SURFACTANT FORMULATIONS TO ENHANCE TRICLOPYR AMINE EFFICACY: EFFECTS ON ADHESION, RETENTION AND CONTACT PHYTOTOXICITY ON THREE HARDWOOD SPECIES

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Abstract

Loblolly pine (*Pinus taeda* L) is the leading Southern (USA) pine, in terms of acres planted (Fortson *et al.*,1996). Since commercial forest acreage is predicted to remain fairly constant over the next 50 years, productivity must be increased if the South is going to meet a larger share of the nation's timber supply needs (Gjerstad and Barber, 1987). Hardwoods have been shown to have a consistent negative growth impact on pines, and uncontrolled hardwoods continue to compete aggressively with pines throughout a rotation, especially when hardwoods remain in the pine canopy.

Competing vegetation can be efficiently controlled by herbicides, which need to be formulated either in-can or in-tank to allow them to perform optimally. Adjuvants have proven essential to increasing the efficacy of herbicides, due to their ability to consistently improve the performance of the basic pesticide product. There are, broadly speaking, two routes by which adjuvants can do this. The first is the minimization of off target deposition and second, by the maximization of the herbicidal effect once it is placed on the target (Reeves, 1989). The major contributors to off-target deposition and retention are drift, in-flight volatilization, droplet shatter, bounce or runoff, washoff, and removal by wind. These losses result in pesticides never reaching the target or achieving only transitory deposition. There are two basic methods of maximizing the effect of the pesticide once it is on the target. The first is to improve coverage by the spray solution, which can be accomplished by lowering the surface tension of the spray with surfactant materials. The second is by improving the penetration or uptake into the target. Organosilicone surfactants can reduce the surface tension of aqueous pesticides far below that which is possible with nonsilicone surfactants, resulting in efficient wetting of even the most hydrophobic leaf surfaces. Additionally,

by virtue of their low surface tension, these adjuvants can significantly increase the uptake of active chemicals directly into the plant via stomatal infiltration (Stevens *et al.*, 1991).

Triclopyr ([(3,5,6-trichloro-2-pyridinyl)oxy]acetic acid) has been found to be an effective herbicide for hardwood control. Its two commercial formulations, a triethylamine (TEA) salt (Garlon 3A) and a butoxyethyl ester (Garlon 4), vary considerably in their acceptability. The current ester formulation has two undesirable characteristics. One is that all ester formulations, regardless of chain length, have some volatility which is usually more than that of water-soluble salts. The second is that the current ester formulation utilizes a kerosene solvent which is known to cause rapid foliar necrosis (possibly inhibiting herbicide translocation) and is a suspected carcinogen (Zedaker *et al.*, 1995). In most applications, the ester formulation has been more efficacious than the amine formulation on both an equal active ingredient basis and on an equal cost basis. Research had demonstrated a potential to enhance the uptake of triclopyr through the use of organosilicones; however, significant problems still existed. It was found that the commercial TEA formulation of triclopyr (Garlon 3A) was "antagonistic" to the organosilicone surfactant Silwet L-77. To take full advantage of the properties of organosilicones, the antagonistic co-formulants of Garlon 3A needed to be removed or replaced, the best surfactant formulation identified, and a cost-effective concentration of the surfactant(s) needed to be found.

To do this adequately required that both physico-chemical processes and biological processes be studied. The relevant physico-chemical processes involved in a formulation's effect on spray impaction on the target plant include adhesion, reflection, retention and run-off. The important biological processes include the uptake and translocation of the herbicide into the plant

The objectives of this study were: to evaluate the influence of formulation, active ingredient concentration, droplet size and leaf surface (adaxial vs. abaxial) on contact phytotoxicity, adhesion and retention to *Acer rubrum, Liquidambar styraciflua* and *Quercus rubra* by triclopyr formulations containing organosilicone surfactants and mixtures of silicone plus conventional surfactants. The adhesion and retention studies also evaluated the influence of leaf angle. Further objectives were to evaluate the influence of formulation and active ingredient concentration on spray retention by the adaxial and abaxial leaf surface of the selected species under field and track-sprayer conditions and to determine whether leaf characteristics (wax character and leaf angle) could explain adhesion / retention.

Garlon 4, Garlon 3A and Triclopyr TEA + sequestrant (each at 0.32%, 1.6% and 3.2% ae) plus various concentrations of the surfactants Polyglycol 26-2, Rhodasurf DA-630, Surfadone LP-100, Silwet L-77 and Silwet 408, were tested for contact phytotoxicity, adhesion and retention on the adaxial and abaxial leaf surfaces of sweetgum, red oak and red maple.

Little or no contact phytotoxicity was observed with any formulation applied to the adaxial surface within 6 hours; some phytotoxicity was noted within 24 hours. Abaxial surface treatments showed much greater contact phytotoxicity. Contact phytotoxicity was caused by (1) increasing concentrations of stock triclopyr products, and (2) the influence of the organosilicone surfactants. However, these results were very species dependent. Conclusions made from the contact phytotoxicity study were: if the droplet size becomes too big, then efficacy will be reduced; increasing the concentration of active ingredient above a certain limit will not increase efficacy, and may in fact reduce it; the addition of the organosilicone surfactants Silwet L-77 and Silwet 408 delayed and reduced phytotoxicity in red oak (the most susceptible species to contact phytotoxicity), and to a lesser extent in red maple, but increased the rate in sweetgum.

Major influences on adhesion were: droplet size (increasing droplet size decreased adhesion); adaxial/abaxial leaf surface (abaxial adhesion less than adaxial); product concentration (increasing product concentration increased adhesion); leaf angle (increasing leaf angle decreased adhesion); and addition of surfactants (variable adhesion).

All new formulations gave greater adhesion than the commercial formulations, with Triclopyr TEA plus sequestrant plus n-octyl pyrrolidone plus Silwet 408 giving, overall, the greatest adhesion. Increasing product concentration gave greater adhesion. Increasing droplet size and angle of impact reduced adhesion. The adaxial leaf surface showed higher adhesion than the abaxial leaf surface. Adhesion was higher on sweetgum, followed by red oak, with red maple being the most difficult species to get formulations to adhere to.

Whereas increasing product concentration improves adhesion, the lowest contact phytotoxicity result would be from lowering product concentration. Looking at both sets of results, the best product concentration of those studied would then be 1.6% ae as this can provide high adhesion, while still enabling us to choose a formulation which gives minimal contact phytotoxicity.

In the laboratory, formulation had no significant effect on retention. However, there are other considerations which affect retention that need to be kept in mind. It was observed that droplets containing organosilicone could impact an already wetted surface and still adhere or be retained, whereas those droplets not containing any organosilicone surfactant would bounce quite a distance on impact with a pre-wetted surface. Impaction with an already wetted surface was not part of this study, and therefore was not studied quantitatively. Also, formulations containing organosilicone surfactants provide greater "wrap-around" to the lower surface (Forster and Zabkiewicz, 1998), which is of great benefit when stomata are only on the abaxial surface, as is the case with these species.

Concentration and leaf angle also had no significant effect on retention. Droplet size was significant, with retention decreasing with increasing droplet size. Retention by the adaxial surface was significantly higher than retention by the abaxial surface. There was no significant difference overall between sweetgum and red oak, but retention by red maple was significantly lower.

Spray retention by the adaxial and abaxial leaf surfaces of the three tree species was also characterized in a field experiment conducted on a right of way site in North Anna, Virginia, USA. Amine (Garlon 3A) formulations of triclopyr combined with Silwet 408, and the commercial triclopyr ester formulation, Garlon 4, were applied using a Radiarc sprayer equipped with 0.508 mm nozzles (approx. 1000 μm droplets) applying 140 l/ha. The addition of the organosilicone surfactant Silwet 408 to the amine formulation gave the same total deposition as the commercial ester formulation, Garlon 4, while enhancing the abaxial retention as a percentage of total deposition. Thus the addition of organosilicone surfactant may have the ability to enhance herbicide uptake via the abaxial leaf surface, and therefore enhance efficacy. Field trial results showed that the alcohol ethoxylate, DA6, is not an essential component of the triclopyr amine / Silwet 408 formulation, in terms of retention.

The field trial application was also simulated on sweetgum, using a track-sprayer at the NZ Forest Research Institute Ltd. As in the field trial, the addition of Silwet 408 to triclopyr amine greatly enhanced abaxial retention as a percentage of total deposition, compared to that of Garlon 4. However, the track-sprayer results were very different from the field results, with amounts of adaxial and abaxial retention and total deposition much lower.

In agreement with published literature, it was found that the micro-roughness of the leaf surface can be used as a guide to explain adhesion results. The difference among trees in terms of leaf angles appeared to be much less important in explaining retention.

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