GLYPHOSATE USE IN LOWER WATER VOLUMES-A REVIEW

D.J. CAMPBELL, R.W. FELLOWES and MARION J. SHEERS

Monsanto Australia Limited
151 Flinders St.,
Melbourne Vic. 3000

Summary. The dominant use of glyphosate in Australia is to control annual weeds in Conservation Tillage situations. Application in low water volumes less than 50 L ha^{-1} is common. Low volume application of glyphosate improves performance by (i) increased surfactant and glyphosate concentration, (ii) enhanced spray cloud characteristics for foliage cover, and (iii) removal of antagonistic effects due to poor quality water. Results from both controlled experiments and field studies confirm this.

INTRODUCTION

Glyphosate (N-phosphonomethyl glycine) was initially developed for control of perennial weeds utilizing its translocated mode of action (Baird et. al., 1971). Since commercialization in Australia as a 0.36 kg ae L^{-1} formulation, Roundup[R] herbicide, glyphosate use on annual weeds in Conservation Tillage situations has increased to now be the dominant use.

Low water volume application is widely used in Conservation Tillage with water volumes commonly less than 50 L ha^{-1} for glyphosate application (Campbell, 1984). In many areas limited good water supplies and the need to rapidly spray large areas have stimulated the adoption of these low water volumes. Increased managerial flexibility on a whole farm scale occurs through the use of low water volumes.

GLYPHOSATE PERFORMANCE

Several published studies; e.g. Buhler and Burnside (1983), Jordan (1981), Merritt (1982), O'Sullivan et. al. (1981), Sandberg et. al. (1978), and Stahlman and Phillips (1979); have demonstrated a consistent improvement in the efficacy of glyphosate as water volume is decreased. The improved performance is related to the factors discussed below.

1. Glyphosate and surfactant concentration.

Reductions in water volume increase the concentration of both glyphosate and surfactant in the spray solution.

The effect of surfactant addition to glyphosate has been extensively studied; e.g. Buhler and Burnside (1983), Jordan (1981), O'Sullivan et. al. (1981), and Turner and Loader (1980). In particular Wyrill and Burnside (1977) found that surfactant addition effects were not evident beyond a concentration of 0.3% w/v. Field evaluation in Australia (data not shown) has confirmed this for annual weeds in Conservation Tillage situations.

Increasing glyphosate concentration alone also independently improves herbicide efficacy. Merritt (1982) separated glyphosate and surfactant concentration effects by applying individual 300 micron droplets with constant surfactant concentration and varying glyphosate levels. The test plants were Wild Oats *(Avena fatua)* and Wild Radish *(Raphanus raphanistrum)*. The dose of glyphosate per plant was kept constant by varying the number of droplets.

Increases in glyphosate concentration increased efficacy as assessed by foliage dry weight (Table 1). Differential performance of glyphosate at relatively low rates is evident on grass and broadleaf weeds in field use and the results reflected this observation.

Table 1. Effect of various concentrations of a single dose of glyphosate on foliage weight of Wild Oat and Wild Radish (Merritt, 1982).

Factor of glyphosate concentration*	Percent reduction in foliage weight from untreated	
	Wild Oat	Wild Radish
1 X	48	18
2 X	68	34
4 X	69	59

* Base concentration 36 g ae L^{-1}. Applied as constant dose of 0.6 μg ae $plant^{-1}$ to Wild Oat and 8.2 μg ae $plant^{-1}$ to Wild Radish.

The results were attributed to the increased glyphosate concentration gradient across the cuticle giving increased penetration. The effect was specific to glyphosate and was not observed with MCPA, paraquat, or difenzoquat probably because localized high concentrations of these herbicides caused severe local damage reducing activity in the foliage after entry. Movement of glyphosate in the assimilate transport system away from the point of entry was thought to offset such effects.

2. Physical characteristics of the spray.

Reduction of water volume by altering atomizers affects the physical characteristics of the spray and deposition and retention on the target foliage surface (Merritt and Taylor, 1978). Reducing water volume by using smaller orifice nozzles results in more droplets in the 100 to 300 micron size range for optimum coverage. The volume of large inefficient droplets is also reduced.

For example, changing flat fan nozzles from 11002 to 11001 reduces water volume from 90 to 45 L ha^{-1} and increases the proportion of 100 to 300 micron droplets from 58 to 74%. The proportion of droplets over 300 micron is reduced from 42 to 22% (Spraying Systems data Sheets; spraying at 280 kPa, 10 km hr^{-1}).

Sandberg et. al. (1978) demonstrated the effects of reducing water volume on coverage and retention of glyphosate on Common Morning glory *(Ipomea purpurea)*. Spray retention increased significantly as water volume was reduced from 750 to 130 L ha^{-1} illustrating the effect of removing large wasteful droplets.

3. Interactions with water contaminants.

Glyphosate activity may be reduced by the presence of metal ions in the spray solution; particularly aluminium, calcium, iron, and magnesium (Stahlman and Phillips, 1979). Similarly colloidal contaminants potentially reduce glyphosate activity due to adsorption of the glyphosate.

Reducing water volume overcomes the effects of water contaminants on glyphosate activity (Buhler and Burnside, 1983; Sandberg et. al., 1978; and Stahlman and Phillips, 1979). The study of Buhler and Burnside (1983) used glyphosate at rates similar to commercial use in Australia (0.1 to 0.4 kg ae ha^{-1}) on Oats *(Avena sativa)* as the test plant. Efficacy was reduced in proportion to the ionic strength of various ion contaminants but the effect was removed by reducing water volume from 190 L ha^{-1} to 24 L ha^{-1}.

Buhler and Burnside (1983) concluded that "reducing carrier volume would be a practical and economical means of preventing a decrease in glyphosate phytotoxicity caused by hard water". This observation is supported by extensive commercial experience with glyphosate over a range of weed species, water sources, and seasonal conditions throughout Australia.

FIELD RESULTS

Most published studies on the effects of water volume on glyphosate performance have occurred under "controlled conditions" in laboratory or glasshouse environments. Responses under field conditions may not always be apparent due to inherent field variability or possible masking of the result by other factors. Effects are most evident where the herbicide rate is marginal and performance is most sensitive.

Data from two field experiments conducted at Tamworth, New South Wales are shown in Table 2. Both experiments were conducted on volunteer Wheat *(Triticum aestivum)* at the one to six leaf growth stage.

Glyphosate was applied at 0.16 kg ae ha^{-1} as the formulated product, Roundup herbicide, in water volumes of 30, 50, and 100 L ha^{-1} using a vehicle mounted boom. Speed was kept constant at 13 to 15 km hr^{-1} and water volume was varied by changing nozzles. The resultant efficacy was a function of glyphosate and surfactant concentration plus the physical behaviour of the spray cloud. Rainwater was used to remove confounding effects from water contaminants.

Table 2. Phytotoxicity of glyphosate* applied at 0.16 kg ae ha^{-1} to Wheat at varying water volumes, assessed 12 days after spraying (mean of two experiments).

Water volume (L ha^{-1})	% Phytotoxicity
30	60
50	46
100	30

* Applied as Roundup herbicide at 0.45 L ha^{-1}.

CONCLUSION

In controlled studies, glyphosate performance is improved by using low water volumes with the effects being due to (i) increased surfactant and glyphosate concentration, (ii) enhanced spray cloud characteristics related to target weed coverage, and (iii) removal of antagonistic effects due to poor quality water.

Commercial experience indicates the main benefit of low water volumes is expressed as more reliable results particularly at low herbicide rates. Separate from this there are distinct managerial benefits to farmers in using low water volumes.

Adoption of low rates of glyphosate to control annual weeds in Conservation Tillage situations in Australia, coupled with low volume spraying technology, has prompted the development of a specific formulation of glyphosate optimizing the rate of acid equivalent (ae) and surfactant for this situation.

This product will be known as Roundup[R] CT herbicide.

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