

THE APPLICATION OF AGRICULTURAL CHEMICALS BY AIRCRAFT ON SUGARCANE

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Abstract

Aerial application of agricultural chemicals has proved extremely successful on Umbombo Ranches, Swaziland, and this paper describes various aspects of the operation. The selection of optimum Volumetric Median Diameter of droplets is discussed and the D-Max method for determination of the VMD described. The methods for determining the optimum Flight Track Interval and nozzle placement on the boom are given. Practical techniques for aircraft loading and marking are described, together with meteorological conditions affecting aerial spraying. Advantages, disadvantages and costs of aerial spraying are discussed and the major chemicals used are mentioned.

Introduction

At Umbombo Ranches, Swaziland, few herbicides were applied to sugarcane lands prior to Spring 1973, weeds having been controlled mainly by hand and mechanical means. In 1973, pre-emergent herbicides were introduced on a systematic basis to reduce the dependence on increasingly expensive labour which was becoming progressively less available. Umbombo Ranches were also undertaking a large expansion programme, in which development much of the labour was deployed. Lasso EC and atrazine were the major herbicides applied by means of three tractor mounted spray-rigs. Broken diaphragms, burst tubes, blocked nozzles and other failures associated with this type of equipment provided a never-ending source of trouble. These tractors were unable to contend with the areas to be treated, and an aircraft was therefore used to assist in the application of diuron and atrazine.

The topography, area and system of farming are well suited to the application of agri-chemicals by aircraft, and on the strength of the excellent results achieved in the 1973 programme, a contract was made with a Swaziland crop spraying company to station an aircraft on the property for that part of the harvesting season in which herbicides were to be applied, namely August to January. As this period was regarded by crop sprayers as an off-season period, the bulk of their flying time being devoted to cotton from January to May, it was possible to negotiate a favourable contract.

Application Technique

Identity of target area

It is most important to identify the target to which the chemical is to be applied. In the case of a post-emergent weedkiller, the target is the weed itself and the chemical is best applied as a fine mist of small droplets to give wide droplet distribution and penetration of the weed sward. For pre-emergent herbicides, the target area is the soil surface on which a large droplet is considered preferable, because its size ensures a higher chemical recovery.

Classification of spray cloud

The spray cloud should conform to the specifications that will accomplish the optimum effect of the chemical on a given target area. The spray cloud is classified according to the spectrum of droplets within the cloud, which is expressed as the Volumetric Median Diameter (VMD). This is the diametric median of the droplets in microns, dividing the spray cloud into two equal parts by volume. In other words, 50% of the volume of the spray cloud comprises many droplets smaller than the VMD, and the

other 50% contains fewer droplets larger than the VMD.

For pre-emergent herbicides, a coarse droplet spectrum with a VMD of 400 to 450 microns is considered to be most effective because recovery of the chemical is important. In post-emergent herbicides, a medium size droplet (300 - 400 microns) is preferable for distribution on and penetration of the weed canopy. In general, fine droplets give better distribution and penetration at the expense of recovery due to evaporation. Coarse droplets give a high chemical recovery at the expense of droplet distribution and penetration.

In order to determine the VMD, it is necessary to make a pass over special collector cards (e.g. Kromekote) whilst emitting a dye (e.g. Solophenyl Blue 4GLC). The VMD is then calculated by the D-Max method. The D-Max is the largest diameter droplet appearing at least twice on the cards. Approximately half of the mass of the liquid emitted by hydraulic pressure nozzles consists of droplets smaller than 0,45 of the D-Max, and the VMD is therefore $D-Max \times 0,45$.

The diameter of the D-Max stain is divided by a spread factor which varies slightly with the type of cards and dye being used. It is affected by the droplet size and is determined by means of a graph. The VMD is then determined as follows:

- (1) Obtain D-Max stain
- (2) Divide D-Max stain by spread factor = D-Max effective
- (3) $D-Max \text{ effective} \times 0,45 = VMD$.

Application rate

The application rate is the total volume of spray mixture applied per hectare, and it naturally influences the application cost. This application rate has a direct bearing on the droplet spectrum within the spray cloud, a high VMD necessitating a high volume.

In aerial spraying, the two types of applications are low volume (5 to 75 ℓ /ha) and ultra-low volume (ULV) (less than 5 ℓ /ha). The ULV technique is normally used for insecticides which are oil based chemicals, and is not applicable to herbicides in sugar cane.

An application rate of 35 ℓ /ha is considered as the optimum rate for both herbicides and ripeners on Umbombo Ranches.

Application Equipment

There is application equipment available to cater for a variety of systems. Each system has its particular merits and disadvantages.

The application equipment which is used to comply with the specifications mentioned above (VMD about 400 microns and 35 ℓ /ha application rate) is a boom with Albus Ivory tee-jet nozzles at an operating pressure between 120 and 170 kPa. For pre-emergent herbicides, the nozzles are set at 180° to produce a minimum of atomization, while for chemical ripeners the nozzles are set at 135°. The droplet spectrum is materially affected by the nozzle angle, as shown in Fig. 1.

The aircraft speed is approximately 165 km/h. The number of nozzles is dependent on the application rate and pump pressure, and they are strategically spaced along the length of the booms to make allowances for the wingtip vortices and propeller wash which otherwise cause a certain amount of swath distortion.

These spacings are determined largely by trial and error, and they depend on the equipment and aircraft in use. It has been found that the greatest losses in recovery are caused by the

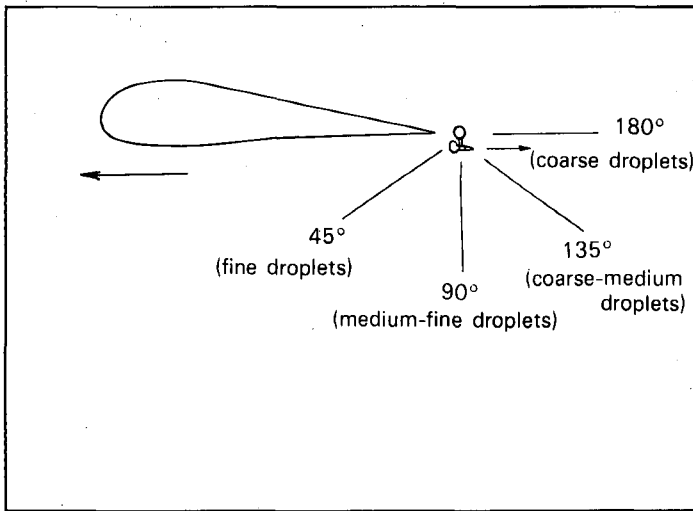


Figure 1: Illustration of a wing section showing spray angle to the line of flight.

wingtip vortices, and to counteract this, it is preferable to move the outermost nozzles well inboard of the wingtips. This has the effect of reducing the effective swath marginally, but this can be overcome by flying at a slightly higher altitude. The propeller wash causes uneven distribution below the aircraft, and this is counteracted by placing more nozzles approximately 1 m from the fuselage along the starboard wing and omitting them for 1 m from the fuselage on the port wing.

The nozzles on the aircraft boom are fitted with an automatic shut-off assembly, which is merely a diaphragm situated in a housing at the back of the nozzle which prevents liquid from leaving the boom below a certain pressure. This ensures that there is always liquid in the boom and that time lags are avoided.

Besides the fan-jet in use on Ubombo Ranches, other types of nozzles are available for a variety of situations. These include cone-jets and Raindrop nozzles. Rotary Atomizers or Micronairs, which are effectively used for ULV applications of insecticides have as yet a limited role in sugarcane.

Spraying height

The distance between the nozzles and the crop is critical, as the greater the distance, the greater will be the amount of evaporation and resultant loss of chemical. Drift also increases as do the detrimental effects of wind and turbulence. On the other hand, the closer the boom is to the target area, the more uneven will be the distribution of the spray cloud, as the cloud does not disperse adequately. For herbicide and ripener applications, 3 m from boom to target is considered to be optimal.

Flight Track Interval

The width of the path over which the chemical is distributed is called the swath. The distance between consecutive runs is termed the Effective Swath Width or Flight Track Interval, and this provides for an overlap of the swath of adjacent runs to maintain a consistent application of the chemical over the area being treated. It is necessary because there is a greater concentration of chemical immediately below the aircraft than there is towards the wingtips.

The Flight Track Interval is determined by spraying a strong dye over collector cards strategically spaced in a line across the flight path of the aircraft. The Effective Swath Width may then be calculated by various means, either visually or arithmetically by the application of formulae, as described in the section which follows.

Method A

1. 40 Collector cards are placed at one metre intervals across

an open expanse of ground. The centre of the line of cards is suitably marked to give the pilot his bearing.

2. The aircraft executes a run over the cards whilst emitting a concentrated dye. In the event of a breeze, the run must be made directly into wind.
3. The cards are collected and numbered in such a way that the first card on either side to display droplet stains, however small, is numbered one and marked as port or starboard. Each card thereafter is numbered until the last card displaying droplet stains is reached.
4. By means of a Strubin optical lens, the droplets are now counted in four positions on each card and the results recorded. For herbicide application, only droplets greater than 300 microns are counted. The total number of droplets/cm² is then established for each card by calculating the average number of droplets counted in the four positions on each collector card, and multiplying by the eye-piece factor of 2,4.
5. These data are then presented graphically, with the total number of droplets > 300 μm/cm² on the y axis and the collector positions at 1 m intervals on the x axis.
6. A Mean Value of droplets > 300 μm/cm² is now calculated by formula. This Mean Value is the minimum number of droplets > 300 μm/cm² acceptable to obtain an adequate chemical recovery. The Mean Value is now used on the graph (Fig 2) and the Effective Swath read off on the x basis.

Example:

Collector position number	4 pos. from each card				Total droplets >300 μm from four positions	Total Ø > 300 μm per cm ²
	1	2	3	4		
1	0	2	2	1	5	3,0
2	2	1	1	2	6	3,6
3	2	3	2	1	8	4,8
...						
29	1	2	1	2	6	3,6
30	1	0	0	1	2	1,2

$$\text{MEAN VALUE} = \frac{\frac{N \times X}{\text{ES}}}{3 \text{ (factor)}}$$

where

- N = mean number of Ø/cm² (in this case Ø > 300 μm)
- TS = total collected swath
- ES = estimated run width as for flow rate
- Ø = droplets.

Method B

1. Lay-out cards as in the previous method
2. Cards are assessed visually. The two cards with the largest deposit of droplets are taken as 100% and the others expressed as percentages of these. These readings can be depicted graphically with 33% being the minimum deposit allowable. Flight Track Interval can then be estimated as the distance within the 33% limits.

This is a practical field method which is frequently used as an alternative, although it is not as accurate as Method A.

Aircraft Loading and Handling

Loading time is a significant factor in this type of operation to reduce cost and increase efficiency. When mixing chemicals, and

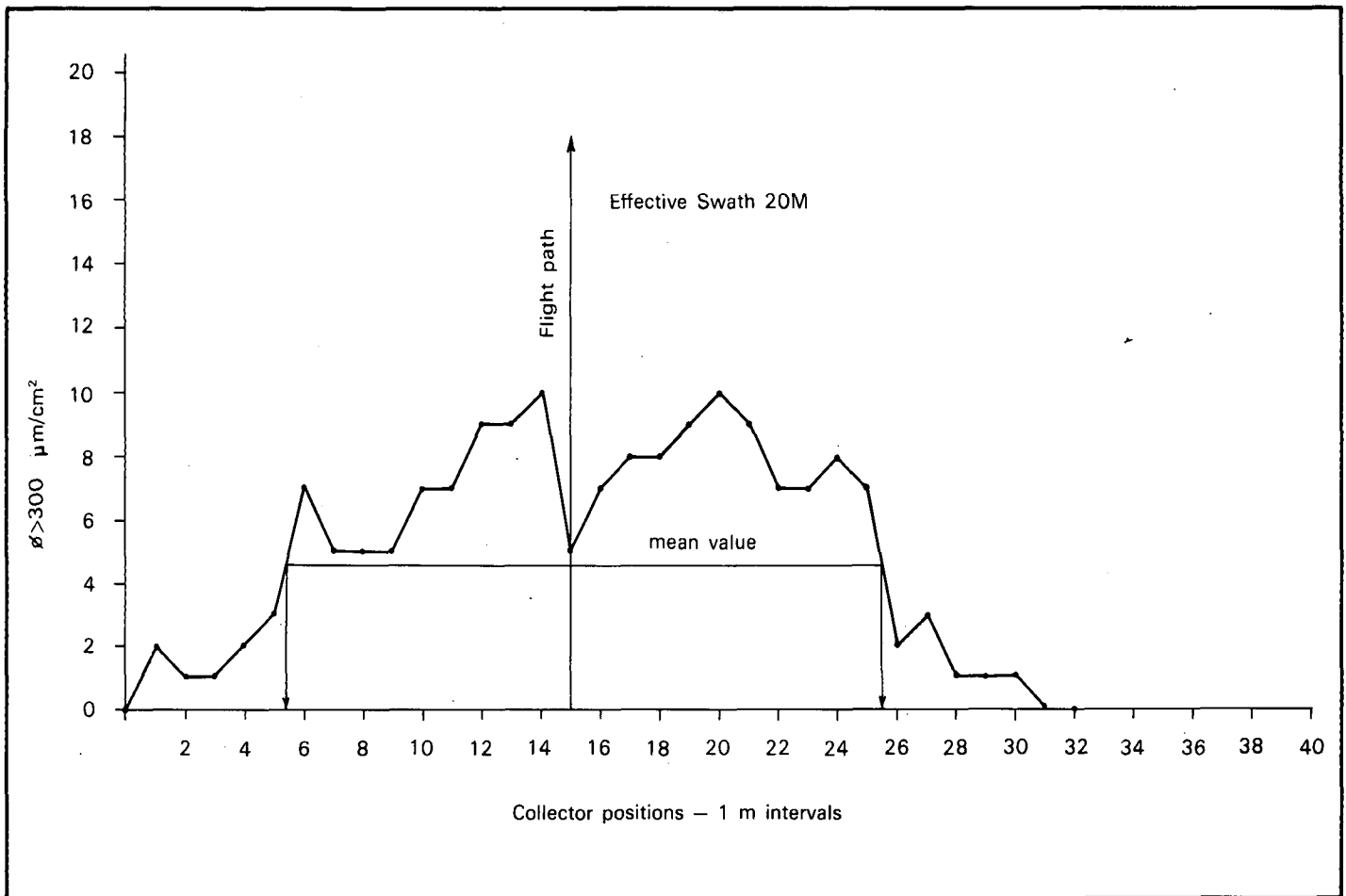


Figure 2: Distribution of droplets $>300 \mu\text{m}/\text{cm}^2$

in particular wettable powders which are usually cheaper than flowable formulations, it is essential to maintain efficient agitation when adding the powder to the water. Compatibility of the different chemicals is also an important consideration when working with application rates from 20 to 50 ℓ/ha . It is often necessary to use wetters, catalysts or emulsifiers to improve the compatibility and suspension of some chemicals.

Two similar aircraft handling techniques are:

- (1) for aircraft of large hopper capacity, ie. more than 600 ℓ of liquid per load.

A mixing tank of approximately 1 000 ℓ capacity is placed in a position on the airstrip accessible to both the aircraft and an abundant supply of clean water. Two small pumps are required, one for transferring the mixture from mixing tank to aircraft, the other to provide agitation in the mixing tank.

Assuming the working load of the aircraft to be 700 ℓ , and the application rate to be 35 ℓ per hectare, a batch of 770 ℓ (for 22 ha) is prepared at first in the mixing tank. Only 700 ℓ is then transferred to the aircraft, the remaining 70 ℓ providing enough liquid to maintain continuous circulation by the agitating pump. For each successive load thereafter, 700 ℓ (for 20 ha) are added to the mixing tank, whilst the agitating pump is running constantly to keep the mixture in suspension.

The mixing tank should be calibrated in 50 ℓ graduations to facilitate the mixing of any volume of liquid required, depending on the area to be treated. A portable fibreglass tank is preferable for ease of handling.

- (2) For smaller aircraft of hopper capacity less than 600 ℓ , the mixture is prepared in 200 ℓ drums.

The chemicals may be mixed in one or two of the drums, depending on which chemical and how much of it is being used, and the other drums are filled with clean water to provide the

necessary dilution. The number of drums depends on the payload of the aircraft, and 200 ℓ drums are conveniently marked in 70 ℓ sections.

The advantage of this system is that after the chemical has been pumped into the hopper, clean water is added to make up the payload, thus reducing chemical spillage on the airstrip when coupling and uncoupling hoses on the aircraft.

Marking

Accurate marking of the areas being sprayed is extremely important, especially in the case of herbicides and ripeners. Inaccurate or careless marking can result in two situations arising. One is over-application which could result in crop damage and waste of chemical. On the other hand, missed areas result in poor weed control, with the subsequent management problems, or loss of response in the case of ripeners.

The spacing between markers, ie. the Flight Track Interval, is measured by means of lightweight chains which are adjustable in length to compensate for marking lines which are not at right angles to the flight path, and to cater for aircraft and operations which have varying Flight Track Intervals.

The flags themselves are orange or yellow plastic sheeting sewn onto a rectangular or square frame of weldmesh approximately 0,9 x 0,7 m which is fixed to a length of 12 mm conduit piping. This type of flag is very light and easy to hold and work with.

The marker must move at right angles to the flight of the aircraft, so a straight line through or along the edge of the field is necessary to form a base line from which the markers will start to move. This line should wherever possible be the longest line through the field, as extra flying time as a result of short runs has a direct bearing on cost and efficiency.

In many cases suitable paths for the markers cannot be found

at right angles to the flight track, especially when ripeners are being applied to tall cane. It is then necessary to adjust the length of the marking chain to compensate for the changed angle between the flight path and the path used by the markers. This distance is calculated trigonometrically by applying the cosine rule (See Fig 3).

Referring to Fig 3, it can be seen that for herbicides the markers will usually take a line through the field, where no road is conveniently placed, in order to move at right angles to the line of flight. For ripeners or fertilizers, the markers will have to move along the road because of the tall cane. The path BE is still at right angles to the base line, but the markers along CD now have to compensate for the offset angle.

When markers are required to move through a field, particularly when herbicides are being applied, it is advisable to place reeds or other marks along the line to ensure that a straight path is maintained. Accurate and imaginative marking will make an operation more efficient and save time and money.

Meteorological Conditions Affecting Aircraft Spraying

The main factors which have a significant effect on aircraft applications are wind, rain and humidity.

Wind

Wind is the most important factor influencing the duration of time that spraying can take place. The large droplets used in pre-emergent herbicide applications are not affected by wind as much as the smaller droplets used in other types of chemical application. As a rule, a wind speed of 14 km/h is considered to be the maximum speed acceptable before suspending spraying for the day. Good results with pre-emergent herbicides have been obtained on occasions on Ubombo Ranches where spraying had to be carried out for one reason or another in strong wind. A Dwyer wind speed indicator is used to measure windspeed when spraying.

Rain

Rainfall can be both beneficial and detrimental to aerial spraying. Providing there is no run-off of high intensity rainfall, rain is beneficial whilst applying pre-emergent herbicides as maximum recovery and soil uptake of the chemical is ensured. In the case of foliar acting post-emergent weedkillers and ripeners, rainfall will remove the chemical from the leaves. Generally, at least 8 hours should elapse before rain falls if most chemicals are to work reasonably efficiently.

Humidity

Chemical recovery is affected by low humidity which causes high losses due to evaporation. Fortunately, spraying normally occurs from first light until 9 or 10 a.m., and during this period conditions of low humidity are uncommon. On Ubombo Ranches, spraying is suspended when the humidity drops below 55%, but in other areas good results are still obtained at lower humidities, depending on the type of chemicals being applied. Usual recommendations are to suspend spraying when the humidity is below 40%; between 40% and 60% is considered marginal; and above 60% is satisfactory.

Aircraft Versus Ground Application

Advantages of aerial application

(a) Very efficient management and labour and utilization. On Ubombo Ranches, 6 500 ha are treated with herbicides and 1 500 ha with ripeners annually. These operations require the services of one senior staff member and four unskilled labourers, in addition to labourers and junior staff required for field marking.

Spraying is carried out during three to four hours on one morning a week, in which period approximately 200 ha are treated. This in effect allows the senior staff member and the labourers to perform other functions and duties during the rest of the week. The marking is managed by the section manager or his assistant, and from two to six labourers

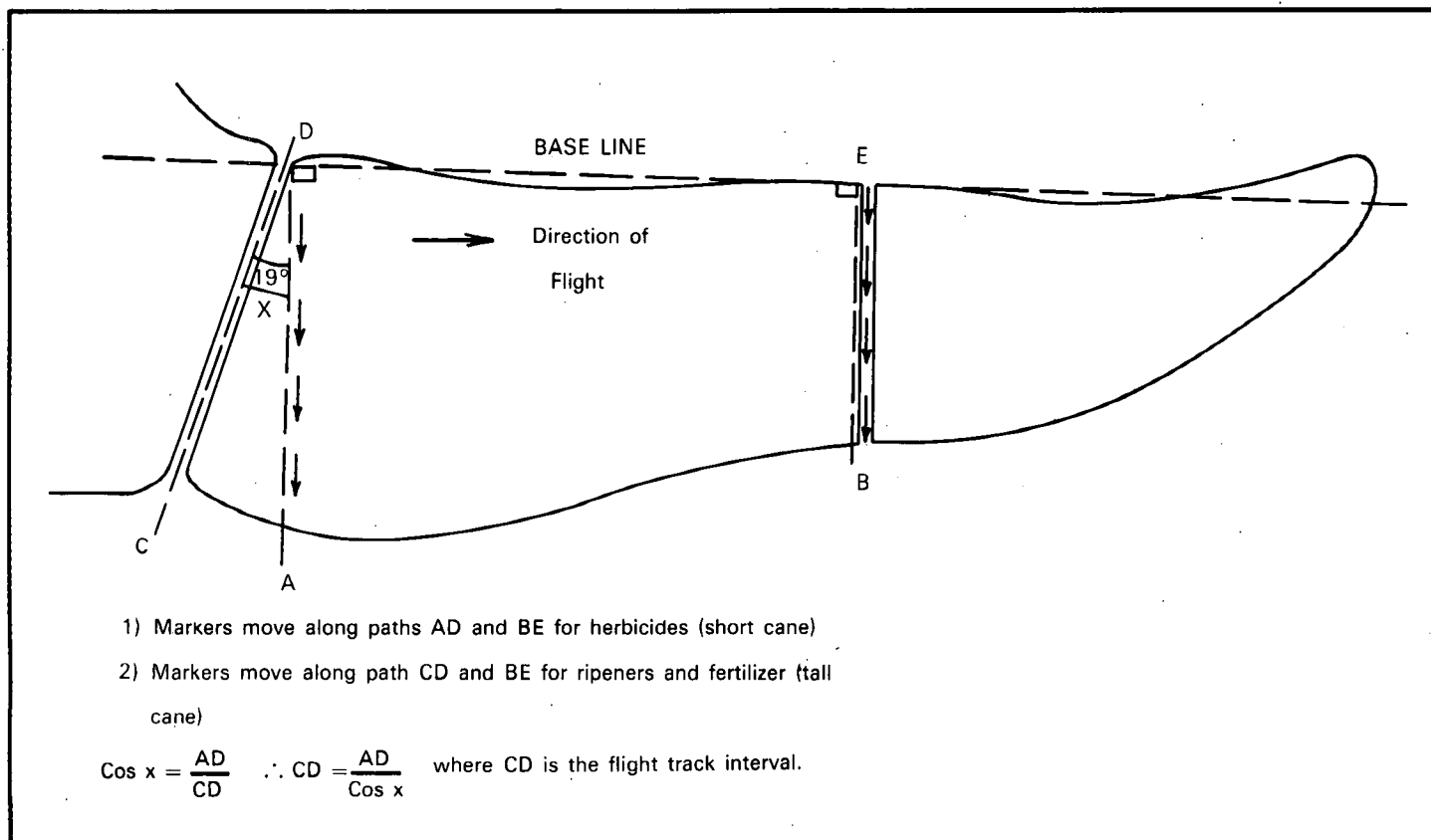


Figure 3: Systems for field marking

depending on the size of the field and manner in which it is being sprayed. Over the nine months during which spraying takes place, this averages 30 minutes a week per section during which these personnel are occupied with spraying.

- (b) The timing of the operation can be more accurate. The speed of the operation means advantage can be taken of optimum conditions, ie. after rainfall when wheel tractors would not be able to work, or to take care of a weed problem that, if left longer, would not effectively be solved. Certain herbicides have specific requirements concerning the conditions under which they must be applied, eg. within 72 hours after soil disturbance, and these conditions can easily be complied with by aerial application.
- (c) Calibration and application rates are accurate, and considerable savings are made by minimizing over-applications and spillage.
- (d) In practice, aircraft experience negligible mechanical failures such as are associated with tractors and spraying rigs.
- (e) Post-ratooning traffic and consequently compaction are kept to a minimum.

Disadvantages of aerial application

- (a) Aircraft applications are affected to a large degree by the elements, of which wind and humidity are significant. At a wind speed in excess of 14 km/h (4 m/sec) aerial application becomes too erratic for consistent results. In the coastal areas wind often presents a problem which fortunately does not usually occur inland. As already mentioned, low humidity has an adverse effect on recovery.
- (b) Topography is often a deciding factor in reducing the overall efficiency of the application, or in precluding the use of an aircraft altogether.
- (c) Certain areas or fields are inaccessible by aircraft due to tall trees, power lines or other obstacles. This also applied to the difficulty of marking fields accurately, particularly in the case of ripeners in tall cane.
- (d) Compatibility often presents a problem with the wide variety of wettable, flowable and soluble powders, and emulsifiable and suspended concentrates that are available. These incompatibilities are particularly significant in the low volume of water being applied by air.
- (e) Aerial application is restricted to pre-emergence and limited post-emergence treatments, as phytotoxicity occurs with the more active post-emergence treatments.
- (f) There is a danger of contamination of susceptible crops in adjacent areas by drift.
- (g) Fields or areas should be large enough to make the operation economically and practically feasible.

Agricultural Chemicals Being Used

Herbicide treatment on Ubombo Ranches is carried out from August to January, and ripeners in March and April. The chemicals currently in use are:-

Sencor 70 WP – Diuron 80 WP: Used as an early post emergence long-residual pre-emergence treatment for most fields harvested from May to the middle of September at a rate of 2 kg of each compound per hectare.

Lasso 479 EC – Atrazine 80 WP: Strictly pre-emergence treatment applied from 2 to 5 days after the last cultivating operation or soil disturbance, giving medium term residual activity (8 to 10 weeks control).

These herbicides present a compatibility problem which has been overcome by the addition of an emulsifier called Berol. Rates vary from 4 to 5 ℓ of Lasso with 2 kg of Atrazine per hectare.

Diuron 80 WP – Atrazine 80 WP: More flexible than the previous treatment, providing pre- and very early post-emergence control of broadleaf and grass weeds for a relatively short period (6 to 8 weeks control). Used mainly from the end of November in conditions of ample moisture and fast crop canopy. Rates currently used are 3 to 4 kg of diuron and 1,5 to 2 kg Atrazine per hectare.

Other herbicides used include MCPA, Actril DS, Velpar, Gesapax and Dual.

Ethrel

Ethrel has been used for three seasons in Ubombo Ranches over areas ranging from 1 200 ha in the first year of commercial application to 1 800 ha in 1978. The rate of application is 1,5 litres product per hectare applied in a total volume of 35 ℓ/ha. After mixing with water, the mixture may not be stored for more than a few hours, as the active ingredient is affected by the change in pH of the mixture. The technique of application and the equipment used are identical to those for herbicides, except that the booms are swivelled down to provide a 135° spray angle. This reduces the VMD of the droplets to approximately 350 microns. The target area for Ethrel application is the active growing leaves at the top of the cane stalk. The slightly finer droplets ensure better distribution and penetration, without penetrating too far down the cane stalk.

Aerial Application of Fertilizer

The application of granular fertilizers, particularly nitrogen, by aircraft is gaining acceptance rapidly. One large sugar estate in Swaziland is applying all of its fertilizer in split dressings to the entire estate. On other estates, supplementary top dressing of nitrogen and potash by air is being carried out on an increasing scale, particularly after intense rain storms where leaching may be a problem, or merely after assessing visual symptoms of nutrient deficiencies in the crop at approximately 6 months of age. In many cases, spot applications can be made conveniently on areas which show obvious nitrogen or other fertilizer deficiencies.

Application cost, is unfortunately, a disadvantage in most instances, although an efficiently co-ordinated programme can prove to be economical with favourable conditions and a well organized aircraft operator.

Application Cost and Economics

Although actual costs are not available for the application of herbicides by tractors, the current flying charges for herbicides and ripeners are between E3,50 and E4,20 per hectare. In addition, overhead costs include senior personnel, and mixing and marking labour. This cost is greatly influenced by the distance of the area to be treated from the airstrip. It is therefore important that the airstrip is as central as possible to the croplands, and in the case of large estates, as with Ubombo Ranches, two or more airstrips should be locally situated to facilitate more efficient and economic accessibility to outlying areas.

When comparing the costs of aircraft and ground applications, the advantages of labour and personnel utilization, optimum timing and speed of application must be borne in mind. These cannot accurately be quantified in terms of money, but there is little doubt that this operation if managed efficiently is the most economical means of applying most agricultural chemicals under the right conditions.

Glossary

Application Rate: The volume of spray mixture distributed over unit area – litres/hectare.

Dosage Rate: The amount of product distributed over a unit area – kg/ha or ℓ/ha.

Flight Track Interval: (Effective Swath Width) The distance between successive spray runs so as to maintain an even distribution throughout the treated area.

D-Max: The largest diameter droplet in a spray cloud. This is then used to calculate the VMD of the spray cloud.

VMD: Volumetric Median Diameter. The diameter of droplets in microns that divides a spray cloud into two equal halves by volume.

Micron: 1/1 000 of a millimetre. Used to express the size of a spray droplet.

Spread Factor: A droplet collected on a collecting surface has a specific spread on that surface; this varies according to type of product and collector cards in use and size of the droplet.

Droplet Density: This is the number of droplets per unit area, ex-

pressed as droplets per cm² (θ/cm^2).

Recovery: The actual amount of the product (chemical recovery) or the volume (volumetric recovery) that is deposited on the target expressed as a percentage of the amount sprayed.

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