D. P. 1990. Forecasting Sahel rainfall – an update. *Weather*, 45: 122-125.

Wardhaugh, K. G. 1964. Notes on the rates of development of the Desert Locust under field conditions. (Mimeographed notes prepared for the Fourth Symposium on the Rates of Development of the Desert Locust in Relation to Environmental Factors held in Cairo 6-13 April 1964.)

Wardhaugh, K. G., Ashour, Y., Ibrahim, A. O., Khan, A. M, & Bassonbol, M. 1969. Experiments on the incubation and hopper development periods of the Desert Locust *(Schistocerca gregaria* Forskål) in Saudi Arabia. *Anti-Locust Bull.,* London, 45. 38 pp.

Weis-Fogh, T. 1952. Fat combustion and metabolic rate of flying locusts *(Schistocerca gregaria* Forskål). *Phil. Trans. R. Ent. Soc. Lond.,* B237: 1-36.

Weis-Fogh, T. 1956. Biology and physics of locust flight. II. flight performance of the Desert Locust *(Schistocerca gregaria). Phil. Trans. R. Ent. Soc. Lond.,* B239: 459-510.

Wewetzer, A., Krall, S. & Schultz, F. A. 1993. *Methods for the assessment of crop losses due to grasshopper and locusts.* Eschborn, Germany, GTZ. 54 pp.

Winstanley, D. 1970. The North African flood disaster, September 1969. *Weather,* 25: 390-403.

WMO. 1965. Meteorology and the Desert Locust. *Wld Met. Org. Tech. Note,* 69. 310 pp.

Zohdy, H. 1969. Cold outbreaks and winter rainfall in Yemen. *UAR Met. Dept, Met. Res. Bull.,* 1: 133-148.

Index

*Tip: the letters in bold (with page numbers after them) refer to the individual guidelines as follows: **B** = Biology and Behaviour, **S** = Survey, **F** = Information and Forecasting, **C** = Control, **O** = Campaign Organization and Execution, **A** = Appendixes. For example **B** 3, 5 means pages three and five in the Biology and Behaviour guideline.*

Index

Tip: the letters in bold (with page numbers after them) refer to the individual guidelines as follows: ***B*** *= Biology and Behaviour,* ***S*** *= Survey,* ***F*** *= Information and Forecasting,* ***C*** *= Control,* ***O*** *= Campaign Organization and Execution,* ***E*** *= Safety and Environmental Precautions,* ***A*** *= Appendixes. For example* ***B*** *3, 5 means pages three and five in the Biology and Behaviour guideline.*

Tip: the letters in bold (with page numbers after them) refer to the individual guidelines as follows: ***B*** *= Biology and Behaviour,* ***S*** *= Survey,* ***F*** *= Information and Forecasting,* ***C*** *= Control,* ***O*** *= Campaign Organization and Execution,* ***E*** *= Safety and Environmental Precautions,* ***A*** *= Appendixes. For example* ***B*** *3, 5 means pages three and five in the Biology and Behaviour guideline.*

Tip: the letters in bold (with page numbers after them) refer to the individual guidelines as follows: ***B*** *= Biology and Behaviour,* ***S*** *= Survey,* ***F*** *= Information and Forecasting,* ***C*** *= Control,* ***O*** *= Campaign Organization and Execution,* ***E*** *= Safety and Environmental Precautions,* ***A*** *= Appendixes. For example* ***B*** *3, 5 means pages three and five in the Biology and Behaviour guideline.*

*Tip: the letters in bold (with page numbers after them) refer to the individual guidelines as follows: **B** = Biology and Behaviour, **S** = Survey, **F** = Information and Forecasting, **C** = Control, **O** = Campaign Organization and Execution, **E** = Safety and Environmental Precautions, **A** = Appendixes. For example **B** 3, 5 means pages three and five in the Biology and Behaviour guideline.*

Tip: the letters in bold (with page numbers after them) refer to the individual guidelines as follows: ***B*** *= Biology and Behaviour,* ***S*** *= Survey,* ***F*** *= Information and Forecasting,* ***C*** *= Control,* ***O*** *= Campaign Organization and Execution,* ***E*** *= Safety and Environmental Precautions,* ***A*** *= Appendixes. For example* ***B*** *3, 5 means pages three and five in the Biology and Behaviour guideline.*

Tip: the letters in bold (with page numbers after them) refer to the individual guidelines as follows: ***B*** *= Biology and Behaviour,* ***S*** *= Survey,* ***F*** *= Information and Forecasting,* ***C*** *= Control,* ***O*** *= Campaign Organization and Execution,* ***E*** *= Safety and Environmental Precautions,* ***A*** *= Appendixes. For example* ***B*** *3, 5 means pages three and five in the Biology and Behaviour guideline.*

*Tip: the letters in bold (with page numbers after them) refer to the individual guidelines as follows: **B** = Biology and Behaviour, **S** = Survey, **F** = Information and Forecasting, **C** = Control, **O** = Campaign Organization and Execution, **E** = Safety and Environmental Precautions, **A** = Appendixes. For example **B** 3, 5 means pages three and five in the Biology and Behaviour guideline.*

Tip: the letters in bold (with page numbers after them) refer to the individual guidelines as follows: ***B*** *= Biology and Behaviour,* ***S*** *= Survey,* ***F*** *= Information and Forecasting,* ***C*** *= Control,* ***O*** *= Campaign Organization and Execution,* ***E*** *= Safety and Environmental Precautions,* ***A*** *= Appendixes. For example* ***B*** *3, 5 means pages three and five in the Biology and Behaviour guideline.*

Tip: the letters in bold (with page numbers after them) refer to the individual guidelines as follows: ***B*** *= Biology and Behaviour,* ***S*** *= Survey,* ***F*** *= Information and Forecasting,* ***C*** *= Control,* ***O*** *= Campaign Organization and Execution,* ***E*** *= Safety and Environmental Precautions,* ***A*** *= Appendixes. For example* ***B*** *3, 5 means pages three and five in the Biology and Behaviour guideline.*

*Tip: the letters in bold (with page numbers after them) refer to the individual guidelines as follows: **B** = Biology and Behaviour, **S** = Survey, **F** = Information and Forecasting, **C** = Control, **O** = Campaign Organization and Execution, **E** = Safety and Environmental Precautions, **A** = Appendixes. For example **B** 3, 5 means pages three and five in the Biology and Behaviour guideline.*

*Tip: the letters in bold (with page numbers after them) refer to the individual guidelines as follows: **B** = Biology and Behaviour, **S** = Survey, **F** = Information and Forecasting, **C** = Control, **O** = Campaign Organization and Execution, **E** = Safety and Environmental Precautions, **A** = Appendixes. For example **B** 3, 5 means pages three and five in the Biology and Behaviour guideline.*