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Managing pesticide use in arable agriculture by improving nozzle selection based on product efficacy to give optimised use and improved spray drift control

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1. Abstract

This project aimed at developing an extended spray/nozzle classification scheme that could accommodate a wider range of nozzle designs than existing schemes and particularly including air-induction nozzles. The extended scheme would have components relating to possible product efficacy and the risk of spray drift as separate elements. The work was based on an initial hypothesis that had two components:

1) there is a negative correlation between product efficacy and deposit variability, so that data relating to deposit variability measured according to specific protocols could be used in an extended classification scheme; and
2) a spray drift risk parameter could be obtained from comparative spray drift measurements made to defined protocols in wind tunnel or field conditions.

Measurements of spray deposits on stainless steel rods in laboratory conditions showed that the highest levels of variability were associated with nozzles and application variables that gave good levels of efficacy when treating the main arable crops with boom sprayers, and therefore the first components of the initial hypothesis, were rejected. Further measurements with a wide range of nozzle designs gave deposit/droplet size relationships that indicated the potential for an efficacy classification based on deposit quantity, but the resolution and experimental repeatability were not sufficient to enable a revised classification approach to be defined at this stage. However, the work did deliver:

- results that supported the approach taken in the AHDB Cereals & Oilseeds Nozzle Guide including considering air-induction nozzles as either “small droplet” or “large droplet”;
- evidence that factors other than droplet size (particularly droplet velocity) are important in determining deposit on targets and could, therefore, be the basis for future work in developing classification systems;
- a specification for a revised test liquid for use in nozzle testing and spray application experiments that did not use a nonylphenol surfactant;
- data to show that application volumes of 75 to 100 L/ha gave deposits on small (<3.0 mm diameter) targets that were greater than at higher volumes;
- evidence that the deposition on small vertical targets was increased by more than a factor of two when the wind speed in the region between the nozzle and the target was increased within the range of acceptable conditions for field applications; and
- approaches that would enable a component of drift risk assessment to be included in an extended classification scheme.

2. Project summary

The current nozzle/spray classification schemes used in the UK (as the BCPC scheme), in the USA (as the ASABE standard) and elsewhere in the world are based on measurements of the droplet size distribution in sprays that are then compared with results from reference nozzles measured in the same way so as to define a spray quality for a given nozzle operating at a stated pressure. These classifications have been widely and successfully used on product labels, codes of practice and machinery operating manuals. However, they have not been well suited to classifying sprays with characteristics that are very different from those of the reference conventional nozzles or that have air-included droplets, such as those produced by air-induction nozzles. In particular, nozzle types producing large droplets that would be classified as coarse or very coarse with implications for low efficacy have been shown to give levels of efficacy that are higher than predicted from such classifications. This has important implications for nozzle selection when balancing efficacy with the need to control drift. This project aimed at developing an extended spray/nozzle classification scheme that could effectively accommodate a wider range of nozzle designs, particularly the air-induction nozzles. The extended scheme would have elements relating to possible product efficacy and the risk of spray drift as separate components. The work was based on an initial hypothesis that had two components, namely:

1) there is a negative correlation between product efficacy and deposit variability, so an extended nozzle/spray classification scheme could be derived from data relating to deposit variability when a defined target matrix was sprayed and sampled according to specific protocols: this was formulated based on the results from earlier project work that showed higher coefficients of variation of measured deposits on artificial targets; and
2) that a spray drift risk parameter could be obtained from comparative spray drift measurements made to defined protocols in wind tunnel or field conditions: as in (1) above, this was based on results from a previous study.

There was a need to establish a test liquid that could be used in nozzle testing and experiments to assess spray deposition performance since the reference liquid specified in the BCPC scheme used a nonylphenol surfactant and such materials are no longer available in Europe. Measurements of the droplet size distributions with a range of nozzle types and sizes spraying different commercially available surfactants showed that there was no existing surfactant that would directly mimic that used as a previous reference. Experiments with Tween surfactants that have applications wider than agricultural plant protection products identified Tween 20 and Tween 80 as potential components for a reference spray liquid. Further measurements of the droplet size distributions and the recoveries of tracer dye solutions containing these surfactants showed that both could be used in water as a reference spray liquid and Tween 20 was, therefore, selected because of it better handling characteristic.

The first component of the hypothesis was explored by treating a defined matrix of stainless steel rods of 1.0 and 2.0 mm diameter supported both vertically and horizontally with a three nozzle boom in the wind tunnel on the Silsoe site. A tracer dye solution was applied using a range of nozzle conditions and deposits on individual rods were quantified using spectrophotometric techniques. Initial experiments examined the distribution pattern across the sampled area to establish and confirm that any spatial variability in the target region would not obscure smaller scale effects at the target level that were likely to be relevant to nozzle/spray classification. The distribution of deposits on individual rods was then assessed when applications were made at a nominal 100 L/ha when directly comparing conventional and "large droplet" air-induction nozzles, at different application volumes from 75 to 225 L/ha without changing the droplet distribution by using a multiple boom arrangement and with a wider range of nozzle types. Results from these measurements showed:

a) the distribution of deposits across the small swath treated with different nozzle types was approximately uniform such that "patternation" distribution effects could be excluded from the analysis;
b) deposits on rods supported horizontally were consistently greater than deposits on the same sized rods supported vertically;
c) greater deposits were measured when applications were made in a low velocity air flow with conventional flat fan nozzles compared with those from large droplet air-induction nozzles: the largest differences were measured when treating the smallest target size (1.0 smm diameter rods) and with the rods mounted vertically when deposits from the two nozzle types differed by more than a factor of two;
d) measured deposits on small vertical targets treated with sprays from a range of nozzle designs showed consistent trends with deposits decreasing as mean droplet size increased;
e) spray deposits measured with treatments applied using conventional flat fan nozzles in a multiple boom arrangement such that droplet size was not a factor, showed that higher deposits were associated with lower application volumes particularly for vertical targets;
f) the effect of wind speed at the target level was to substantially increase deposits on vertical targets when treatments were applied with conventional flat fan nozzles operating over a range of application volumes: wind speed had a very much smaller effect on the deposits on vertical targets treated with sprays from the large droplet air-induction nozzle and on deposits on targets supported horizontally.

It was noted that the results from the initial series of experiments did not support the original hypothesis since the variables that tended to give the greatest variability in measured deposits were known to be associated with generally higher levels of product efficacy in field conditions (i.e.

the use of conventional flat fan nozzles to make applications at circa 100 L/ha). A second series of deposit measurements were made on 1.0 mm rod targets supported both vertically and horizontally to further explore the potential for using measured spray deposits as a component in a nozzle/spray classification scheme representing likely product efficacy. Spray deposits were correlated with measured droplet size distributions and linked to the existing classification scheme.

Deposits on vertical 1.0 mm targets decreased when treatments were applied with conventional flat fan nozzles of increasing size (higher flow rates at a given pressure). This was recognised from the first series of experiments as being due to both the effect of increasing application volume and a larger droplet size. Deposits from pre-orifice and air-induction nozzles were higher than would have been expected, based on an extrapolation of the results for the conventional flat fan nozzles. Similar forms of relationship between measured deposits and the mean droplet size in the spray were recorded for the horizontal targets.

Combining the results of all deposits measurements made in the wind tunnel on the Silsoe site showed a considerable variability in the results obtained of which only some could be explained by differences in the experimental protocols used. However, some consistent trends were observed, namely:

1) deposits on horizontal targets were consistently higher than on the same targets supported vertically and subject to the same treatments;
2) deposits from treatments using air-induction nozzles were substantially greater than would have been predicted based on the results for the effects of droplet size obtained with conventional flat fan nozzles;
3) the slope of the spray deposit with droplet size relationship was shallower for air-induction nozzles than for conventional nozzles: air-induction nozzles were selected to give a range of (relatively large) droplet sizes at a single nozzle size (flow rate) – comparisons with conventional nozzles are therefore compounded since increasing droplet size with such conventional nozzles is related to higher flow rates and therefore increased application volumes.

Results from equivalent experiments conducted in a modified spray chamber at IPARC gave results that followed the same trends as those observed in experiments conducted in the Silsoe facilities.

It was concluded that direct measurement of deposits were unlikely to be sufficiently robust to be part of a spray/nozzle classification scheme mainly due to lack of repeatability in such measurements. However, the project did deliver results that have important implications for improving spray applications using boom sprayers, namely by providing:

- data that supported the approach taken in the AHDB Cereals & Oilseeds Nozzle Guide including considering air-induction nozzles as either “small droplet” or “large droplet”;
- evidence that factors other than droplet size (particularly droplet velocity) are important in determining deposit on targets and could therefore be the basis for future work in developing classification systems;
- a specification for a revised test liquid for use in nozzle testing and spray application experiments that did not use a nonylphenol surfactant;
- results to show that application volumes of 75 to 100 L/ha gave deposits on small (<3.0 mm diameter) targets that were greater than at higher volumes;
- results to show that the deposition on small vertical targets was increased by more than a factor of two when the wind speed in the region between the nozzle and the target was increased within the range of acceptable conditions for field applications: these wind speed conditions at target level could be related to recommended wind speeds for making spray applications that are measured at boom height; and
- approaches that would enable a component of drift risk assessment to be included in an extended classification scheme.

Measurements of droplet size and velocity distributions were used to calculate a retention parameter and impact energies and the results compared with the measured deposits on vertical and horizontal targets. Results for the computed retention parameter showed that performance for the different nozzle types used could be discriminated but that the match with measured deposits ranked the air-induction and pre-orifice nozzles incorrectly. Results from this part of the project indicate that there is the potential to derive a ‘deposit parameter’ based on the measurement of the physical parameters of a spray (droplet size, velocity and spray volume distributions) but that further work is needed to examine the relationships with measured deposits, the reliability of such methods and the effect of changing nozzle design variables including spray angle.

Measurements of spray drift in both field and wind tunnel conditions with systems regarded as both as having a high and a low drift risk showed that a scale of drift risk could be defined based on direct measurements downwind of an application system operating in a wind tunnel and made to a defined protocol. Details of such a scale and the terminology associated with such a scale would be the subject of a wider debate but it has been proposed that this could be based on an extension of the star rating system used in the existing Local Environmental Risk Assessment for Pesticides (LERAP) scheme. It was noticeable that while the trends in low drift performance gave relatively good agreement between measurements made in field and wind tunnel conditions, in the field tests the high drift scenarios tended to be under-recorded in comparison with results from wind tunnel tests. This probably related to airborne spray from full-sized application equipment reaching heights above those of the sampling matrices even though measurement in field conditions were made relatively close to the edge of a treated swath (5.0 and 10.0 m downwind).