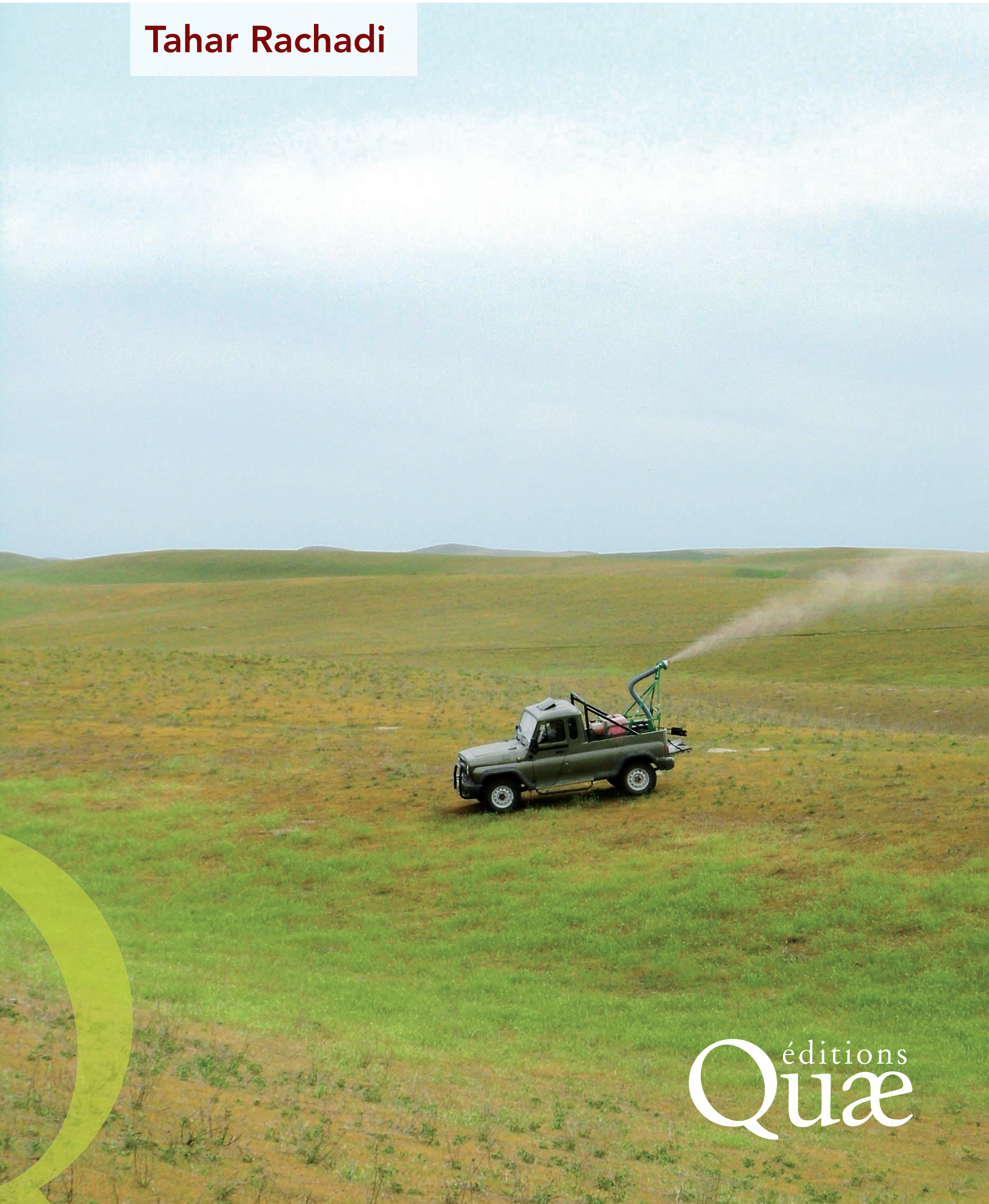
Guide pratique

Locust control handbook

Tahar Rachadi



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Contents

Introduction

Availability of food in many developing countries is tenuous at best due to increasing population and climatic change which creates further challenges in what are often already marginal conditions for food production. Locust outbreaks and grasshopper outbreaks can dramatically reduce crop yields and instigate mass food shortage.

Apart from emergency situations in which the International Community plays an active role, locust and grasshopper control should be organised at local and national levels. Furthermore, management at the regional level is appropriate for countries which are likely to be affected by perennial outbreaks. At the time of the 1987-1989 Desert locust plague, large amounts of insecticides were sprayed on millions of hectares. The impact on the environment of such large scale applications is significant and therefore appropriate application techniques to minimise adverse effects and maximise control are critical.

Under these circumstances, applications of insecticides in locust control should be undertaken under optimal conditions of efficacy. That requires a multi-disciplinary approach, which combines entomology application techniques and socio-economics, together with the need to preserve the environment. The range of locust control operations, from individual farmer intervention to the use of aircraft, should also be considered. Of course it is imperative to prevent upsurges by controlling large scale locust outbreaks but that should not be done at any cost. It is essential to maximize the efficacy of the pesticides to reduce the quantity required for control.

From this point of view, enhancing and improving application techniques becomes an **economic and environmental necessity.**

Most of the documents and practical books devoted to locust control deal mainly with insecticides. There are a few which show how pesticides should be applied. It is obvious that good results cannot be expected if a product is spread with a watering can, because the active ingredient must be uniformly distributed on the whole area to be protected. It is however less apparent that a wide droplet spectrum spray can be equally wasteful. Very small droplets can drift far from the target (**exodrift**) and large drops will tend to fall directly on the soil (**endodrift**). Both have a negative effect on the environment and do not accurately target the locust pest itself. Therefore it is essential to understand the application process in locust control as the most appropriate techniques are not always readily understood.

Both safety and effectiveness of pesticide use are to a large extent, determined by their method of application. In most cases of locust control, pesticides are applied using rotary atomisers to create a mist of small uniform sized droplets. The range of spraying equipment available is relatively sophisticated, thus requiring a high level of maintenance, training and skill in operation. By understanding the nature of locust and grasshopper outbreaks and the challenges involved in control, researchers can assist in improving current practices of pesticide application, increase control efficacy and improve safety for operators. Furthermore, an increase in control efficacy will result in a reduced pesticide use, lower costs and less environmental impact.

Since the discovery of synthetic insecticides, application techniques for locust control have developed rapidly. Pesticides have over the years become more potent and specific and therefore demand more precision in application. Application equipment has also dramatically improved thanks to the development of new materials and technologies. This resulted in significant improvement of ultra low volume (ULV) equipment and today it is widely used in aerial and ground spraying. During the 80’s, more than 90 % of locust control applications were performed by implementing this technique, while water-based spraying, baits and dusting applications were negligible. Therefore the ULV technique and its equipment is an important tool in locust control and this book attempts to provide operators with a useful and practical manual, to guide them in the application process.

To be effective, any crop protection treatment should be applied at the right moment, in the right place, using the relevant product with the correct equipment, which should be well calibrated before application.

These precautions are crucial to avoid misapplications which lead to:
- a dramatic increase in application costs;
- a costly waste of chemicals, potentially hazardous for humans and the environment;
- increased risk to operators and non target organisms;
- excessive residues that contaminate the environment.

Poor calibration of equipment has other consequences. Failures in applications are often mistakenly attributed to failure of products. Sometimes when a treatment looks ineffective, operators overdose or apply multiple treatments.

This manual is intended to address application errors and the misuse of pesticides. The first section is concerned with the principles of ULV application addressing issues of droplet generation and meteorology. The second section introduces the various types of aerial and ground application equipment and the third section is concerned with operational procedures to maximise control efficacy, operator and environmental safety and minimise waste.

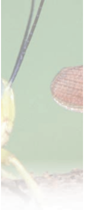
Spraying Principles

The application of crop protection products involves the atomisation of spray liquid into numerous droplets which are then dispersed over the target area. However, this definition is simplistic. To achieve accurate distribution on the target area requires the production of spray droplets of an appropriate size, neither too large which fall out onto the ground or too small which drift off target.
It is therefore important to understand the mechanics of spray droplet formation in order to understand how to select the most appropriate equipment and to teach operators to correctly calibrate and use only the minimal quantity of pesticide required to achieve control.
This chapter consists of five parts:

- The **target** and **active ingredient**. This section intends to define the locust or grasshopper target and its characteristics to find out the best way to reach this target.
- The **distribution and deposition of spray droplets**. This section discusses the droplet generation and methods of spray deposit assessment.
- **Spray volumes**. The description of spraying modes make it possible to prevent ambiguities which often induce wrong choice of anti-locust equipments.
- **Droplet transport**. The study of these concepts reveals the importance of the action of atmospheric agents upon spraying, particularly ULV technique. A good knowledge of atmospheric phenomena is essential to correctly perform ULV spraying.
- **Assessment of the spray quality**. The aim is to ensure that a spray is in accordance with the requirement and rectify any calibration error.

Target and active ingredient

To be efficient, a crop protection application should, at first, define the target in terms of time and space. A spray treatment will be most efficient if it is applied when the target pest is most susceptible, which requires knowledge of the target pest biology and behaviour. The space in which the target pest moves during the residual activity period of a given pesticide, should be understood. In fact, a given number of hoppers do not cover the same area as the equivalent number of flying locusts. The approach adopted with a locust should not be the same as for another locust or grasshopper.



Pesticide that does not reach its target is wasted and is an economic loss and an unnecessary hazard to the environment. Therefore, a good application should aim at achieving the maximum control with **minimum contamination of non target area.** This means that an application technique should attempt to reduce the quantity of pesticide while raising the quantity that actually reaches the target. This implies reducing leaching and uncontrolled drift. Whatever the pesticide, its mode of action should be known because all active ingredients are not the same. Contact acting, for example pyrethroids and organophosphates should not be applied in the same manner as IGRs (Insect Growth Regulators). To be efficient the contact acting pesticides must target the insect directly while the latter affects insects only after ingestion of contaminated vegetation. These data and the environmental characteristics should be considered for defining the spraying parameters which ensure the best way to attain the acridid target.
Except settled swarms or isolated hopper bands, the locust or grasshopper target generally consists of scattered population (scattered adults, scattered hopper bands) and the most frequent approach is to spray a defined area in which the insects wander, rather than treating directly the insects. In this case it is better to call it a **target area.**
Defining the target in terms of both time and space and the dose is the main factor for defining the objective of the treatment.
The locust target to be determined can be under three biological stages: egg, larvae (hoppers) or imago (adult). Being buried in the soil, the eggs are sheltered from sprayed insecticides. Hence it is hoppers and adults that constitute the locust target.

To define the locust target, several factors should be considered:

Threat

The threat posed by a locust infestation must be considered in both immediate and future time frame. Thereby the threat of a grasshopper population should be assessed according to the proximity and the susceptibility of susceptible crops; e.g. a field of millet is very susceptible at the emergence and grain formation stages. In contrast, a population of locust will be considered an appropriate target, as soon as it attains the gregarious stage, even when it is hundreds of kilometres away from any crop. This may seem disproportionate with regards to the evidence of damages.

Susceptibility

Hoppers, mainly young instars are reputed to be more susceptible than adults. The fact that they do not move very far makes them easier to control. Hoppers and adults may be more easily controlled in an open field rather than in a shrubby area or under a canopy.

Mobility

Locust adults may fly over tens or even hundreds of kilometres per day. During their life they may traverse thousands of kilometres. Swarms are good targets only when they settle, especially if they are less mobile when cold. Under hot conditions, the target is three-dimensional and fleeting. The same swarm can be seen in many places almost at the same time. In that case the biological target is capable of moving more rapidly than survey and control teams.

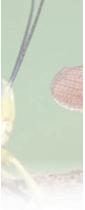
Hoppers are less mobile than adults as they only move by marching or leaping. Thus they form a more practical target. Hopper bands may march up to several kilometres per day. They constitute a relatively sedentary target for a few weeks which once located are easy to follow and treat.

Size

Within a uniform habitat where target outlines are similar, adults and nymphs of grasshoppers generally occupy the same space, whereas the area occupied by a swarm markedly varies during the day with temperature, wind, air stability, the nature and the structure of plant canopy and also with locust activity. Besides, it is frequent that a swarm infests an area twenty times larger than that covered by the hopper band from which it was originated. An inappropriate approach to treating a large swarm may result in partial efficacy and a fragmentation into isolated swarms, thereby creating many other targets covering a larger area and therefore much more difficult to control.

Hopper bands of locusts are often very dense, particularly at the young instar stages. Several thousand per square metre are often observed. The area covered by a hopper band may vary from less than a square metre to hundreds of hectares (fig. 1). They may break up into smaller bands but rarely disperse by individual means. Hopper bands are good target easy to define once located.

Figure 1. A hopper band of Desert locust (5th instar) crossing a road in Senegal (October 1988). Hopper bands of Desert locust may have a density of several hundreds of hoppers per square metre and may cover tens of hectares.



Droplet dispersal and deposit

Active ingredient and dose rate

A spray is a means to disperse, as evenly as possible, a given amount of active ingredient on a given area referred to as a dose rate and often expressed as grams of active ingredient per hectare (g a.i./ha).
Locust control operation should first ensure that the correct dose is applied. Control staff should particularly refrain from the tendency to spray over dose where locust density is high. In contrast they should not under dose in areas of low density.

Spray volume

The need to rapidly treat large areas particularly during Desert locust plagues, necessitates the implementation of considerable logistic resources. The need to apply products quickly had led to the development of Ultra Low Volume application technique to eliminate the need to mix products in water and treat vast areas quickly.
Research with the exhaust nozzle sprayer (ENS) demonstrated that efficacy was improved by reducing the volume applied as droplet size decreased and droplet number increased. **Consequently, utilizing a uniform spray with a small droplet size is much more efficacious than applying a higher volume of liquid.**
Classifications of sprays according to the volume applied per hectare are based on subjective criteria. The following classification distinguishes five types (tab. I): **high volume** (HV), **medium volume** (MV), **low volume** (LV), **very low volume** (VLV) and **ultra low volume** (ULV).
The ULV technique uses an application volume as small as possible while still conserving an optimal efficacy. Generally in crop protection the volume of spray applied depends on the type of target and the characteristics of the habitats such as plant coverage (tab. I). Sometimes, the type and active ingredient content of the formulation determine the volume of application in spite of target zone requirements. It is the responsibility of locust control officials, at national and regional levels, to assess the situation and provide their field staff with the most relevant formulation in order to meet the target requirement.

Type of spray	Quality of spray	Volume (l/ha)	Typical droplet size (µm)
High volume	Coarse	600 - 1,000	> 500
Medium volume	Coarse	100 - 600	300 - 500
Low volume	Medium	25 - 100	200 - 300
Very low volume	Fine	5 - 25	50 - 150
Ultra low volume	Very fine	< 5	40 - 60

Table I. Classification of sprays according to the volume of application per hectare.

Generally with aerial treatment, the volume of application seldom exceeds 1 litre per hectare as most operations take place in the areas with a low plant cover. However it is judicious to fix some limits so as to avoid excess. For practical purposes the lower spray volumes applied by air are 0.5 l/ha. However to apply such low volumes requires relatively uniform spray droplet sizes with µm around 50-60 µm. Use of uniform sized droplets is referred to as Controlled Droplet Application (CDA) after Mathews (1985).

ULV applications with water-based formulations are not suitable because locust and grasshopper control most often take place under hot and dry conditions and droplets under 200 microns are susceptible to quick evaporation.

Spraying for locust control can be defined as ULV: **a technique for producing even sized and small droplets using oil formulations with application volumes less than five litres per hectare.**

ULV formulations almost always are oil-based and applied without mixing (ready to use). When it is required to decrease dose rate or to rise the volume of application, it is possible to mix the original formulation with an oil. This oil should, of course be compatible so, tests should be made before final mixing. In this regard, the manufacturer of the pesticide should be consulted for recommended diluent.

1. Calibration

A formulation contains 450 g a.i./l. How much diesel must be added so that it is possible to treat a Desert locust infestation with 200 g a.i./ha or a grasshopper infestation with 150 g a.i./ha. In both cases the volume of application is 1 l/ha.

Note: to facilitate the calculations, cm^3 or millilitres (ml) are adopted as units.

First, the ***quantity of formulation containing the dose*** *should be determined. For this purpose use the formula:*

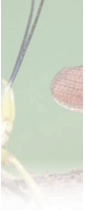
Q = (D x 1,000) / C

where: ***Q*** *= the quantity expressed in* ***ml***
D *= the dose expressed in grams of a.i. per ha*
C *= active ingredient content of original formulation*

Case of the Desert locust: ***Q*** *= (200 x 1,000) / 450 =* ***444 ml***
Case of the grasshoppers: ***Q*** *= (150 x 1,000) / 450 =* ***333 ml***

Then, the quantity of oil diluent to add will be:
for Desert locust: 1,000 - 444 = ***556 ml***
for grasshoppers: 1,000 - 333 = ***667 ml***

So, 444 ml of original formulation will be mixed with 556 ml of diesel oil (444 + 556 = 1,000 ml) for treating 1 ha of Desert locust and 333 ml of original formulation will be mixed with 667 ml of diesel oil (333 + 667 = 1,000 ml) for treating 1 ha of grasshoppers.



Droplet density and spray coverage

The spray coverage is the number of droplets per unit area reaching the target. It can be assessed and expressed by **the number of droplets per cm^2 and is usually measured on the vegetation or oil sensitive paper targets placed in the vegetation on which the locusts move and feed**.
It should be noted that the density of droplets that contact the foliage in the target zone is high when the size is small and the efficacy is better when droplet number is high. So it is more efficacious to spray with numerous small droplets rather than a few large drops.

Type of vegetation	**Spraying equipment**			
	Aerial ULV	Vehicle-mounted	Battery-operated	Knapsack mist blower VLV
Grassy sparse	0.5	0.5	1	5
Grassy moderately dense	1	1	2.2	5.0 - 10.0
Grassy, dense discontinuous	1.5 - 2.0	2	3	10.0 - 20.0
Grassy, dense continuous	2.0 - 3.0	3.0 - 5.0		> 20.0

Table II. Volume of application (in l/ha) for spraying ULV and VLV, in relation to the vegetation and the type of equipment used.

Usually for ULV spraying, twenty droplets per cm^2 are sufficient with a contact acting insecticide, while in barrier treatment with persistent insecticides, the coverage decreases with downwind swath. Formerly, barrier treatments operated with dieldrin, had a good efficacy with 1 to 5 droplets per cm^2 (Castel, 1982).

Except in barrier treatment, in most cases of acridid control, 20 droplets per cm^2 are sufficient to ensure an acceptable efficacy.

Droplet size

When a droplet is falling, it forms a sphere. The diameter of the droplet indicates its size.
In the previous paragraph, it has been stressed that with equal doses the efficacy of a treatment is better when droplets are small rather than when they are larger. This is evident because small droplets have a better penetration into the foliage and thus the coverage is better. Similarly smaller drops are more effective at intercepting flying insects.

VMD	% of deposit	Type of use	Remarks
500	> 95	Application of herbicides, no drift accepted. HV or MV applications.	With aerial application the aircraft must fly very low.
200-500	80-95	Public health applications. LV applications on crops, including herbicides.	Suitable for water-based formulations, even for aerial spray.
125-250	50-80	VLV application of contact action insecticides and positioning on all crops.	Good coverage with VLV. Water-based formulations under cool and humid conditions
60-120	30-20	ULV application of contact action insecticides and positioning in most cases of crop protection. **Most used method in Acridid control**.	Good deposit inside canopy. Specific ULV formulations
30-60	15-30	Contact applications against flying or settled insects (mosquitoes, Tse Tse fly...). ULV method.	Strong drift. Low deposit. Application under atmospheric inversion
15-30	< 15	Aerosol for contact treatment against flying insects. ULV method.	Very strong drift. Almost no deposit.

Table III. Selecting droplet size according to the type of use (after Lerch, 1984).

For a given volume, small droplets cover a wider area, since the number of droplets available from a given volume is inversely related to the diameter. Thus, dividing by two the diameter of a droplet results in multiplying by eight their number and by two the area covered (fig. 2).

It should be noted that, according to their size, the behaviour of droplets is influenced by the gravity and air movement. Thus:

- Droplets of more than 300 microns fall downward, almost vertically under the force of gravity. In almost all cases these droplets will end up on the soil, because even if they are intercepted by the vegetation they are not retained (fig. 3). Large droplets contain the greater proportion of the sprayed liquid (i.e. of applied a.i.).

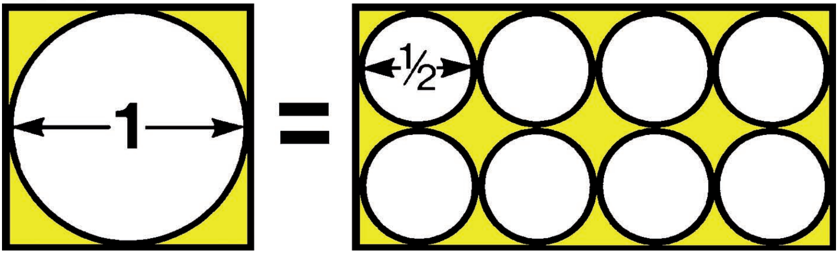


Figure 2. Relationship between droplet diameter and number (after Hoechst). For the same volume, dividing the diameter by two results in multiplying the area covered by two.

- Droplets between 100 and 300 microns also fall by gravity but they are subject to lateral drift by wind before being intercepted by vegetation or soil. They reach the target by sedimentation and by interception. They are moderately retained by vegetation.
- Droplets within 30 and 100 microns may be carried away, far from the emission point, by lateral wind movements while sedimenting simultaneously and progressively. They reach the target mainly by interception on foliage. They have a good penetration of the plant cover and they are retained on the foliage and on insect teguments (fig. 4).

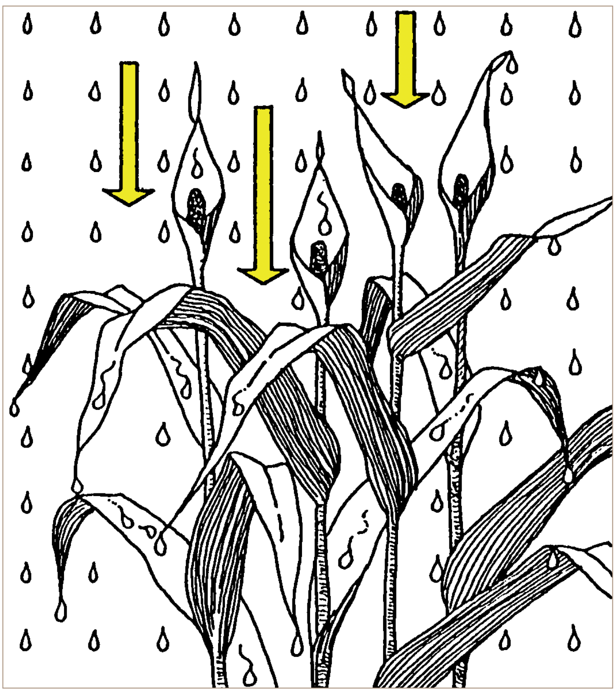


Figure 3. Large drops are poorly retained by the vegetation cover and generally end up on the soil (after Hoechst).

Figure 4. Small droplets reach the target by interception and have a good penetration of the vegetation cover (after Hoechst).

- Droplets smaller than 30 microns are very small and their trajectory largely affected by prevailing wind movements rather than gravity. They remain airborne, being carried some distance from the emission point. This type of spray is not usually used against locusts or grasshoppers as spray is often 'lost' from the target area due to convective air currents. Such small drops are used in public health against flying insects such as mosquitoes and Tse Tse flies (tab. IV) as the target is the air space in which the insects fly rather than the vegetation locust insects move and feed on.

Type of target	Coverage rate (droplet density per cm²)	Estimate % of deposit
Flying insects	Airborne droplets	15
Insects on the soil	20 - 30	15 - 40
Weed in post-emergence Fungus	30 - 40 50 - 70	40 - 80 50 - 80

Table IV. Droplet coverage and percentage of deposit according to the target type (after Lerch, 1984).

To achieve 20 droplets per cm², the amount of the spray liquid required is:

1 000 l/ha with 985 microns droplets,
200 l/ha with 576 microns droplets,
50 l/ha with 363 microns droplets,
20 l/ha with 267 microns droplets,
5 l/ha with 168 microns droplets,
4 l/ha with 156 microns droplets,
3 l/ha with 142 microns droplets,
2 l/ha with 124 microns droplets,
1 l/ha with 98 microns droplets,
0.1 l/ha with 46 microns droplets.

One litre of liquid applied evenly over a 1 hectare area achieves the following numbers of droplet/cm²:

387 droplets of 20 microns,
298 droplets of 40 microns,
88 droplets of 60 microns,
37 droplets of 80 microns,
19 droplets of 100 microns,
11 droplets of 160 microns,
2 droplets of 200 microns.

In ULV locust control, the size of useful droplets is within 50 and 100 microns. To reduce evaporation of droplets, ULV formulations should be of low volatility.

Droplet spectrum

Spectrum

Spray atomisers generally produce a range of droplet sizes, referred to as the droplet spectrum.

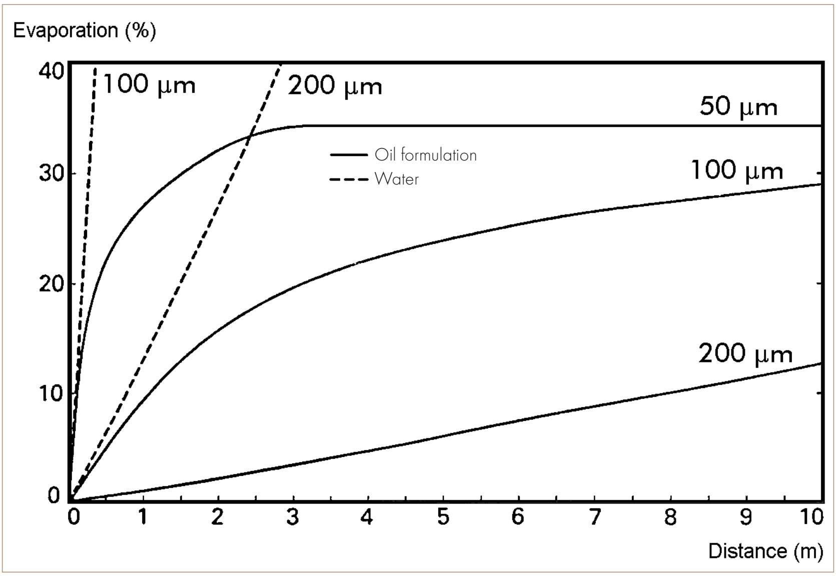


Figure 5. Evaporation rate of an ULV formulation, compared to that of water according droplet size and the distance between the emission point and the impact (after Ciba-Geigy, 1984). The assessment was realised in laboratory at 30 °C.

The droplet sizes produced by an atomiser can be expressed in various ways: the volume median diameter (VMD), the number median diameter (NMD).

Droplet diameter (microns)	Temperature (°C)	Relative humidity (%)	Longevity (in seconds)
100	20	70	20
		40	9
	30	70	17 - 18
		40	8
	40	70	16.8
		40	7.8
50	20	70	5
		40	2
	20	40	1.9

Table V. Longevity of droplets of water according their diameter, air temperature and relative humidity (after von Eickstedt in Gröner 1985).

Volume median diameter (VMD)

The volume median diameter is the median diameter where 50 % of the spray volume is less than this sizing. Half of the volume of the spray is composed of droplets smaller than the VMD and half of it of drops larger than the VMD (fig. 7, p. 20).
Calculations can be made through image analysis of spray deposits under a microscope or using laser based particle size analysis to determine the VMD. To assess sprays quality under field conditions, the VMD may be estimated by using the following equation:

$$\mathbf{VMD = 0.45 \times D_{max}}$$

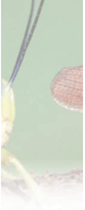
Where D_{max} is the diameter of the largest drop (the practice of determining D_{max} will be discussed in the paragraph entitled "the quality of sprays").

Number median diameter (NMD)

The number median diameter is the droplet size at which 50 % of the spray droplets by number are smaller.
If the droplets are ranged in order of magnitude and counted from the smallest upward, when 50 % of the number is reached then the diameter of the droplet at this median number is the NMD (fig. 7). Half of the total number of drops is below this value and half have diameters above it. On its own the NMD can be misleading in that it is influenced by large number of small drops which usually comprise only small proportion of the volume of spray liquid.
By dividing the VMD by the NMD we can derive a ratio that has often been used to determine the uniformity of a droplet spectrum. The lower the two values the more uniform the droplet sizes.

Uniformity of a spray

As a small number of large droplets contain more liquid than a large number of small droplets, the VMD is always greater than NMD.
Using the VMD/NMD ratio then the higher this value the greater the range of spray droplets.



For ULV application against locusts we require a very uniform spray droplet size with VMD/NMD ratios less than 2.
When SPAN is used to reflect the spray droplet size range then for locust control with ULV application we require values to be less than 1.

Spatial coverage

For wide area treatment, a good spray coverage is an important factor of efficacy. An important measure of spray coverage is the coefficient of variation Cv of spray deposits across the treated area. For short duration contact insecticides (less than 6 hours) the Cv should be small (less than 50 %) however with the longer acting pesticides – 24 to 48hrs – this is less important as the mobility to the locust or grasshopper will bring the insect into contact with the spray deposit. For residual sprays (for example insect growth regulators) with up to 3 weeks efficacy then the uniformity of spray deposit is not important as the active ingredient can be laid down in strips or barriers through which locust and hopper band move through.
For blanket treatment, a good spray coverage is an important factor of efficacy. The spatial coverage may be assessed by a ratio (fig. 8), which should be smaller as the a.i. has short residual activity. In other words the coverage should be even when the a.i. has a short residual activity.

Modes of spraying

Sprays may be categorised according to the mechanisms of droplet generation and the type of energy (nozzles).

Hydraulic energy nozzle

Liquid is forced under pressure through a small orifice so that the liquid spreads into a thin sheet and then ruptures into droplets of different sizes. Droplet size depends on the pressure, the type of nozzle and the size of the orifice. A low pressure together with large nozzle orifices produces larges drops. Whereas a high pressure with small nozzle orifice will produce smaller drops. With this type of spray however, the droplet spectrum is always very wide. The volume of the largest droplets may be as high as one million times the volume of the smallest.
There is a wide variety of nozzles with different forms and diameters of orifices available. There are several types of nozzles such as cone nozzle, fan nozzle and deflector nozzle. The flow rate and droplet size can be decreased but not sufficiently to make them small enough for ULV spraying. However, with cone nozzles (fig. 9) it is possible to perform VLV aerial spraying as the high air velocity from the aircraft will reduce droplet sizes further (fig. 10).