Pesticide Chemistry and Adjuvants

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Abstract

Droplet size is often considered to be the most important variable in spray application for control of pests, weeds and diseases, and delivery of fertilizers and other agricultural products. Extensive research around the world over the last few decades has shown that the main control over droplet size can be achieved through selection of the best nozzle or atomizer, and its setup and use on the sprayer (liquid/air pressure, angle, sprayer speed, etc). The tank mix can also have an important effect on droplet size, through determining the liquid physical properties of surface tension, shear and extensional viscosity. Some emulsion-based adjuvants can produce narrower droplet size spectra (e.g. fewer driftable smaller droplets under some conditions) than solution-based adjuvants of similar surface tension and viscosity characteristics.

Introduction

The effective application of pesticides and other chemicals in agriculture, forestry and vector control requires delivery of the tank mix in an appropriate droplet size spectrum for maximizing deposition on the target area and minimizing off-target losses such as runoff and drift. Retention of droplets on surfaces is also important to allow exposure of the target to the active ingredient in an effective form for sufficient time for desired levels of control.

The importance of application conditions in determining droplet size, velocity and transport conditions cannot be understated. However, a surprisingly large number of studies and data sets on nozzle and atomizer performance do not sufficiently describe performance for real tank mixes, where water or water with a surfactant may not accurately represent the majority of actual sprays.

The present paper examines the effects of tank mix physical properties on spray performance, with particular emphasis on the formation, evaporation, transport and deposition of droplets under field conditions.

Factors Affecting Droplet Size

Application conditions and tank mix physical properties have the greatest effect on droplet size at the timeframe of atomization through a nozzle, which typically occurs in 5 to 50 milliseconds. Meteorological conditions of wind speed, air temperature and relative humidity affect droplet size through affecting evaporation rates while the spray is traveling from the sprayer to its point of deposition. Droplet size is also an important variable in this process (Teske et al, 1997).

Application Conditions

In general, sprays become finer with the following application factors:

- Smaller discharge orifice
- Wider spray plume angle
- Higher liquid pressure (however, with solid stream and narrow angle/ plume nozzles, lower pressures usually cause finer sprays)
- Higher air shear, e.g. greater flight speed, greater nozzle angle, or higher fan speed in airblast applications.

Furthermore, some types of atomizer produce finer sprays than other types, due to the specific mode of atomization and/ or energy input.

Liquid Physical Properties

Tank mix liquid physical properties have an important effect on the formation, and therefore droplet size, of sprays. This has been confirmed in studies such as those of the Spray Drift Task Force where atomization of liquids with a near-maximum range of values from tank mix types was tested through a wide range of nozzle types (Hewitt et al, 1997), and in studies involving adjuvants (e.g. Hewitt et al, 2001).

Although the effects of tank mix are usually lower than those of application conditions, tank mix physical properties can nonetheless change the droplet size spectrum sufficiently to move a spray one or two ASAE (1999) droplet size classification categories.

Forces from surface tension and viscosity tend to resist the breakup of liquid sheets and ligaments into droplets, thereby increasing the average droplet size (Hewitt and Hermansky, 1997). Conversely, if surface tension or viscosity are reduced, the liquid sheet can more easily expand and initiate the development of wavy perforations leading to breakup with smaller droplets. Breakup length from sheets and ligaments can be reduced by adding materials such as non-ionic surfactants that lower the surface tension.

Lower surface tension is a desirable characteristic for most agricultural sprays because it 1) facilitates the spreading of droplets upon impaction on leaves or other target surfaces, to increase the surface active area, 2) improves penetration and uptake of the product into the plant, and 3) can facilitate retention of the material by the rain, ensuring improved rainfastness. Therefore, many surface acting agents (or surfactants) are added to tank mixes for their spreading, wetting and sticking characteristics. However, as explained above, there is often a less desirable effect from the production of smaller droplets at atomization, which may increase the drift potential of the spray under unfavorable conditions.

Recent research has shown that solution adjuvants such as non-ionic surfactants, tend to cause the production of greater proportions of small droplets per average droplet size for a given dynamic surface tension than do many emulsion adjvants. Figure 1 shows an example of this trend for a wind tunnel atomization study with the application of herbicides as extremely coarse sprays through narrow plume nozzles under helicopter application conditions. When emulsion adjuvants (e.g. modified seed oils) were used to obtain specific dynamic surface tension values, there were fewer very small droplets per volume median diameter value than when solution adjuvants (e.g. non-ionic surfactants) were used (Figure 1, and Hewitt, 2003). Similar reductions in the proportion of small droplets have also been observed for some invert emulsion/ suspension and lecithin-based adjuvants (Hewitt et al, 2001).

Viscosity affects droplet formation through resistance to flow, which can include elongational flow if a polymer or other extensional viscosity modifying adjuvant is present in the tank mix. An increase in shear viscosity tends to cause an increase in droplet size. On the other hand, an increase in extensional viscosity can cause an increase in the average droplet size (e.g. volume median diameter or $D_{v0.5}$) as well as in some cases an increase in the proportion of smaller droplets with diameter below ~200µm. Such an increase in the range of droplet sizes within a spray (relative span, or $D_{v0.9}$-$D_{v0.1}$/$D_{v0.5}$) is usually not desirable, so it is important to determine the effect of a particular adjuvant on the entire droplet size spectrum, not just the $D_{v0.5}$, when selecting it for a specific effect such as drift management. Also, some adjuvants cause a change in one pattern with one nozzle type, but a completely different trend with a different nozzle type (Figures 2 and 3 for addition of a polymer to tank mix applied through flat fan and disc-core nozzles). The same can apply to tank mix partners, with some organic solvents possibly affecting some adjuvants differently than others. Some polymers

Figure 1. Relationship Between Droplets with Diameter Below 153µm and Volume Median Diameter of Herbicide Sprays Including Emulsion and Solution Adjuvants

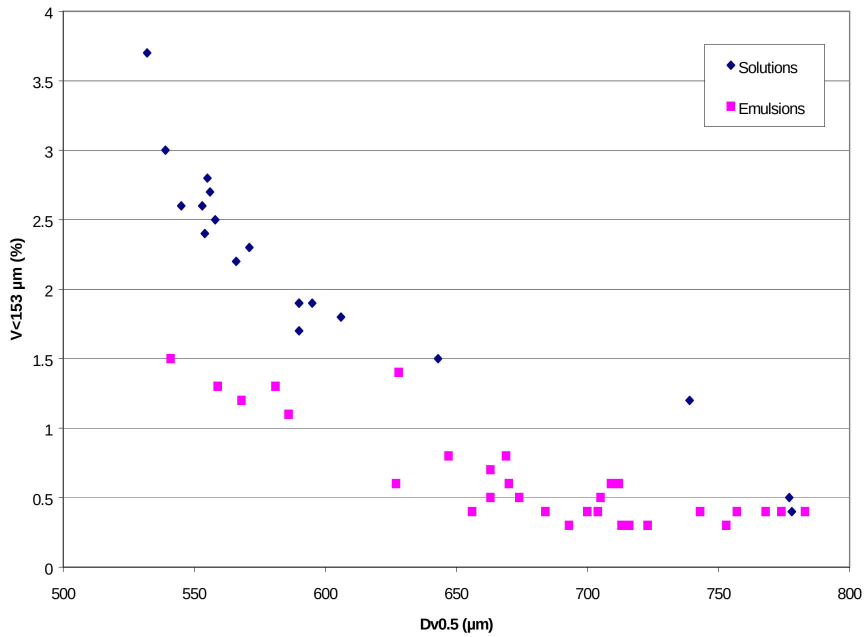

Figure 2. Atomization of Herbicide Through Flat Fan (left) and Disc-Core (right) Nozzles by Sheet Breakup (Hewitt, 2002)

Figure 3. Atomization of Herbicide with Polymer Adjuvant Through Flat Fan (left) and Disc-Core (right) Nozzles (Hewitt, 2002)

(especially some polyacrylamides) break down when pumped through typical agricultural spraying equipment. In view of these complex trends, actual testing of adjuvants with real active ingredient pesticides (or at least blanks representing the composition of such pesticides without the active ingredient components) through several different types of nozzle and pumping regimes is important in assessing behavior under real-world conditions. The American Society for Testing and Materials (ASTM) is finalizing standards for such testing.

Factors Affecting Droplet Transport and Deposition

Following release though a nozzle or atomizer, droplets will tend to be carried in the air until collecting on surfaces by impaction (onto vertical and horizontal surfaces) and sedimentation deposition (onto horizontal surfaces). The size of the droplets, as well as the release height and meteorological conditions affect such transport and deposition patterns. These phenomena are well understood through equations of motion and particle transport and diffusion, and can be studied with models such as AGDISP and AgDRIFT (Teske et al, 2002). The physical properties of the tank mix affect this process through influence on the emission droplet size spectra, as well as evaporation rates and density which can affect fall rates. Again, once the relevant physical properties are known, such movements and deposition can be studied using appropriate models such as AGDISP.

Factors Affecting Droplet Retention

Many adjuvants have value in improving the retention of droplets on leaves and target surfaces, through sticking and rainfastness, as well as assistance in penetration and uptake, which reduces the time available for the active ingredient to be lost through a rain event, or by lift-off in evaporation. Some researchers have proposed theories of co-distillation of active ingredient with water lost from leaves, which has been theorized as a possible factor contributing to secondary movements of pesticide hours or even days after application. However, such losses have not been definitively proven or measured, and in any case would only apply to relatively volatile products that are not incorporated or uptaken into the soil or plant. It is possible that some adjuvants, such as polymers may reduce the possibility of such secondary movements of pesticide; however, significant research has not yet been conducted in this area.

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