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Effect of Herbicide Rate and Carrier Volume on Glyphosate Phytotoxicity[1]

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ABSTRACT

Glyphosate [(N-phosphonomethyl) glycine] toxicity to waterhyacinth [*Eichhornia crassipes* (Mart.) Solms] increased as 1.7 Kg a.e/ha of the herbicide was applied in decreasing carrier volumes from 935 to 187 l/ha. Control of waterhyacinth at 12 weeks after treatment varied from 57 to 100% depending on the carrier volume used. Increasing the herbicide rate to 2.8 Kg a.e./ha, however, eliminated any differences in control due to carrier volume. Waterlettuce (*Pistia stratiotes* L.) was less susceptible to glyphosate. A treatment rate of 4.5 Kg a.e./ha was required to maintain acceptable control of waterlettuce over the 12-week experiment. None of the reduced carrier volumes tested significantly enhanced glyphosate efficacy on waterlettuce. The species differential responses to low carrier volumes were attributable, in part, to differences in herbicide retention and dispersal pattern on the leaf surfaces of waterhyacinth and waterlettuce.

Key words: glyphosate, phytotoxicity, carrier volume, waterhyacinth, waterlettuce.

INTRODUCTION

Glyphosate is a non-selective, translocated, foliage-absorbed herbicide that has been used to control a wide spectrum of annual and perennial weed species. Recently, glyphosate has been registered for use in and around aquatic sites for control of many emersed grass and broadleaved species. Previous studies indicated that glyphosate phytotoxicity may be influenced by several application and environmental factors. Attempts to enhance glyphosate phytotoxicity by reducing the carrier volume (3,8,10), using various additives (4,10,15) or chelating agents (13) have proven successful. These application modifications have allowed reduced herbicide dosages, resulting in lower cost while maintaining effective weed control.

The characterization of glyphosate efficacy under aquatic conditions has received limited attention. Riemer (11) reported that greater long-term control of phragmites (*Phragmites communis* Trin.) was achieved with low spray volume of 187 l/ha when compared to the same rate applied to 748 l/ha. Baird *et al.* (2) also observed that aerial applications of low volume (140 l/ha) provided excellent control of spatterdock (*Nuphar lutens* L.) at 2.5 kg a.e./ha glyphosate.

Waterhyacinth [*Eichhornia crassipes* (Mart.) Solms.], a perennial free-floating plant, has a wide distribution in subtropical and tropical regions, and is listed among the ten most serious weeds of the world (7). Waterlettuce (*Pistia stratiotes* L.) is another troublesome floating aquatic weed that often occurs in mixed populations with waterhyacinth. Problems associated with waterlettuce are caused by the formation of dense mats, similar to those of waterhyacinth which interfere with virtually every conceivable use of the water resource. This study was undertaken to evaluate phytotoxicity of glyphosate to waterhyacinth and waterlettuce and to determine if low-volume applications would enhance the herbicide performance in the control of these two aquatic weeds.

MATERIALS AND METHODS

Susceptibility of waterhyacinth and waterlettuce to glyphosate was studied in Fall 1982 in outdoor pools located on the grounds of the Fort Lauderdale Research and Education Center, University of Florida, Institute of Food and Agricultural Sciences, in Fort Lauderdale. The pools were 0.8 m wide by 2.2 m long (1.7×10^{-4} ha) and filled with pond water to a maximum depth of 0.6 m. A commercial water-soluble fertilizer (N:P:K, 20:20:20) and a chelated iron powder (10% Fe) were added to the water to yield 5 mg/l N and 1 mg/l Fe. Fertilization was repeated once every 2 weeks, and pond water was added to the pools as needed to replace that which was lost through evapotranspiration.

Plants were allowed to grow for 4 to 6 weeks, forming a dense canopy completely covering the pools before herbicide treatments were made. Three replications each of 2.2, 2.8, 3.4, 3.9, and 4.5 kg a.e. glyphosate per ha were applied. A commercial formulation of 54% isopropylamine salt of glyphosate (Rodeo®)[3] was used, and 0.05% (v/v) of the non-ionic surfactant X-77 (alkylarylpolyoxyethylene glycol, fatty acids, and isopropanol) was included in all treatments. All rates were applied in pond water at the equivalent of 935 l/ha using a compressed-gas sprayer equipped with a single-nozzle handgun. Phytotoxicity ratings were made on 2-week intervals up to 12 weeks after treatment. Ratings were on a 0 to 100% scale, with 0% representing no injury and 100% representing death of the entire plant population.

To evaluate the effects of carrier volumes on glyphosate phytotoxicity, the herbicide was applied broadcast with a boom at rates of 1.7, 2.2, and 2.8 Kg a.e./ha. An additional rate of 3.4 Kg a.e./ha was applied to waterlettuce,

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[3]Mention of a trademark name, proprietary product, or specific equipment does not constitute a guarantee or warranty by the U.S. Department of Agriculture or the University of Florida, and does not imply its approval to the exclusion of other products that also may be suitable.

[4]Spray Systems Co., Wheaton, IL 60187.

since this species was found to be less susceptible to glyphosate. Each of these rates were applied at three different carrier volumes equivalent to 187, 468, and 935 l/ha. Flatfan[4] nozzles orifice numbers 8001, 8003, and 8006 were used to achieve the different carrier volumes. The carrier in all experiments was pond water from the same source as described by Van and Steward (16). The surfactant X-77 was added in various amounts to maintain a concentration level of 0.05% (v/v) in all final spray mixtures. The experiments were arranged in a randomized complete block design with three replications. All experiments were conducted twice, in 1983 and 1984, and the data were combined.

A dye technique as described by Sandberg *et al.* (12) was used to compare herbicide retention and runoff after glyphosate treatments to waterhyacinth and waterlettuce. Various carrier volumes were obtained using the same nozzle orifices and the same concentration of surfactant as above. Sulfonine red dye was added to achieve a final concentration of 4 g/l in the spray solution. The spray that was retained on the leaf surface was washed off immediately with deionized water and brought to equal volume. Absorbance was measured at 500 nm in a spectrophotometer. Leaf area was determined by photocopying the leaves, and tracing the outlines of the leaf images with a planimeter.

RESULTS AND DISCUSSION

Mean injury ratings of waterhyacinth and waterlettuce at 2 and 12 weeks after treatment are presented in Table 1. Results for waterhyacinth indicate that glyphosate treatments at 2.8 Kg a.e./ha and greater provided better than 90% control at 12 weeks after treatment. Little or no regrowth of waterhyacinth was observed at these treatment rates. Visual symptoms were manifested as a gradual wilting and yellowing of the treated plant which progressed slowly to complete browning and ultimate decomposition of plant tissues 6 to 8 weeks after treatment.

Waterlettuce was less susceptible to glyphosate. Initially, a fast burndown was observed in all treatments (Table 1); however, regrowth occurred rapidly through the formation of multiple daughter plants, resulting in decreased efficacy ratings in treatments at lower rates 12 weeks after treatment. A rate of 4.5 Kg a.e./ha glyphosate was required to maintain better than 75% control of waterlettuce over the 12-week experiment. At the higher rates,

TABLE 1. CONTROL OF WATERHYACINTH AND WATERLETTUCE 2 AND 12 WEEKS AFTER TREATMENT WITH DIFFERENT RATES OF GLYPHOSATE.

Glyphosate (Kg/ha)	Percent Control[1] Weeks after Treatments			
	2	12	2	12
	Waterhyacinth		Waterlettuce	
Check	0 d	5 c	0 c	3 d
2.2	40 c	65 b	78 b	38 c
2.8	77 b	93 a	72 b	52 bc
3.4	95 a	95 a	83 ab	49 bc
3.9	95 a	100 a	96 a	68 ab
4.5	92 ab	97 a	92 a	75 a

[1]Values within a column followed by different letters are significantly different at the P = 0.05 level as determined by the Waller-Duncan test.

visual symptoms were similar to those in waterhyacinth with slow and gradual discoloration and necrosis and eventual decomposition and sinking of the treated plant 8 weeks after treatment.

The effects of various combinations of herbicide rate and carrier volume on glyphosate phytotoxicity to waterhyacinth are presented in Figure 1. In general, waterhyacinth control increased as carrier volume was decreased from 935 to 187 l/ha. The response to decreased carrier volumes was most evident at the lower glyphosate rate. Visual injury ratings at 12 weeks after treatment indicate that 1.7 Kg a.e./ha glyphosate provided 57 to 100% control of waterhyacinth depending on the volume of the carrier in which the herbicide was applied. Increasing glyphosate rate to 2.8 Kg a.e./ha, however, eliminated any differences in waterhyacinth control due to carrier volume.

Similar studies conducted on waterlettuce indicated that glyphosate phytotoxicity did not increase when carrier volume was decreased from 935 to 187 l/ha (Figure 2). At 12 weeks after treatment, more control was obtained in treatments at higher rates; however, except at 3.4 Kg a.e./ha, no significant differences in glyphosate activity due to carrier volume was observed.

There are several possible explanations for increased glyphosate phytotoxicity when carrier volume is decreased. The smaller spray droplets, the higher herbicide concentration and higher surfactant level in the low-volume spray mixtures have been shown to enhance glyphosate toxicity by increasing herbicide absorption and penetration (1,3,8,9,10). Decreasing carrier volume also reduces the amount of impurities in the carrier that would have inhibited glyphosate phytotoxicity. Buhler and Burnside (4) reported that decreasing carrier volume from 190 to 24 l/ha eliminated phytotoxicity inhibition from hard water near Lincoln, Nebraska.

Increased spray retention is another possible factor in increasing glyphosate activity when carrier volume is decreased. Sandberg *et al.* (12) reported that loss of herbicide due to runoff became significant in tall morningglory [*Ipomea purpurea* (L.) Roth] when carrier volume was increased above 190 l/ha. The effects of carrier volumes on herbicide retention on the leaf surfaces of waterhyacinth and waterlettuce are presented in Table 2. Since the concentration of the sulfonine dye in the spray solution was the same, herbicide retention as estimated by absorbance should increase proportionally with the increase in carrier volume. At a given carrier volume, therefore, the difference between the calculated value of absorbance and the value actually measured represents herbicide loss due to runoff from the leaf surfaces. Table 2 indicates that herbicide runoff may have been a major factor contributing to the reduced glyphosate toxicity to waterhyacinth at the higher carrier volumes. At 935 l/ha, less than half of the spray solution as measured by dye retention was retained on the treated waterhyacinth leaves. In contrast, no runoff was observed in waterlettuce when carrier volume was increased from 187 to 468 l/ha, and only 17% of the spray solution was lost at 935 l/ha. The smaller losses of herbicide due to runoff may account for, in part, the lack of response to low-volume applications observed in waterlettuce.

Visual observations of the waterhyacinth during spraying with sulfonine red dye revealed a herbicide dispersal pattern very similar to that described by Hess *et al.* (6) for the waxy cabbage (*Brassica oleracea* L.) leaves. When carrier

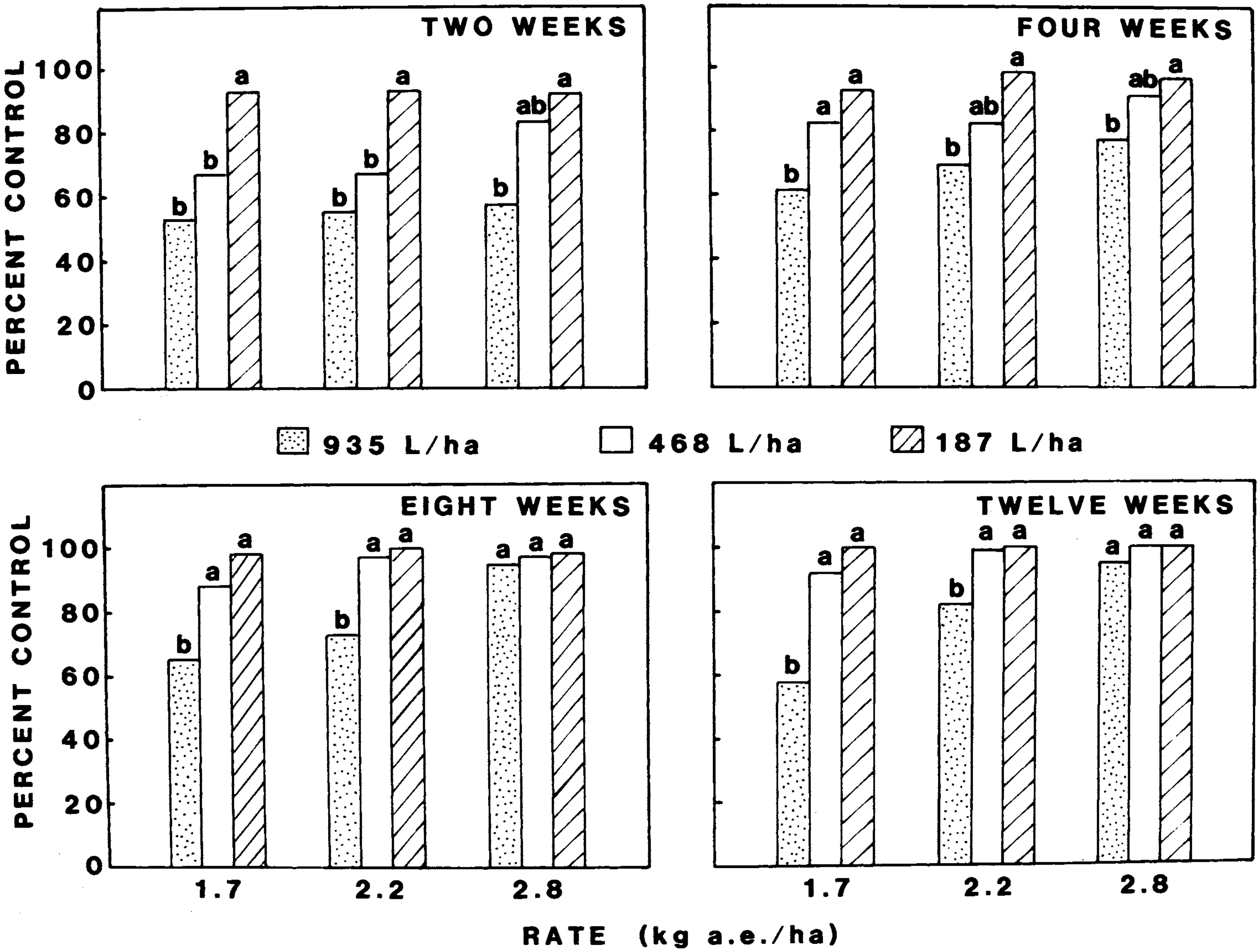

Figure 1. Effect of herbicide rate and carrier volume on glyphosate toxicity to waterhyacinth. Within a treatment rate, bars with different letters are significantly different at the P = 0.05 level using Waller-Duncan test.

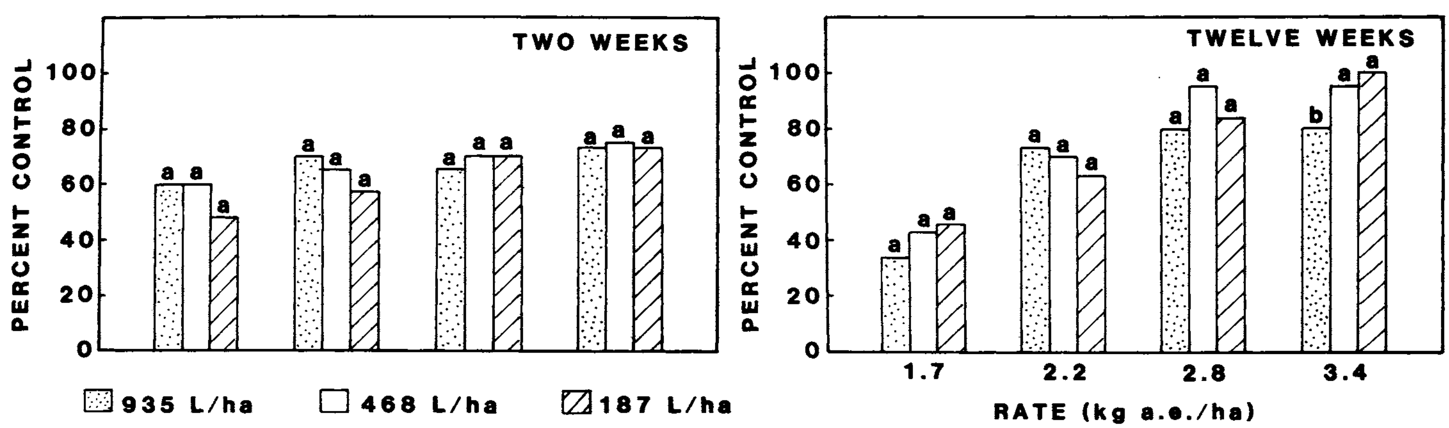

Figure 2. Effect of herbicide rate and carrier volume on glyphosate toxicity to waterlettuce. Within a treatment rate, bars with different letters are significantly different at the P = 0.05 level using Waller-Duncan test.

TABLE 2. EFFECT OF CARRIER VOLUME ON THE RETENTION OF SULFONINE RED DYE ON THE LEAF SURFACES OF WATERHYACINTH AND WATERLETTUCE.

Species	Carrier volume (l/ha)	Measured absorbance[1] (OD/dm^2)	Calculated absorbance[2] (OD/dm^2)	Herbicide runoff[3] (%)
Waterhyacinth	187	0.08 a	0.08	—
	438	0.15 b	0.20	25
	935	0.17 b	0.40	58
Waterlettuce	187	0.07 a	0.07	—
	438	0.18 b	0.18	0
	935	0.30 c	0.36	17

[1]Values followed by different letters are significantly different at the P = 0.05 level as determined by the Waller-Duncan test.
[2]Assuming that absorbance increases proportionally with the increase in carrier volume.
[3]Based on difference between calculated and measured absorbances.

volume was increased to 935 l/ha, much of the spray coalesced into large drops which subsequently fell off from the treated leaves. At the lower spray volume, the spray remained in the form of numerous small droplets with minimum runoff at the 187 l/ha carrier volume.

The herbicide distribution pattern on the pubescent leaf surface of waterlettuce was strikingly different from that observed in waterhyacinth. Spray drop coalescence leading to runoff at 935 l/ha was minimal. Furthermore, results of a study by Hess *et al.* (6) suggested that herbicide applications using higher carrier volumes may have been more desirable in a species with pubescent leaves. Using the cathodoluminescence detection mode of a scanning electron microscope, these authors observed that large spray drops from high application volumes shattered on impact with the leaf hairs of turkey mullein (*Eremocarpus setigerus* Benth.) breaking into numerous smaller droplets, resulting in a significant amount of herbicide reaching the leaf surface. Spray drops from low application volumes, however, lodged on the hairs with very little reaching the leaf surface. Further studies are required to determine the effects of this dispersal pattern on herbicide absorption and penetration into pubescent leaves.

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