Water quality affects herbicide efficacy

Introduction

Quality of water used in spray tanks can affect herbicide efficacy. Water is the primary carrier for herbicide applications. In fact, it usually makes up over 99% of the spray solution. Considering that, it should be no surprise that the chemistry of water added to the spray tank greatly impacts herbicide effectiveness. This article describes how water quality affects herbicides, then discusses several herbicides commonly used by nursery producers and which water quality factors affect those products the most.

A vast majority of the herbicide spray is added water, therefore, water quality can greatly affect herbicide performance.

Weak acids

Acids are compounds that release H+ ions when dissolved in water. Weak acids are compounds that release H+ ions, but just slightly. Postemergence herbicides used by nursery producers that are weak acids include: glyphosate (Roundup), paraquat (Gramoxone), bentazon (Basagran), clethodim (Envoy), sethoxydim (Poast), and 2,4-D (many products).

Herbicides that are weak acids partially dissociate (split into two pieces) when mixed in water. When mixed in water, a portion of the herbicide molecules will dissociate and the rest will not. Herbicides not dissociated (the compound remains whole) are more readily absorbed by plant foliage than those that dissociate. How much the herbicide dissociates depends primarily on pH of water in the spray tank.

Clean water, free of suspended solids is essential for spraying Roundup or Gramoxone.

Dissociated herbicide molecules have a negative charge. After being dissociated, herbicides might remain as negatively charged molecules, or they might bind with other positively charged cations. Binding to some cations improves herbicide uptake and absorption, binding to others antagonizes herbicide activity by decreasing absorption or activity in the cell.

Water pH

Water pH is a measure of the H+ ion concentration in water. As water pH decreases, it becomes more acidic and the number of H+ ions increases. Water pH at nurseries in the North Willamette Valley (based on just a few samples) is neutral to slightly basic (pH 7.0 to 7.5). Acidic conditions (pH 3 to 6) are most suitable for mixing postemergence herbicides classified as weak acids. When water pH exceeds 7, consider adding adjuvants to lower pH.

Weak acids dissociate less under acid conditions where H+ ion concentration is high. Dissociated herbicides are absorbed more slowly across plant cell membranes. Ideally, spray water pH should be low such that herbicides do not dissociate, or dissociate at low levels. Avoiding herbicide dissociation is the primary reason water used in pesticide mixing should be acidic.

Sulfonylurea (SU) herbicides are different. This class of herbicide is very popular in agronomic crops, however, only halosulfuron (Manage, Permit) is occasionally used by nursery producers. Increasing pH can increase the solubility of sulfonylurea herbicides, and theoretically increase their activity (this has yet to be thoroughly proven).

Hard water

Hard water contains high levels of calcium (Ca), magnesium (Mg), sodium (Na), or iron (Fe). Other cations can cause hard water, but these are the usual suspects.

Ca, Mg, Na, and Fe cations (positively charged ions) attach to negatively charged herbicide molecules. Often, the association between herbicides and these cations renders the herbicide ineffective.

High pH and hard water act together to reduce herbicide effectiveness. High pH causes more of the herbicide to dissociate while high concentrations of cations bind with the dissociated herbicide to reduce its effectiveness.

With some weak acid herbicides, hard water is not by itself problematic. Research in Wisconsin showed that when spray tanks (pH = 3.5) were purposefully spiked with high concentrations of Ca or Na, no reduction in sethoxydim efficacy was observed (Nalewaja et al., 1994). However, when pH was raised above 7 and spiked with high concentrations of Ca or Na, herbicide effectiveness was reduced.

Because pH in Oregon water supplies are slightly alkaline, nurseries with high concentrations of any cation should take corrective action. High Na would be the greatest cause for concern among Oregon nurseries. When these conditions warrant it, use adjuvants to lower pH in spray tanks. When labels permit, additions of ammonium sulfate to the spray tank overcome many interactions with herbicides and cations (see below).

Measure the concentration of Ca, Mg, Na, and Fe in water used for pesticide mixing. If the sum of the concentration (ppm) for all of the cations exceeds 400 ppm, action may be necessary.

Alkalinity

Alkalinity refers to carbonate (CO32-) and bicarbonate (HCO3-) levels in water. Alkalinity of water supplies in the North Willamette Valley range from 50 to 150 ppm (mg/L CaCO3). Alkalinity only becomes a problem with some herbicides when levels exceed 300 ppm and thus would rarely be a consideration in Oregon. Alkalinity should be requested on any analysis of your nursery's water supply as it has great impact on soil/container pH (not related to this discussion). If these analyses indicate excessively high bicarbonates (>300 ppm), corrective action in your spray tank may be warranted.

Turbidity

Turbid water, or water containing suspended solids, soil, or organic matter can reduce effectiveness of postemergence herbicides. Water should be clean and clear for all pesticide applications, however, some pesticides are not as sensitive to turbidity as others.

Pesticides are measured for their ability to bind to soil particles. This information is typically used to assess their potential for off-site movement or leaching through the soil profile. The soil sorption coefficient (Kd) and the soil organic carbon sorption coefficient (Koc) are used to describe the binding strength of herbicides to soil. They represent the ratio of herbicide that is bound to soil particles when the herbicide is mixed with a slurry of water and soil.

Table 1. Sorption coefficients of several commonly used herbicides, and their responsiveness to water turbidity.

Herbicide	Koc (mg/L)	Turbidity effect
Glyphosate	24,000	Yes
Sethoxydim	100	No
Clethodim	-	No
Bentazon	34	No
2,4-D amine	100	No
2,4-D ester	24	No

Herbicides with high Koc or Kd values (Koc is more commonly referenced) bind more tightly to soil particles (Table 1).

The herbicides glyphosate (Roundup, and many other brand names) and paraquat (Gramoxone) have very high Koc values. Because of their high Koc, these herbicides will bind to soil and organic matter particles suspended in water and will not be available for absorption into weed foliage. Comparatively, dicamba (Banvel) has a low Koc and has been found to be relatively unaffected by suspended solids in spray water.

Glyphosate and paraquat are commonly used in nursery production. Be sure water is clear and free of suspended soils or organic matter when using these products. If water is noticeably murky or discolored, find an alternate water source.

Glyphosate (Roundup)

Glyphosate is the active ingredient in Roundup and numerous other products. Different formulations of Roundup and other products utilize different surfactants and additives, but in every case glyphosate is the active ingredient. Glyphosate kills plants by binding to an enzyme called EPSP synthase. When bound to EPSP synthase, the enzyme cannot function and the plant cannot produce three critical amino acids. Plant death ensues.

Glyphosate has a high Koc value (24,000 mL/g) and therefore rapidly and tightly adsorbed to soil particles and organic matter. As described above, turbid water with soil and sediment will greatly reduce herbicidal activity.

Hard water also affects glyphosate. Ca, Mg, Fe, or Na can form a complex with the glyphosate molecule so that it is unable to bind to EPSP synthase. If glyphosate cannot bind to the enzyme, it will not provide control.

Adding ammonium sulfate (AMS) to the spray tank overcomes adverse effects of hard water. The ammonium cation preferentially attaches to the glyphosate molecule and thus prevents Ca, Mg, Fe, or Na from doing so. When ammonium is attached, the molecule binds readily to EPSP synthase and the herbicide functions normally.

Some plants contain high levels of Ca in their intracellular spaces. Just like hard water in a spray tank, high Ca levels between plant cells can reduce Roundup effectiveness. AMS in the spray tank also alleviates physiologically-induced Ca interference.

Adding AMS (assuming water is not hard) only improves effectiveness against plants that have elevated Ca levels described above. Velvetleaf (*Abutilon theophrasti*) and quackgrass (Agropyron repens) are the most notable plants where adding AMS (even when water quality is perfect) enhances control with glyphosate.

Clethodim and sethoxydim (Envoy and Vantage)

Clethodim and sethoxydim are similar chemicals used for selective postemergence grass control. Both are weak acids. Koc for these chemicals are low (100 mL/g for sethoxydim), and thus are not prone to problems with turbid water.

Dicamba	2	No
Paraquat	1,000,000	Yes

Velvetleaf control with Roundup is improved when ammonium sulfate is added to the spray

Under conditions of low pH (less than 6.0), hard water has no substantive effect on these products. Low pH likely prevents the herbicide molecules from dissociating. When pH is higher than 7, hard water can interfere with herbicide activity. Higher pH allows the herbicide molecules to dissociate, after which they are quickly bound to free cations.

Water pH in the Willamette Valley is sufficiently high and in some areas contains sufficiently high salt concentrations to antagonize these herbicides. I have seen several instances of 'unexplained' poor control from these products. Poor water quality may have been the culprit.

2,4-D

Herbicides containing 2,4-D are available in two broad categories, ester and amine formulations. Many growers prefer the amine formulation because it is less volatile and less prone to drift off target and injure valuable ornamental crops. However, amine formulations are more sensitive to poor water quality than esters.

Amines of 2,4-D can be sensitive to hard water. Accurate guidelines are currently not available. Reports from Saskatchewan indicate that hardness greater than 600 ppm (not likely in our area) or alkalinity greater than 500 mg/L $CaCO_3$ (again, not likely) can reduce 2,4-D effectiveness. If water analyses indicate your water is approaching these levels, consider finding a more pure water source or switching to an ester formulation of 2,4-D.

Summary

Water supplies in the North Willamette Valley can negatively affect some postemergence herbicides. Water pH in our area is sufficiently high that temporary or localized elevated salt levels can antagonize herbicides and render them ineffective. Analyze water used in filling spray tanks for pH, alkalinity, Ca, Mg, Na, and total suspended solids (turbidity). Take corrective action if any parameter exceeds values discussed in this article.

Disclaimer: This article is for educational purposes only. Mention of a specific product should not be interpreted as an endorsement, nor should failure to mention a product be considered a criticism. Always read the product label prior to using any herbicide.

Literature Cited

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