THE 1997 BRIGHTON CROP PROTECTION CONFERENCE – Weeds 5A-1
(re-scanned: RPB, April 2005)

THE INTERNATIONAL (BCPC) SPRAY CLASSIFICATION SYSTEM INCLUDING A DRIFT POTENTIAL FACTOR

E S E SOUTHCOMBE,
BCPC Applications Committee, c/o AgrEvo UK Limited, Chesterford Park, Saffron Walden, Essex, CBI O I XL, UK

P C H MILLER,
Silsoe Research Institute, Wrest Park, Silsoe, Bedford, N4:K45 4HS, UIK

H GANZELMEIER,
Biologische Bundesanstalt fur Land- und Forstwirtschaft, Messeweg 11/12, D-38104 Braunsweig, Germany

J C VAN DE ZANDE
Instituut voor Milleu- en Agritechniek (IMAG-DLO), Mansholtlaan 10-12, 6700-AA Wageningen, The Netherlands

A MIRALLES
ANPP / CIETAP, c/o Cemagref, 3 61 rue J F Breton, F-') 403 3 Montpellier, France

A J HEWITT
Stewart Agricultural Research Services Inc., PO Box 509, Macon, MO 63552, USA

ABSTRACT

The system for classifying sprays and atomizers used to apply pesticide products introduced by BCPC in 1985 has been extended. In addition to the existing categories of spray quality, a new set of categories classifying sprays by their drift potential, as measured in comparative wind tunnel tests or comparable procedures, has been introduced. The two components will be combined to provide a more comprehensive means to describe sprays and atomizers. Benefits of the classification system are to allow suppliers and users of pesticide products to match their spraying equipment more closely to the requirements of biological performance and environmental protection. The procedures and protocols used to make the measurements of droplet size spectrums and drift potential will be issued as standards in due course.

INTRODUCTION

The spraying devices used to apply crop protection and other pesticide products employ a variety of nozzles to atomise the spray mixture into a spray of droplets which is then directed towards the target. Instructions given on the labels of crop protection products indicate clearly the dose of product and the volume of spray mixture, usually in water, to be applied to the target. However, information on the nature of the spray to be used is often missing or unclear.

In 1985, the British Crop Protection Council (BCPC) proposed a system for classifying sprays and the nozzles producing them into categories of spray quality. (Doble *et al*., 1985; Southcombe, 1988a,b). The technical basis of this system was simple using analysis of droplet size spectrum compared to a set of standard reference nozzles. Later, BCPC recognised the need to develop the technical basis to include consideration of the drift potential of sprays. To meet the increasing interest in the system from a number of other countries, a meeting of interested parties from many European countries and the USA was held in Rotterdam in October 1994, and agreement was reached on most of the issues related to spray classification.

This paper outlines the new spray classification system that has been proposed by two Working Groups established at Rotterdam and which is now being presented as an international system to all regions and countries interested in adopting a means to advise on, or to control the use of spraying equipment.

OBJECTIVES

Classification of sprays and nozzles serves two main functions, namely:

(i) to define the spray quality most appropriate to the product, pest and target that can be communicated on the product label, and

(ii) to enable the use of sprays likely to be environmentally unacceptable to be avoided.

The original BCPC classification system relied on an analysis of the droplet size spectrum or 'Spray Quality'. Three broad categories covered most of the nozzles commonly found. The terminology used to describe them - 'Fine', 'Medium', 'Coarse', etc. - was deliberately practical to appeal to the end-user.

In developing this new approach to spray classification, we have maintained a practical approach based on a scientific background. We recognised that to evaluate all the causal parameters relating to droplet production, droplet life, transport, impact and off target drift was beyond the resources available to this project. We therefore concentrated our efforts on developing a means to define the effects of these parameters in terms of a spray quality as previously, and with an additional element relating to the potential within a spray for some of its components to be displaced in a wind, which we have termed the Drift Potential factor. This allows a difference to be made between sprays with the same nominal descriptor such as volume median diameter or spray quality category, but of very different widths in their droplet size spectrums. We have also recognised that a practical approach with relevance and appeal to the end-user is needed, and that the following criteria need to be met in a successful classification system :-

- It may need a pragmatic approach where scientific solutions are not easily available.
- It must be acceptable to Regulatory, Health & Safety and other authorities in the countries adopting it and to the suppliers and users of atomizers and spraying equipment.
- It should be flexible and cover all reasonable atomizer and spray types

- The methods and protocols must be standardised and usable by all interested parties.
- It must be presented to the end-user in simple, meaningful and understandable terms when used on labels and in literature.

SPRAY QUALITY

Most atomizers produce a range of droplet sizes by virtue of their atomization process. Some well designed rotary atomizers produce a narrow range; most hydraulic nozzles produce a wider range of sizes. In the original system, to classify a nozzle at a particular pressure, a reference chart was constructed by plotting the droplet spectrums of four Reference Nozzles. These were, with one exception, characteristic of the three categories of spray quality (Table 1). The threshold boundaries between the categories were determined by interpolation mid-way between the adjacent characteristic curves. The perceived benefit of this was to allow some latitude in deciding which category to place test nozzles that coincided with category thresholds. The droplet spectrums for test nozzles must be measured with the identical equipment setup and conditions at the same time as the reference nozzles.

In the new system, the same basic principles have been retained except that the Reference Nozzles now define the ***thresholds*** between categories. This change reflects the opinion of a number of organisations consulted who required a positive demarcation between categories.

Table 1. Reference Nozzles

Category	**Threshold Nozzles**	**Characteristic Nozzles**
'Very Fine' / 'Fine'	F 110 / 0.48 / 4.5 (11001)	
'Fine'		F 110 / 0. 85 / 3.5 (11002)
'Fine'/'Medium'	F 110 / 1.18 / 3.0 (11003)	
'Medium'		F 110 / 1.44 / 2.5 (11004)
'Medium' / 'Coarse'	F 110 / 1.93 / 2.0 (11006)	
'Coarse'		F 110 / 2.58 / 2.0 (11008)
'Coarse' / 'Very Coarse'	F80 / 2.88 / 2.5 (8008)	

Note : Nozzles given in BCPC Nozzle Code - (angle) / (litre/min) / (bar) followed by typical manufacturers' code

One of the major advantages of this classification scheme is that it facilitates the use and comparison of droplet size data measured using different particle size analysers and sampling techniques. Despite considerable advances in the design of instruments to measure droplet sizes, numbers and velocities, there are still significant differences between the results produced, making direct comparisons and the use of absolute figures difficult.

The Working Groups have devised, in collaboration with other groups studying the measurement of agricultural sprays, a series of protocols covering the most commonly used laser based droplet sizing instruments. In addition, several nozzle manufacturers are supplying sets of standardised reference nozzles, which will be validated by an independent laboratory and lodged at selected organisations in those countries operating the system.

There are some types of atomizers that do not easily fit into a comparison with the hydraulic reference nozzles. The three most important types are rotary, twin-fluid and air-inclusion nozzles. Rotary atomizers normally produce a narrow droplet size spectrum and can therefore be easily classified by a specific parameter such as the volume median diameter.

Nozzles in which air is used as part of the spray formation process often produce droplets containing air inclusions. Twin-fluid types are fed with air under pressure, whilst other design types draw air in using a Venturi principle. Each droplet size analyser treats these droplets differently and they produce results that cannot be used to classify the nozzles. It is known that the actual size is larger than those from an equivalent flat fan nozzle with water, but that the density is lower than for a water droplet. The presence of the air bubbles undoubtedly affects both droplet transport and deposition patterns. It is recognised that the protocols currently available will not be able to effectively categorise the sprays produced by this type of nozzle because they are physically very different from those of the Reference Nozzles. Work will continue to seek ways in which an effective definition of spray quality can be used in such cases.

DRIFT POTENTIAL FACTOR

The recognition that the risk of spray drift was not a function only of the droplet size distribution meant that test methods were needed to establish the risk of drift associated with different nozzles operating on boom sprayers. Wind tunnel tests provide one way in which the risk of drift from given nozzle conditions can be quantified but it is accepted that the use of field measurements and modelling approaches are also valid in determining a relative drift risk factor.

Wind tunnel approaches

Initial studies with a range of single nozzles spraying in a wind tunnel have shown that differences in the risk of drift could be related to measures of the airborne spray profile (Helck *et al*., In preparation, Helck *et al*, 1997, Miller *et al*., 1989) or the spray deposition on the floor of the tunnel downwind of the nozzle (Young, 1991; Miralles & Bogliani, 1993).

A comparative study involving five different research facilities in the LTK examined the measurement of airborne drift profiles from a range of nozzle types operating in different wind tunnel configurations and using a number of different sampling methodologies. Results from this work showed relatively good agreement between the quantities of airborne drift measured in the different conditions particularly when these were normalised using results for the original BCPC reference flat fan nozzles (Miller et al., 1993). The agreement was closest for wind speeds in the range 2.0 to 2.5 m/s and was further improved by taking results from tunnels which met defined criteria in terms of the minimum dimensions of the cross-section (Parkin, Wheeler, 1996). An outline test protocol for use when conducting wind tunnel tests to assess the risk of drift from different nozzles systems was proposed as a result of this work (Miller et al, 1993).

Subsequent collaborative work at the BBA in Braunsweig, Germany and at Silsoe Research Institute in the UK showed that there were some limitations to this proposed outline protocol. Measured airborne profiles from different nozzle systems, when plotted as airborne spray volumes at different heights, gave characteristic curves that overlapped. (Helck & Herbst, 1997). The reference nozzles were used to define characteristic curves of cumulative airborne spray volume against distance below the nozzle and to define classes of drift risk assessment (Miller et al, 1995). However results from a series of tests with different nozzle systems gave characteristics which did not have the same form as those for the reference nozzles. This was particularly the case for spinning discs and some cone nozzles with relatively low initial droplet velocities. The wind speed of 2.0 to 2.5 m/s was shown to be critical with respect to the degree that an air flow would penetrate the spray fan from conventional pressure nozzles of different flow rate capacities operating with the spray fan at right angles to the air flow. Substantial differences were then observed between the volumes and airborne distribution of spray liquid detrained from single nozzles and from multiple nozzles mounted on a boom because of the change in air flow patterns around and through the spray structure (Miller *et al*, 1995)

It was therefore recognised that any comparative analysis of the airborne spray profiles downwind of a test nozzle in a wind tunnel needed to take account of the total volume and the vertical distribution of airborne spray. Two possible approaches have been identified for use in a standardised protocol, namely:

(i) to make measurements at a distance that is far enough away downwind from the nozzle such that the effects due to spray structure and droplet size distribution within the spray have settled; or

(ii) to make measurements closer to the nozzle and use a comparative method of analysis which accounts for the total airborne spray volume and its vertical distribution.

Method (i) above has advantages in terms of a simplified analysis and a result that can be closely related to the field performance of a nozzle or a boom sprayer. However, it requires a relatively large wind tunnel facility, sampling typically 5 metres from the nozzle and may not adequately address the assessment of drift risk close to the sprayer. Method (ii) can be used with a smaller tunnel system and work is now in progress to finalise the methods by which results from such tests can be used to define a comparative drift potential factor. This again will use the reference nozzles to define the categories for this factor. A comparative scale will be established based on a calculation of the first moment of the airborne drift profile measured at a distance of 2.0 metres downwind of the nozzle. This will be calculated as follows:

$$DPF = \sum V_n \frac{\sum V_n h_n}{\sum V_n} = \sum V_n h_n$$

where V_n is the volume of airborne spray collected at height h_n , and DPF is the drift potential factor. A drift potential factor will then be compared with the equivalent results obtained with the appropriate reference nozzles.

Work at Cemagref, Montpellier France, has involved macroscopic evaluations of the wind effects on sprays emitted by nozzles in the laboratory. The technique is based on the comparison between the liquid distributions obtained on a patternator when the spray is subjected or not to a wind. To measure the wind effect from the liquid distributions, two notions have been considered :

(i) the distribution displacement corresponding to the natural displacement on the soil, and

(ii) the drift which is the water leaving the patternator.

The displacement is calculated from the equation :

$$A = \frac{\sum_{i=1}^{i=N}(i-0.5)v_i}{\sum_{i=1}^{i=N}v_i} e$$

where "A" represent the displacement (m), "I" the test-tube index, "N" the total number of test-tube, "v_i" the water quantity collected in the test tube (ml/min) and "e" the collector channel wide (0.05 m for the Cemagref patternator).

The total drift is calculated from the equation:

$$D = 100\left(1 - \frac{\sum_{i=1}^{i=N}v_i}{Q_0}\right)$$

where "D" represents the drift (%),"i" the test-tube index, "N" the total number of test-tube, "vi" the water quantity collected in the test tube (ml/min) and Q_o the nozzle flow rate at the same pressure.

This methodology has been employed on single nozzle (Miralles, 1992, 1993, 1994) to compare the drift potential of nozzles at different pressures, heights and nozzle orientation to the air stream including flat fan nozzles with the spray perpendicular or parallel to the air flow Again, comparison of the results obtained with test nozzles with those from the reference nozzles will form the basis for determining the drift potential factor.

Drift models

A number of models exist to predict the movement of spray droplets and hence the risk of drift. Two examples are mentioned here to show how characteristics of the sprays are used in different ways. Future work will need to refine the relationships between such models and the principles of spray quality and drift potential described in this paper. It is likely, however, that the use of models, in conjunction with the appropriate experimental data, will provide an alternative approach for determining the drift potential factor

The drift model IDEFICS developed at IMAG-DLO, Wageningen in the Netherlands simulates the paths through air of drops starting at the nozzle outlet and calculates downwind deposits on the ground (Holterman, Van de Zande, 1996). The model simulates the spraying process of a conventional boom sprayer in a cross wind, accounting for sprayer related parameters (such as nozzle characterisation), crop height and atmospheric conditions. The simulation method differs from the wind tunnel approach in that the nozzle is placed in a cross wind, yet accounts for a head wind contribution due to driving speed, These simulations are closely linked to single nozzle experiments outdoors where a single nozzle moves on a track in a cross wind situation. These experiments show a much higher reproducibility than drift measurements with a more practical setup using a real sprayer in a real crop. The single nozzle experiments are primarily used for validating the drift models, but they also offer a good perspective to investigate spray drift for nozzle classification.

Working under a co-operative research and development agreement, the Spray Drift Task Force (SDTF), United States Environmental Protection Agency and United States Dept. of Agriculture have developed a computer model, AgDRIFT® for predicting pesticide movements and deposition (Hewitt, 1997). One of the most important of the input parameters is the droplet size spectrum of the spray. An option for describing the emission droplet size spectrum is the use of categories of spray quality. In addition to selection of the droplet size spectrum in terms of spray quality category (for example from a catalogue/ applicator handbook or other source), AgDRIFT® allows data to be input from various sources including measured data and data generated from an empirical atomisation model, DROPKICK®, developed by the SDTF. The physical properties of the tank mix, such as surface tension, density, shear and extensional viscosity can be input to DROPKICK® to produce a model-predicted droplet size spectrum.

The description of droplet size in terms of spray quality category provides an excellent tool for making decisions on application practices. It is likely that increasing numbers of pesticide labels in the USA may describe droplet size requirements for spray applications based on classification schemes. For example, buffer zone recommendations may be based on spray droplet size category and other factors such as spray release height, boom length and meteorological conditions such as wind speed. Based on deposition rate predictions using measured or predicted droplet size data, the label for a particular product might indicate that a nozzle classified as no finer than a specified category should be used to achieve acceptable spray coverage and efficacy and minimal drift potential for specific non-target entities at defined distances downwind of the application area.

TERMINOLOGY

This new classification system has two components - spray quality and drift potential Spray quality terms are well established and accepted as the series 'Very Fine', 'Fine', 'Medium', 'Coarse' and 'Very Coarse'. It is not expected that the new classification system will significantly change the categories already applied to nozzles at different working pressures.

Drift potential terms will be related to the percentage reduction in drift to a defined reference nozzle. This will be the threshold reference nozzle at the finer boundary of the test nozzle's spray quality category. This will mean that most drift potential terms will refer to a reduction in drift potential for that spray quality category. so avoiding terms such as 'High Drift Potential' which in practice are not acceptable. Some proposed terms, which have not yet been formally adopted, might be :-

Drift reduction %:	< 0	0-25	25-50	50-75	> 75
Drift potential term:	Higher	Normal	Low	Double low	Triple low

It is clear that for any spray quality category there will be a limited number of Drift Potential categories which in practice will be applicable. For example a 'Fine' spray is unlikely to have a 'Double Low' Drift Potential category.

Examples of the use of the two components on a product label for application by ground sprayer are :-

(i) A product which poses no significant threat to neighbouring areas might be : "Apply as a 'MEDIUM' spray with 'NORMAL' drift potential"

(ii) A product which must not be allowed to drift onto neighbouring areas might be : "Apply as a 'MEDIUM' spray with 'LOW' drift potential"

It is expected that both these terms will also be incorporated into the performance tables supplied by nozzle manufacturers so that product suppliers, advisors and users can select nozzles or other atomizers that satisfy the requirements for both biological performance and environmental protection.

DISCUSSION

The principle of spray and nozzle classification has been embraced by organisations in a number of countries. An improved and extended system is now proposed which enables classification to be made from two perspectives - spray quality and drift potential. This allows a more accurate and comprehensive way to characterise the spray produced by nozzles and other atomizers, and a more flexible way to indicate desirable or mandatory spray characteristics to the end-user. This might be to give optimum biological performance with adequate environmental protection, or to ensure the highest level of environmental protection, for example where no-spray or buffer zones have to be enforced.

The methods and protocols needed to operate the system are being prepared and are expected to be issued in due course as standards. The sets of reference nozzles are also being manufactured and validated (at the time of preparing this paper) and will be lodged with selected institutions in participating countries.

It will have been noted that no reference has been made to the spray liquid. The Working Groups have agreed that the test fluid will be water, unless the atomizer depends on a modified water or oil for its correct operation. As the effects of product formulations on spray characteristics are complex and often not easily predicted it is not possible to cover all possibilities with a single test fluid.

BCPC and the "Rotterdam" Working Group are also developing a system for classifying the potential hazard of all types of pesticides application techniques and equipment. (Parkin *et al*., 1994). This is now known as the Pesticide Application Safety Scheme (PASS) and again involves a multi-national collaboration. Spray classification will eventually form a component of the PASS scheme.

ACKNOWLEDGEMENTS

The "Rotterdam" group and its Working Groups have received the enthusiastic support of many organisations amongst which the contributions made by the following are gratefully acknowledged : -

AgrEvo UK Limited; Albuz, France; AN-PP/CIETAP, France; BBA, Braunsweig, Germany; Cemagref, Montpelier, France; Central Science Laboratory, UK; CRAG, Gembloux, Belgium; Delavan Limited, LTK; Hardi International, DK; IMAG-DLO, Wageningen, NL; IPARC, Silwood Park, UK; ISMA, Monterotondo, Italy; Lechler GmbH, Germany. Long Ashton Res.Station, LTK- Lurmark Limited, LTK; Micron Sprayers, UK; Ministry of Agriculture, Fisheries and Food, UK, Norwegian Inst.Agric.Engineering, As, Norway; Res. Centre, Bygholm, DK- Silsoe College, Univ.Cranfield, UK. Silsoe Research Institute, UK; Spraying Systems / TeeJet; Sprays International Ltd., UK; Tecnoma SA, France; SKL, Wageningen, NL, University of Agric. Sciences, Uppsala, S; US Spray Drift Task Force.

Thanks are also due to Dr.Andreas Herbst (BBA), Dr.Peter Walklate (SRI), Dr.Andrew Gilbert (CSL), Henk Porskamp (IMAG-DLO) for their particular help and advice.

REFERENCES

Doble S J, Matthews G A, Rutherford 1, Southcombe E S E (1 985). A System for Classifying Hydraulic and Other Atomizers Into Categories of Spray Quality. *Proceedings British Crop Protection Conference - Weeds*, **3**, 1125-1133.

Helck C, Herbst A (1997). Drift Potential Index - Eiiie Neue Kennzahl zur Beurteilung von Pfianzenschutzduesen Hinsichtlich Ibres Abtriftpotentials. To be published in Nachrichtenblatt des Deutschen Pflanzenschutzdienstes, Stuttgart

Helck C, Herbst A, Ganzelmeier H (1997). New approaches to determine drift potential for nozzles. Spray and nozzle classification: meeting of the reference nozzle and driftability Working Groups - Silsoe April 1997 (unpublished)

Helck C, Herbst A, Ganzelmeier, H (In preparation) Drift potential index - a new parameter to characterise the drift risk from agricultural nozzles. To be submitted to *The Journal of Agricultural Engineering Research*

Hewitt A J (1997). Droplet Size and Agricultural Spraying, Part 1. *Atomization & Sprays*, **7**, (3), 253-244

Holterman H J, van de Zande J C (1996). Drift Reduction in Crop Protection: Evaluation of Technical Measures Using a Drift Model. *Proceedings British Crop Protection Conference - Pests & Diseases*. 111 - 116

Miller P C H, Hislop E C, Parkin C S, Gilbert A J (1993). The Classification of Spray Generator Performance Based on Wind Tunnel Assessment of Spray Drift. In Proc. *ANPP/BCPC Second International Symposium on Pesticide Application*, Strasbourg.

Miller P C H, Mawer C J, Merritt C R (1989). Wind Tunnel Studies of the Spray Drift from Two Types of Agricultural Spray Nozzle. *Aspects of Applied Biology*. **21**. 237 - 238

Miller P C H, Smith R W, Tuck C R, Walklate P J. (1995). The Classification of Agricultural Sprays Based on Droplet Size Distributions and the Results from Wind Tunnel Tests. *Proceedings British Crop Protection Conference - Weeds*, 1125-1134.

Miralles A (1992). Simulacio de Derivaen Barresde Polvoritzacio: Documenyt de Cours Réalisé pour la Formation Continue Organisée par La Estacion Maquinaria Agricola (Lerida). 18p.

Miralles A, Bogliani M (1993) Evaluation Macrooscopique du Vent sur un Jet de Pulverisation. In *Proceedings ANPP/BCPC Second International Symposium on Pesticide Application*, Strasbourg. **1**, 117 - 124.

Miralles A, Boisgontier D, Bouvier J L (1994). Comparison de Dérive de Différents Produits Phytosanitaires. Rapports confidential No.46, 130 p.

Parkin C S, Gilbert A J, Southcombe E S E, Marshall C J (1994). The British Crop Protection Council Scheme for the Classification of Pesticide Application Equipment by Hazard, *Crop Protection*, **13** (4), 281-285

Parkin C S, Wheeler P N (1996). Influence of Spray Induced Vortices on the Movement of Drops in Wind Tunnels. *Journal of Agricultural Engineering Research* **63**, 35-44

Southcombe E S E (1988a). The BCPC Nozzle Selection System. Proceedings *International Symposium on Pesticide Application*, Paris. 71-78.

Southcombe E S E (1988b). The Coding and Selection of Agricultural Spraying Nozzles. Proceedings US Agricultural Research Institute Workshop on Improving On-target Placement of Pesticides, Reston, VA, USA.

Young B W, (1991). A Method for Assessing the Drift Potential of Hydraulic Nozzle Spray Clouds, and the Effect of Air Assistance. In *Air-Assisted Spraying in Crop Protection*. BCPC Monograph No.46 (eds. Lavers. Herrington, Southcombe) 77 - 86.