Summary page

Water often comprises at least 95% of the spray solution. Its effect on product efficacy can be reflected in the success of the spray operation. Water is usually viewed as a clean input, and not a lot of thoughts are given on its purity. However, some water properties, such as water hardness and pH, can skew the herbicide application process. Previous research has shown that weak acid herbicides, such as 2,4-D and glyphosate, have reduced activity on weed control in hard water and high pH, and that the response is weed species-, herbicide- and water hardness dependent. Hard water contains dissolved minerals, with Ca^{2+} and Mg^{2+} being predominant, which can be problematic when used as a carrier for weak acid herbicide applications. These cations can easily react with the herbicide, which leads to decreased herbicide penetration into the plant cuticle or can cause precipitation of the herbicide from the solution. To prevent the formation of the hard water cation-herbicide complex, addition of water conditioning adjuvant is recommended. Ammonium sulfate (AMS) is most used water conditioner. Ammonium ions build a complex with a weak acid herbicide and outcompete the antagonistic cations which leads to enhanced herbicide absorption and translocation. The sulfate anions bind with the antagonistic cations preventing the formation of hard water cation-herbicide complex which is less readily absorbed. The addition of AMS also increases ammonium accumulation in the cell which alters the pH. The increase of hydrogen inside the cell decreases cellular pH if allowed to accumulate. To maintain cytoplasmic pH in the range of 7.5-8, hydrogen ions are pumped across the cell membrane into the cell wall. This causes the cell wall pH to become more acidic. For weak acid herbicides, acidic conditions cause more of the herbicide molecules to be present in non-ionized, lipophilic form which allows for passing through the cell membrane.

In the effort to better understand how water quality affects herbicide performance we designed two projects investigating addition of water conditioning adjuvants and testing several levels of water hardness and pH on herbicide efficacy. The results have shown that addition of phosphoric acid to glufosinate and glyphosate increases weed biomass reduction, as well as addition of phosphoric acid and AMS to 2,4-D compared to herbicides alone in 240 ppm water hardness and 7 pH. It was also observed that herbicides applied in soft water at high carrier volume (187 L ha^{-1}) are not statistically different than herbicides applied in 1000 and 1500 ppm water hardness at low carrier volume (47 L ha^{-1}). Due to label restrictions Enlist One (2,4-D) and Liberty (glufosinate) cannot be applied at 47 L ha^{-1}. This only emphasizes that addition of water conditioning adjuvant will be important when 2,4-D and glufosinate are applied in very hard high carrier volume. It was also observed that smaller droplet size (150 µm) increases biomass reduction for waterhemp and common lambsquarters, whereas larger droplet size (900 µm) increases green foxtail biomass reduction when glufosinate and glyphosate are applied in 187 L ha^{-1}. However, when applied in 47 L ha^{-1} droplet size is not significant. Again, low carrier volume and more concentrated droplets manage to overcome the antagonistic hard water cation effect since there is far less cations to bind with the herbicides.

Before starting a tank mix, water should be tested to see if any properties need to be altered with water conditioners for maximum spray application effectiveness. If found that water has unfavorable conditions for a certain herbicide, water conditioning adjuvant should be added to the tank prior the addition of an herbicide. Since this research was conducted in the greenhouse, therefore reduced herbicide rates were used for better observing differences among treatments, it would be beneficial to repeat the studies in the field. This would allow for weeds to be more vulnerable to the environmental conditions and also use of the label recommended rates that would genuinely represent the influence of water quality on herbicide performance.

Once the spray solution characteristics are managed, applicators need to make sure they have the correct set up for optimized pesticide application. This includes nozzle selection, boom height and equipment calibration. Optimized pesticide application means making sure the most of the (already managed) solution being sprayed is deposited onto the target. Off target movement has been a concern since the introduction of pesticides. Intensive use of auxin herbicides has brought greater attention to minimizing spray drift. This resulted in changing label recommendations and label restrictions for tank-mix partners increasing the spray drift. One of the first steps in managing drift is nozzle selection. Selecting a nozzle that produces large enough droplets to resist being carried with the wind, but provide efficient coverage is crucial in pesticide applications. Introduction of air inclusion nozzles – nozzles that can provide much larger droplets than conventional flat fan nozzles under the same flow rate – allowed farmers to enhance pesticide application. Many efforts were given to understanding pesticide drift by performing field large-scale drift trials. These endeavors are challenging due to environmental conditions that cannot be controlled, time being consumed, and labor needed. However, they are crucial in building the data set that can help estimate the downwind deposition at certain conditions. The US Environmental Protection Agency uses Agricultural Dispersal (AgDISP) model for that purpose. AgDISP was initially developed for aerial applications, but overtime was updated with the ground model. However, the model needs more support with empirical data since the introduction of newer technology for broadcast applications. The purpose of our research was to collect the downwind depositions with air inclusion nozzles and compare the empirical data with the estimated depositions by AgDISP, and potentially update the model with more information on drift produced by these nozzles. The results show that the model tends to underpredict the downwind deposition across the nozzles and distances, and overpredict the deposition for the standard flat fan nozzle at greater distances (>10 m from the end of spray swath). These results were expected since the model is more sensitive to larger droplets. Moreover, TTI nozzle produces droplets bigger in size than the model's upper limit.

It is of crucial importance that the model is handled correctly. The knowledge of the parameters in the model are essential before changing any of them. For example, choosing the Air Injection option over Flat Fan for the air inclusion nozzles is important because of the logarithms behind the model that calculate the jet velocity which is different between the two nozzle types. Also, setting the Swath Displacement to 0 under Advanced Settings since this option is for aerial applications.

The model has a great potential which was seen with numerous research on aerial applications, and the data collected in our research is beneficial for better understanding the droplets faith once they exit the air inclusion nozzle.