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Accounting for Effects of Real World Tank Mixes on Droplet Size Estimates for the USDA-ARS Spray Nozzle Atomization Models

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Research Objective: To determine if the present USDA-ARS Spray nozzle models that were developed using water plus non-ionic surfactant can be used to estimate spray droplet characteristics of other real world tank mixes or if new product specific models will be required.

Research Methods: Testing included the CP11TT nozzle body (CP Products, Tempe, AZ) fitted on a CP-06 swivel and outfitted with a series of 40 degree flat fan tips. Following the experimental design required to generate a spray nozzle models, 27 operational treatments covering orifice sizes from 4 to 30, orientation angles from 0 to 90, spray pressures from 20 to 60 psi, and airspeeds from 120 to 200 mph were evaluated for droplet size for 12 unique spray solutions. Atomization testing for these treatments was conducted in the USDA-ARS Aerial Application Technology (AAT) groups new high speed wind tunnel which has an operation range across airspeed ranging from 0 to 215 mph (Figure 1). Droplet size measurements were made using a Sympatec laser diffraction instrument which was traversed vertically through the spray plume for each replicated measure. For each treatment a minimum of three replicated measurements were made at each operational setting.

Figure 1. USDA ARS Aerial Application Technology high speed wind tunnel and nozzle testing facility.

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The 12 spray solutions tested included two "blank" solutions and ten active product solutions. The blank solutions included water and water plus a non-ionic surfactant. The active product selected for the other solutions was Roundup PowerMAX (PM) (Monsanto Company, St Louis, MO). One solution was the PM alone and the other nine had an additional adjuvant added. The adjuvants included non-ionic surfactant, crop oils, emulsions, and polymers. All 12 spray solutions were evaluated across each of the 27 operational points. The results from each of the solutions at each operational point were then compared to the water and water plus non-ionic surfactant to determine how well they represented the active product tank mixes. Additionally, the surface tension and viscosity of each solution was measured to determine whether they could be used to predict changes in atomization as compared to the blanks.

Research Results: Comparing the atomization results of the different spray solutions, droplet sizes where generally 15 – 20% lower with the active product spray formulations as compared to water only and 5 – 10% lower with the active product spray formulations as compared to the water and non-ionic surfactant. However, the differences were not consistent across the operational settings or with respect to the physical properties of the solutions preventing the development of a simple correction factor. There were very minor differences in atomization between the PM and PM plus adjuvant solutions, regardless of adjuvant, as a result of the overwhelming impact of the high speed air shear. As larger differences and more dramatic adjuvant effects were anticipated, additional research is planned to further investigate the complex interactions between formulated active products, spray adjuvants, and nozzle type and operational settings under aerial application conditions.

One of the other issues that this research highlights is the significant differences between the new spray nozzle models that are being developed with updated measurements systems and techniques and those models currently available that were developed with older systems and methods. The current models were generated using a Particle Measurement System Optical Array Probe, which had a minimum droplet size resolution of 34 µm, and thus underestimate the smallest fraction of the spray effectively over-estimating the entire droplet spectrum. New measurement systems, such as the Sympatec HELOS laser diffraction system, better account for all generated spray droplets and better methods allow for more accurate estimates of droplet size. As an example, when comparing newly measured droplet size data done as part of this study with the laser diffraction system to the current model estimates for a 40 degree flat fan nozzle across all of the operational points, the D_{V10} and D_{V50} values are, on average, 30% lower and the D_{V90} is, on average, 20% lower. This is consistent with results conducted by other researchers. It should be noted, however, that the droplet size classifications will remain largely unchanged with the new models as compared to the old models as they will be assigned based on new droplet size curves for the reference nozzles also generated using the new laser measurement system.

Conclusion: The results of this work reflects several years of ongoing research targeted toward incorporating new systems and methods to develop scientifically based spray nozzle models that accurately estimate spray droplet size resulting from applications made with typical aerial spray nozzles as well as real world spray formulations.