# The value of controlled droplet application (C.D.A.) as a spot spray technique for the control of noxious weeds in Victoria

J.H. Combellack
Keith Turnbull Research Institute
Vermin and Noxious Weeds Destruction Board
Department of Crown Lands and Survey
Frankston 3199, Victoria

SUMMARY

In Victoria 100 million ℓ of spray mix are used for spot spraying weeds. Possible methods of improving the efficiency of the spot spray operation are discussed. The principles of application of herbicides are reviewed and in particular the relative merits of various atomizers are compared. The reasons for, and the best methods of producing, controlled droplet application (C.D.A.) of herbicides are commented upon. The variables affecting droplet movement to, and impaction upon, the target are reviewed. The reasons for, and the extent of, a research program to develop C.D.A. are reported with particular emphasis being placed on its advantages and disadvantages.

## INTRODUCTION

Application of large volumes of dilute spray has been generally accepted as the standard technique for the spot spraying of weeds in Australia. Since the behaviour of the spray differs according to the volume applied it is essential that one first classifies the volume used in any spray operation as high, medium, low or ultra-low volume. As there is confusion about these terms the following definitions are suggested:

high volume - the liquid is sprayed until surface saturation occurs and excess liquid runs off. The volume per ha will vary with the size of the plant and its leaf area, however, the range would normally be from 500 to 3000 ℓ/ha.

medium volume - is when the liquid is sprayed over the surface of the target until some coalescence of droplets occurs (N.B. spraying is stopped before run-off occurs). The normal volume range would vary from 100 to 500 ℓ/ha.

low volume - is when the liquid is sprayed over the surface of the target and remains as discreet droplets (N.B. there is very little or no coalescence of droplets). Volumes from 5 ℓ/ha up to 50 ℓ/ha would be the normal range.

ultra-low volume - is when the liquid is dispersed over the plant surface as small discreet droplets. Volumes of less than 5 ℓ/ha are regarded as ultra-low volumes.

In Victoria, the Department of Crown Lands and Survey employs some 650 workmen to control vermin and noxious weeds. A survey of Inspectors of Land Settlement in 1975 (Combellack, unpublished) to determine the activities of the workmen, has been used to make the estimates presented in Table 1.

Table 1. Expenditure of noxious weed control effort by the Department of Crown Lands and Survey

| Weed species | % weed control time | No. of man years | Man days of actual spraying* | Litres of spray per man day** | Litres sprayed per annum |
|---|---|---|---|---|---|
| Blackberry (*Rubus fruticosus* L. agg.) | 31.0 | 124.6 | 27,428 | 900 | 20,185,000 |
| Variegated thistle (*Silybum marianum*) | 12.9 | 51.9 | 9,342 | 550 | 5,138,000 |
| Horehound (*Marrubium vulgare*) | 11.9 | 47.8 | 8,604 | 550 | 4,732,000 |
| Furze (*Ulex europaeus*) | 11.7 | 47.0 | 8,460 | 900 | 7,614,000 |
| Paterson's curse (*Echium* spp.) | 10.4 | 41.8 | 7,524 | 550 | 4,966,000 |
| Ragwort (*Senecio jacobaea*) | 9.2 | 37.0 | 6,660 | 450 | 2,997,000 |
| Other (i.e.remaining 87 noxious weeds) | 12.9 | 51.9 | 11,418 | 500 | 5,707,000 |
| Totals | 100 | 402 | 64,436 | - | 51,341,000 |

* Although 220 man days/year is the maximum possible working year, the figure used was 180 days, the other 40 days assumed to be wasted due to inclement weather etc..

** These vary with the species due to size and scatter etc..

The above table clearly shows that in excess of 50 million ℓ of spray mix passes through the Lands Department's equipment each year. One could tentatively conclude that in excess of 100 million ℓ of spray mix is used annually in Victoria for spot spraying by all operators. It can thus be seen that any improvement in the efficiency of spot spraying would lead to an enormous saving in time and effort. For example, within the Lands Department operation a reduction in the spray volume of 25 to 30% has been estimated to give a potential saving of approximately $500,000 per annum on the present wage structure.

The degree of weed control achieved with low (5 to 50 ℓ/ha) and even ultra-low volumes (less than 5 ℓ/ha) is often comparable with that obtained using high volumes (Taylor and Merritt, 1974, 1975 and 1976; O'Keefe <u>et al</u>, 1976; Bailey and Smartt, 1976; Rogers, 1975; Rogers <u>et al</u>, 1976; Combellack and Harris, 1978). Because of this there has been an increased interest in these application techniques for economic reasons. However, as pointed out by Bals (1969) "the efficiency of a spraying machine is inversely proportional to the range of droplets it emits, whilst the suitability for a specific problem depends on the actual size of the droplets emitted".

This paper considers those factors which affect the efficiency of spray applications including droplet production, movement to, and impaction upon, the target. In particular, it assesses the value of controlled droplet application (C.D.A.) defined as "the production and application of droplets of the appropriate size for the target which have a narrow and predictable variation in droplet size at any volume".

PRINCIPLES OF SPRAYING

Before any improvements to spraying systems in use can be considered, a basic understanding of the principles of application is essential. This paper will be restricted to considering those applications where the herbicide is released or propelled through the air in the liquid state. Such methods of application can be divided into four phases:

(a) Production of droplets

(b) Movement of those droplets to the target

(c) Impaction and retention of those droplets upon the target, and

(d) Uptake and distribution of the active material within the droplets by the plant.

(a) Production of droplets

The disintegration of liquids into droplets is effected by a mechanical device known as an atomizer. The functions of the atomizer are to accelerate and disintegrate the liquid into droplets, to meter the liquid and to disperse the resulting droplets in the preferred pattern. Where possible the atomizer should produce a narrow and predictable variation in droplet size so that the biologically optimum droplet size, as defined by Himel (1969) can be produced. Furthermore, it is important that predictable droplet sizes are produced if one is to be able to assess drift potential.

There are four types of atomizers used in the spraying of agricultural chemicals:

(i) Pressure atomizers - the most commonly used, require pressure energy to produce droplets. Examples of this type of atomizer are fan, hollow cone and solid cone jets. Their energy input requirement varies with the pressure used which in turn governs the droplet spectrum, droplet propulsion and output volume. They are widely used because they are cheap and easy to manufacture, easy to service, reasonably durable, and by using various size orifices the output can be varied. They are, therefore, very flexible atomizers, however, they have two drawbacks; firstly they require a fairly high energy input and secondly they produce a large variation of droplet sizes. A number of variables govern the production of droplets, see Table 2, and, as will be noted, when used on aircraft further variables are introduced.

(ii) Rotary atomizers - which are becoming more widely used, require centrifugal energy to produce droplets. Spinning cages, spinning discs and spinning cups are examples of this type of atomizer. Energy requirements for such atomizers vary enormously between systems used.

Spinning cages with fans to provide droplet propulsion require considerable mechanical energy, usually provided by a hydraulic pump. In the case of 'Micronaire' spinning cages, as used on aircraft, the cages are revolved by impeller blades which obtain their energy from the plane's slipstream. In the case of hand-held sprayers a small electric motor, which uses very little power, is used to spin the cup or disc.

Droplet propulsion is also very different for each type of machine. In the case of the spinning cage with fan, droplet propulsion is good, whilst droplet propulsion from hand-held sprayers is minimal and thus movement of droplets to the target is dependent upon natural forces. Also the fan cage type of machine gives a relatively broad range of droplet sizes, as does the 'Micronaire' whilst the hand sprayers can give a very narrow droplet spectrum.

This latter aspect is very important in drift control; however variations in the range of droplet sizes can easily be affected by a number of variables (see Table 2).

The cost of the machine, ease of manufacture and service, and variation in output also varies from machine to machine. The fan cage is expensive to manufacture, cheap to maintain, relatively easy to service, and has a reasonable variation in output. The 'Micronaire' is similar to the fan cage. The hand-held C.D.A. equipment is cheap to manufacture, easy and cheap to maintain and service but has a limited variation in output. One of the main advantages of rotary atomizers is that they can be developed to be used with low or ultra-low volumes. However for such application systems to be successful a number of other variables has to be considered (see Table 4). Overall the rotary atomizer offers the cheapest form of atomizer capable of producing a narrow droplet spectrum.

(iii) <u>Twin fluid atomizers</u> - are commonly known as airblast machines or misters and rely upon gaseous energy to disintegrate the spray liquid. Machines using these atomizers are widely used for agricultural spraying, their main use being in orchards or, in the case of knapsack misters, for the control of weeds in relatively inaccessible places. However these machines have a high energy requirement to produce hydraulic atomization and then a sufficiently powerful air stream to carry the droplets to the target. They are expensive to manufacture, service and maintain. Furthermore the droplet spectrum produced is broad and often contains a large proportion of droplets less than 100 μ in diameter. Because of these small droplets, control of drift is not practical which restricts their use. Because of their weight and noise level, knapsack misters are not well accepted by workers. This system of atomization is not regarded as being of great value for spot spraying unless a more controlled droplet spectrum can be produced. As a large number of variables affect droplet production (see Table 2) the production of a narrow droplet spectrum will be difficult.

(iv) The Ultrasonic atomizer - is probably the least well known and least developed atomizer, e.g. the 'Vibrajet' being one known system. This type of atomizer relies upon a rapidly vibrating nozzle to break up the liquid. These atomizers usually require electrical energy to produce the necessary vibrations and are capable of producing a uniform droplet spectrum. There are two drawbacks; firstly, the droplets receive only minimal propulsion, and secondly, a machine to produce uniform small droplets of 100 to 200 μ which are required for agricultural purposes has not been manufactured.

As there are few variables affecting droplet production (see Table 2), development of this atomizer for C.D.A. seems worthwhile.

In conclusion, the ideal atomizer for spot spraying should be easy to manufacture, easy to service, of low cost, durable, capable of producing a variable but narrow droplet spectrum, usable over a wide range of volumes and capable of being included in a suitable device to effect adequate droplet propulsion.

Table 2. Some variables which affect droplet production

| | Pressure atomizers e.g. fan, solid and hollow cone jets | Rotary atomizers e.g. spinning discs and spinning cages | Twin fluid atomizer e.g. air-blast | Ultrasonic atomizer e.g. 'Vibrajet' |
|---|---|---|---|---|
| Formulation | Viscosity<br>Volatility/ Evaporation<br>Surface tension | Viscosity<br>Volatility/ Evaporation<br>Surface tension | Viscosity<br>Volatility/ Evaporation<br>Surface tension | Viscosity<br>Volatility/ Evaporation<br>Surface tension |
| Atomizer | Discharge pressure<br>Swirl plate size and shape<br>Swirl chamber size and shape<br>Nozzle orifice size and shape | Angular velocity<br>Flow rate onto disc or cage<br>Droplet issuing point | Discharge pressure<br>Swirl plate shape and size<br>Swirl chamber shape and size<br>Nozzle orifice shape and size | Discharge rate<br>Vibration rate |
| Other physical factors | Nozzle orientation in relation to direction of travel ) Variable Shear factor<br>Nozzle location on aircraft )<br>Wind speed )<br>Air speed ) | Cage orientation<br>Propellor orientation<br>Cage location<br>Wind speed<br>Air speed | Shape and diameter of outlet<br>Available power to drive the fan<br>Fan delivery in cubic metres/min and velocity in km/h | Not applicable |

Ripper (1956) stated, in reference to pressure atomizers, that "it has so far proved impossible to design nozzles with droplet spectra inside the limits of 100 and 300 μ; at present spray nozzles which produce no droplets under 90 μ give too coarse a spray even for weed control". That statement still stands. The use of pressure atomizers for spot spraying is not practical at low or ultra-low volumes. This is because the small droplets produced, which contain a high concentration of active ingredient, present a drift problem. Thus in situations where control over drift is desirable the only promising atomizers are centrifugal atomizers (e.g. spinning disc) and ultrasonic atomizers. As the former have been better developed from a manufacturing viewpoint, they are being tested for use as atomizers for spot sprayers. The use of these atomizers, taking into consideration the variables contained in Tables 2 and 4, are considered to be most appropriate when spot spraying small infestations or when spraying plants close to susceptible non-target species.

(b) Movement of droplets to the target

The variables affecting the movement of droplets to the target are shown in Table 3.

Table 3. Variables affecting the movement of droplets to the target

| Formulation | Atomizer | Meteorological | Propulsion/ Distance from target |
|---|---|---|---|
| Volatility | Droplet range | Temperature<br>Relative humidity<br>Wind speed | Mass (droplet size)<br>Velocity (function of pressure and mass) |
| Evaporation | | Rainfall | Air stream (e.g. from a fan or the slipstream of aircraft) |
| Surface tension | | | |

In the ideal situation uniform droplets are produced using a non-volatile chemical in a non-evaporative carrier, projected under conditions of low wind, high relative humidity and low temperature. Unfortunately as the latter three factors cannot be controlled this phase of application is extremely variable.

As the formulation can greatly affect the movement of droplets from the atomizer to the target, special attention has been paid to producing suitable formulations for the hand-held spinning disc sprayers, thus giving an overall C.D.A. system. The features of these formulations are reported elsewhere (Combellack and Shaw, 1977; Shaw and Combellack, 1978). Modification of the formulation and carrier systems for other atomizers also affects the movement of droplets from the atomizer to the target.

(c) Impaction and retention of droplets onto the target

A knowledge of the factors affecting impaction is necessary if one is to improve the efficiency of application. The terminal velocity, or residual kinetic energy of a droplet, is governed by its size and to some extent its propulsion and the effects of meteorological factors between the point of its production and the target. Terminal velocity is important in determining the number of

Table 4. Characteristics of some typical spot sprayers

| Variables | High volume spot spray (pressure atomizer) | Knapsack mister (Twin fluid atomizer) | Knapsack sprayer (Pressure atomizer) | C.D.A. hand sprayer (Rotary atomizer ) | 'Span Spray' (Rotary atomizer ) | Vibrajet hand sprayer (ultrasonic atomizer) |
|---|---|---|---|---|---|---|
| | 4 * | 2 | 4 | 5 | 3 | 5 |
| Control over drift (i.e. control over droplet size and droplet spectrum) | Varies with pressure. Good with low pressure to poor with low volumes and high pressure. | N.B. drift a hazard due to small droplets. | Depends on pressure and output. Large droplet range. | Droplet size can be varied and has narrow droplet range. | Droplet spectrum relatively large. | Droplet size can be varied and has narrow droplet range. |
| | 5 | 3 | 4 | 1 | 5 | 2 |
| Control over output volume | Very good but requires orifice and disc change plus pressure change. | Limited to low or ultra-low volumes. | Depends on nozzle type and pressure. | Any change results in change in droplet spectrum. | Very good but requires change in pressure and orifice size. | Very limited. |
| | 5 | 3 | 3 | 2 | 4 | 1 |
| Control over droplet propulsion (i.e. does one need to be able to spray plants from a distance) | Achieved by change in droplet spectrum and pressure change. | Air volume and velocity not easily controlled. | Sufficient pressure for good propulsion not possible. | Almost entirely dependent on natural forces. | Air volume and velocity can be varied. | Poor as used at low pressure. |
| Ability to spray: | | | | | | |
| single plants | 5 | 3 | 5 | 4 | 1 | 4 |
| small clumps (up to 10 $m^2$) | 5 | 5 | 5 | 5 | 3 | 5 |
| large clumps (over 10 $m^2$) | 5 | 5 | 2 | 3 | 5 | 2 |
| Capital outlay: | 2 | 3 | 5 | 5 | 1 | 4 |
| Maintenance costs | 2 | 2 | 5 | 5 | 3 | 4 |
| Durability | 4 | 3 | 5 | 5 | 4 | 4 |
| Operator safety: | 4 | 3 | 5 | 5 | 4 | 5 |
| Operator comfort: (e.g. noise level-effort required etc.) | 3 | 1 | 3 | 5 | 4 | 5 |
| Operator output: | 4 | 4 | 2 | 3 | 5 | 2 |
| Total score | 48 | 37 | 48 | 48 | 42 | 43 |

* Basis of score:
Very good = 5
Good = 4
Moderate = 3
Poor = 2
Very poor = 1

droplets which impinge upon the target (Brooks, 1947). Droplet size is also important in determining whether the droplet is retained upon the target surface (Ford and Furmidge, 1966).

Size, area, and oritentation of the target have a considerable effect on droplet retention. The structure of the target's surface is also important, as such factors as the cuticular waxes, and the size and shape of leaf hairs influence retention.

Microclimate also has a considerable bearing on the retention of droplets upon the target, in particular the wind speed is important around the target (Brooks, 1947).

Thus the impaction and retention of droplets upon the target is a complex interaction of physical phenomena and of the many factors involved only the formulation and droplet spectrum can be changed to improve efficiency.

(d) Uptake and distribution of the spray

Successful uptake and distribution of a spray applied to the foliage of a plant is influenced by a number of factors which can be placed in two groups:

(1) properties of the spray including the medium in which it is presented to the plant surface

(2) the properties of the plant.

As group one is the only one influenced by the application process the properties of the plants will not be considered. Uptake and efficacy appears to be influenced by a complex interaction between droplet size, droplet numbers and concentration of herbicide within the droplet. The work by Behrens (1957) indicates the complexity of the interactions and some of the variations to be expected. With hormone herbicides it is generally felt that an application rate to give 25 to 30 droplets per $cm^2$ is ideal (Anon, 1975). Further work is needed in this very important field as indications are the species vary in their response (Combellack and Harris, 1978). Centrifugal atomizers are ideal for studying such interactions because they produce uniform droplets which can easily be varied in size and density. It is essential that a better understanding of this aspect of application is gained as it should determine the type of equipment used to produce the ideal droplet size, density and concentration.

SELECTION OF A SUITABLE SPOT SPRAYER

With an understanding of the principles of application it is possible to determine the most important variables that should be considered for spot sprayers (see Table 4). A careful examination of Table 4 shows that each system has certain merits and that one's ultimate choice depends upon that variable which is considered the most important. If drift control is considered very important then C.D.A. hand-held rotaty atomizers or 'Vibrajets' are the preferred systems, whilst pressure atomizer spot spray units are the best where high volumes are required (e.g. for the control of gorse).

The value of C.D.A. can be judged from Table 4 and though not the ideal spraying system it is considered to have many virtues and hence a research program has been initiated at the Keith Turnbull

Research Institute. This C.D.A. research program is aimed at developing suitable spot spray equipment, developing and evaluating suitable C.D.A. formulations and evaluating the efficacy of the C.D.A. system against a number of perennial and annual weeds.

REFERENCES

Anon (1975).- Correct Aerial Application of Pesticides. Published by Ciba-Geigy Ltd., Basle, Switzerland.

Bailey, R.J. and Smartt, A. (1976).- The results of a controlled drop application technique for herbicides in cereals. *Proceedings 1976 British Crop Protection Council - Weeds,* 2 : 383-385.

Bals, E.J. (1969).- Design of rotary atomizers. *Proceedings 4th Int. Agric. Aviat. Congr.* 156-165.

Brooks, F.A. (1947).- The drifting of poisonous dusts applied by aeroplanes and land rigs. *Agric. Eng.* 28 : 233-240.

Combellack, J.H. andShaw, K. (1977).- Does Controlled Droplet Application (C.D.A.) have a place in Australian Forest Situations? *Proceedings Australian Forest Development Inst. Conf.* 1, 94-97.

Combellack, J.H. and Harris, R. (1978).- Field trials with C.D.A. spot sprayers. *Proceedings of the First Conference of Council of Australian Weed Science Societies* (in press).

Combellack, J.H., Richardson, R.G. and Shaw, K. (1978).- The ideal C.D.A. hand-held sprayer, and formulations for spot spray. British Crop Protection Council Symposium on Controlled Droplet Application (in press).

Ford, R.E. and Furmidge, C.G.L. (1966).- Impact and spreading of spray drops on foliar surfaces. Soc. Chem. Ind. Monograph, No. 25, 417.

Himel, C.M. (1969).- Spray droplet size in the control of spruce budworm, boll weevil, bollworm and cabbage hopper. *J. of Econ. Entomol.* 62, 4 : 916-918.

O'Keefe, M.G., Dudley, J. and Dickson, J.W. (1976).- The application of some cereal herbicides by controlled drop applicators. *Proceedings 1976 British Crop Protection Council, Weeds* 2 : 377-381.

Ripper, W.E. (1956).- Application Methods for Crop Protection Chemicals. *Ann. App. Biol.* 42 : 288-324.

Rogers, E.V. (1975).- Ultra-low Volume Herbicide Spraying - Forestry Commission Leaflet 62, H.M.S.O., U.K.

Rogers, E.V., Matthews, G.A. and Morgan, N.G. (1976).- Controlled Droplet Application and U.L.V. Spraying. Published by British Petroleum No. MP 548.

Shaw, K. and Combellack, J.H. (1978).- The concepts and problems of formulating phenoxy herbicides for spot spray application using controlled droplet application (C.D.A.). *Proceedings First Conference of Council* of *Australian Weed Science Societies* (in press).

Taylor, W.A. and Merritt, C.R. (1974).- Preliminary field trials with 2,4-D ester, barban and tri-allate applied in spray volumes of 5-20 ℓ/ha. *Weed Res.* 14 : 245-250.

Taylor, W.A. and Merritt, C.R. (1975).- Some physical aspects of the performance of experimental equipment for Controlled Drop Application with herbicides. *Proceedings 8th Br. Insectic. Fungic. Conf.*, 161-170.

Taylor, W.A., Merritt, C.R. and Drinkwater, J.A. (1976).- An experimental, tractor-mounted, very low volume uniform-drop-size sprayer. *Weed Res.* 16 : 203-208.