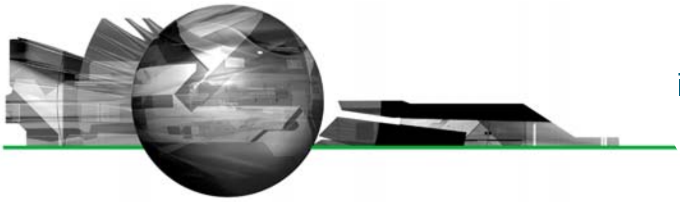

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application note

Characterization of agricultural spray nozzles using the Malvern Spraytec

Introduction

The droplet size and size distribution of the droplets produced by nozzle systems are important in defining the performance of agrochemical application systems. The droplet size must be matched against the nature of the target (table 1). Fine droplet sizes are often required when targeting insects, and can be useful when uniform surface deposition on the leaves of a small target plant is required for herbicides. Alternatively, the use of coarser droplet sizes can help penetrate the plant canopy. This can aid the coverage of broad leaf plants, and can also allow the active to reach the soil, where it can be taken up into the plant via the root system. These requirements need to be balanced against the risk of contamination via soil run-off, associated with large droplets, and spray drift away from the target.

Spray drift

Drift of an agricultural spray occurs when the droplets are deposited on any area other than the target. As the risk of spray drift increases, so does the potential to cause harm to wildlife, residential areas and watercourses. Concern regarding this issue has increased in recent years, as pesticides have become increasingly active. Preventing spray drift is therefore one of the most challenging problems facing pesticide manufacturers and users.

The main factors that influence spray drift are [2]:

- wind velocity and local atmospheric conditions
- droplet size and spray quality
- vehicle speed
- spray boom height

Of these, droplet size is a major and controllable factor. Changing the size and uniformity of the droplet size distribution can significantly reduce the occurrence of spray drift. This, in turn, can increase the range of weather conditions under which crops can be sprayed, improving the timing of the application of pesticides.

Spray drift is affected by the droplet size because the settling velocity of a particle is proportional to the square of the particle diameter. Smaller droplets are, therefore, more likely to be carried off target by the wind. Smaller droplets are also more likely to evaporate, increasing losses during application. By using nozzles and operating conditions which produce larger droplets, the occurrence of spray drift can be decreased. There has recently been an important move toward using sprays with larger droplet size distributions. However, this must be balanced against the requirements for effective delivery of the active to the target.

Active	Target/ Mode of action	Spray size
Herbicides	Soil Uptake	Medium-coarse
	Broadleaf Plants	Medium
	Grasses	Fine
Fungicides	Systemic delivery	Medium
	Contact delivery	Fine
Insecticide	Systemic delivery	Fine-medium
	Contact delivery	Fine

Table 1: Correlation between mode of action and spray size.

Spray nozzle selection

The most important part of the spray equipment for producing the correct droplet size distribution is the spray atomizer nozzle. A wide range of nozzles are available, producing plumes of different shapes (flat fan, hollow cone) and droplets of different sizes. The importance of the nozzle has prompted the development of a classification scheme by the British Crop Protection Council (now the British Crop Production Council). This scheme aims to aid in the selection of the most appropriate spray size and distribution required for particular products, and to do this in a way that is easily communicated to the user. In this way, it is hoped that the use of sprays that may be environmentally unacceptable, for example by contamination due to spray drift, will be reduced [3].

The original BCPC scheme classifies agricultural nozzles into five droplet size categories (Very Fine, Fine, Medium, Coarse, Very Coarse), and the American ASAE derivative adds a further size category (Extra Coarse) [4]. Nozzles can then be selected for use, based on the target and the risk of spray drift.

Experimental

In this application note, five nozzles which define the boundaries of the BCPC/ASAE nozzle classes have been characterized using the Malvern Spraytec laser diffraction system. Using these measurements several further nozzles have been analyzed under different operating conditions and assigned a classification based on size measurements.

Droplet sizing

The Malvern Spraytec laser diffraction system provides a robust, rapid method for assessing the particle size produced by atomizer systems, aiding researchers in the development of new agrochemical devices and formulations.

Laser diffraction systems calculate droplet size distributions by measuring the intensity of light scattered by spray droplets as they pass through a collimated laser beam. The angle at which the droplets scatter light is inversely proportional to their size. As such, if the changes in scattering intensity are measured as a function of angle, it is possible to calculate spray size distributions by comparing the acquired data to an appropriate scattering model.

The design of the Spraytec allows for the technique of laser diffraction to be applied to a wide range of spray applications. The features which are particularly suited to the measurement of agricultural sprays are:

- The distance between the transmitter and receiver can be adjusted up to a maximum of 2.5m in order to cope with different spray geometries.
- A large working distance, essential for measuring wide spray plumes. Particles larger than 5μm in size can be detected and accurately measured even when they are 1m away from the detection system.
- A wide size range (0.1 – 2000μm) means that both fine and coarse droplets can be detected in a single measurement.
- An air purge system can be used to prevent spray deposition on the optical components.
- A patented multiple scattering analysis enables the accurate measurement of high concentration sprays.

In this case, each spray was measured as it was traversed across the Spraytec's measurement zone. This allowed the change in particle size as a function of position within the plume to be determined. The characteristic size distribution for the entire spray plume was then obtained by calculating the average of all the results obtained during the spray traverse, weighted according to the concentration of the spray at each measurement point.

Results

BCPC Nozzles

The cumulative size distributions for the standard BCPC/ASAE boundary nozzles (BCPC01 – 01F110@ 4.5 bar; BCPC03 – 03F110@ 3.0 bar; BCPC06 – 06F120@ 2.0 bar; BCPC08 – 08F80@ 2.5 bar; and BCPC10 – 10F65@2.0 bar) are shown in Figure 1. As the nozzle classification number increases, so the measured particle size increases. The volume median diameters (Dv50) for each of these five nozzles can then be used to define the BCPC

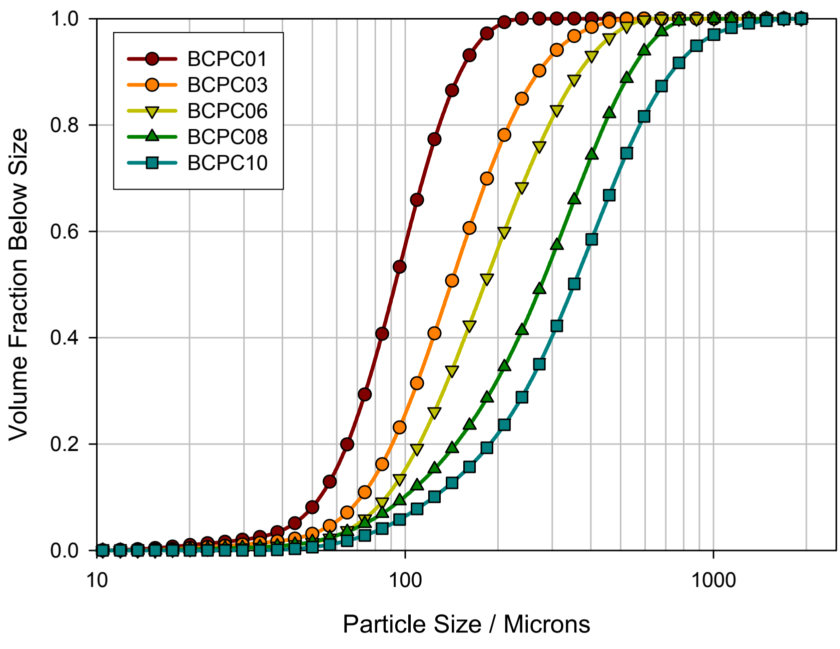

Figure 1: Cumulative size distributions for the BCPC standard nozzles

classification grid for droplet sizes starting from Very Fine (particle size less than that measured for the BCPC01 nozzle) through to Extra Coarse (droplet size greater than the BCPC10 nozzle). The output of other nozzle systems can then be compared against the BCPC grid.

Determining Nozzle Performance

The liquid feed pressure dependence of the output of three flat-fan nozzles (a conventional 0075 nozzle, a DG015 pre-orifice atomiser nozzle and an IDK015 air-induction nozzle) was determined using the Spraytec system. Figure 2 shows how the Dv50 changes with operating pressure for each of the nozzles. The Dv50 for each of the BCPC nozzles is also plotted, in order to define the nozzle classes.

The results show that the Dv50 for nozzle 0075 varies from 191µm at 0.75 bar to 117µm at 5 bar. Between 1 and 4 bar pressure this nozzle is classified as fine, and is therefore a suitable nozzle for use with insecticides. The Dv50 for nozzle DG015 varies from 283µm at 1 bar to 167µm at 5 bar. From 1.5 to 3.5 bar this is a medium spray, suitable for the treatment of broadleaf weeds. Finally the Dv50 for nozzle IDK015 varies between 583µm at 1.5 bar and 306µm at 4 bar. The droplets produce by this nozzle are coarse, very coarse or extra coarse dependent on the pressure, and as such are suitable for soil-applied herbicides.

Plume Geometry Assessment

In addition to looking at the average size for the whole plume, the Spraytec can also be used to look at how the droplet size varies across the spray plume. In continuous mode, the Spraytec produces a particle size distribution once a second for up to an hour (it can also be used in a rapid

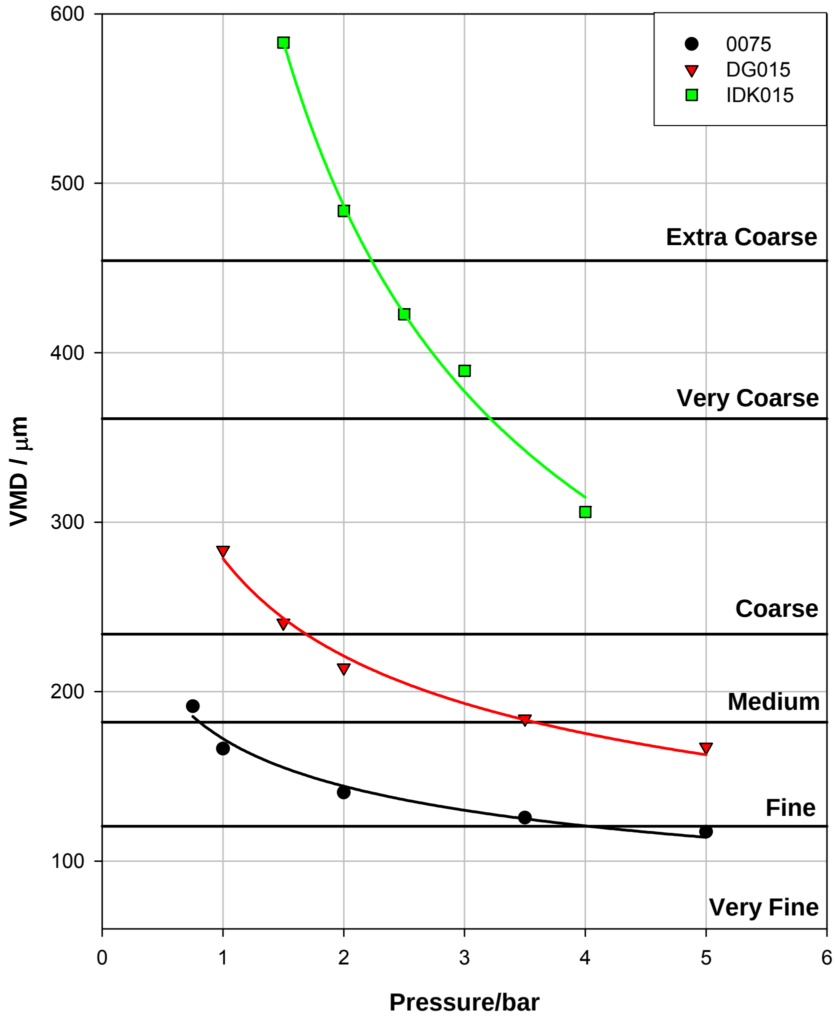

Figure 2: VMD vs pressure for 3 nozzles. The classifications are based on the BCPC standard nozzles show in figure 2.

mode where the acquisition rate can be up to 10 kHz for shorter acquisition times). This allows the change in droplet size to be monitored as a function of time as the spray is traversed through the measurement zone.

Figure 3 shows the particle size histories for the DG015 nozzle measured for spray traverses carried out at a series of different pressures.

For this nozzle, each traverse of the plume has a characteristic shape, with larger droplets being detected at the edges of the plume and smaller droplets at the centre. Increasing the pressure of the liquid reduces the droplet size produced by the nozzle. However, this is not the only affect of pressure on the spray plume. Figure 3 also shows that the duration of the particle size history increases as the

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liquid pressure is increased. Since each traverse was carried out at the same speed, this suggests that the width of the spray plume must become wider at higher pressures. Therefore, as well as having an affect on the droplet size, the pressure at which a nozzle is operated also affects the plume angle. This increase in plume angle with pressure may become important when setting the boom height to ensure a consistent spray at the target level.

Conclusions

This application note has covered the importance of droplet size in agricultural spraying. The efficacy of crop coverage, the occurrence of soil run-off and spray drift are all dependent on the droplet size. The droplet size must therefore be tailored to the target and spraying conditions. Hence it is essential that the performance of agricultural nozzles is well understood.

The Spraytec has been used to characterize the reference nozzles which define the BCPC size categories. Three further nozzles, 0075, DG015 and IDK015, have been measured at a range of pressures. The results obtained enable the nozzle classification at each pressure to be determined along with suitable applications for each nozzle.

The results described above are averages from the whole of the spray plume. However, the Spraytec has also been used to obtain dynamic information about the spray plume. The particle size history from each traverse shows how the particle size varies across the plume. The measurements of particle size histories at increasing pressure have also shown that the spray droplet size becomes finer and the plume becomes wider at higher pressures.

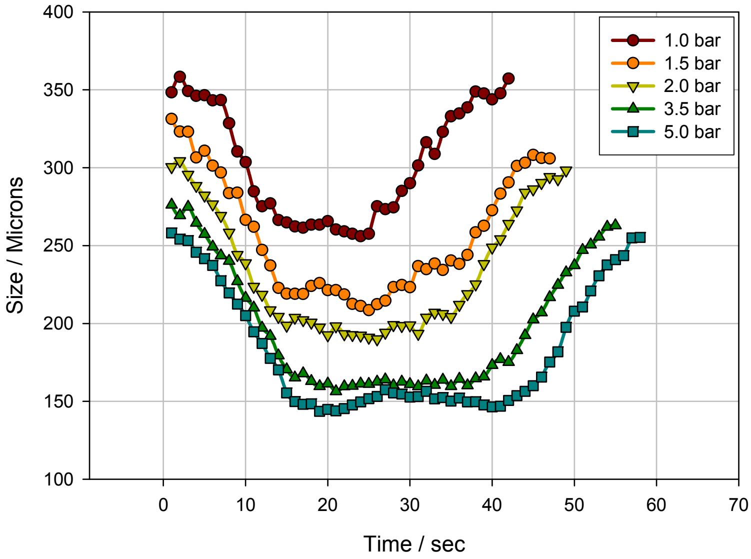

Figure 3: Particle size histories recorded for the DG015 nozzle at increasing pressures.

Acknowledgements

We acknowledge the help and expert advice of Clive Tuck and Paul Miller at The Arable Group's Silsoe Spray Applications Unit in preparing this application note and for providing access to their facilities in order to carry out the measurements described above.

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