Extended Delivery Herbicide©[1]

Glenn B. Fain, Charles H. Gilliam, and Ken M. Tilt
Auburn University, Dept. of Horticulture, Auburn, Alabama 36849

Glenn R. Wehtie
Auburn University, Dept. of Agronomy and Soils, Auburn, Alabama 36849

James H. Edwards
USDA-ARS, National Soil Dynamics Laboratory, Auburn, Alabama 36830

Timothy L. Grey
University of Georgia, Georgia Station, Griffin, Georgia 30223

Broadcast applications of granular herbicides for preemergent weed control in container crops results in significant herbicide loss between containers as nontarget loss. This study was conducted to evaluate potential extended delivery carriers of pre-emergent herbicides. Our objective was to develop a controlled-release herbicide that could be applied directly to nursery containers annually; virtually eliminating nontarget herbicide loss. Two experiments were conducted: one in the laboratory and one in the greenhouse. The labaratory experiment tested release rates of oryzalin from three polymeric resins. There were two anion exchange resins (A300 and A400) and one sorbent resin (MN400). After 57 leaching events the MN400, A300 and A400 still retained 96.73%, 91.3%, and 88.74% of oryzalin, respectively. The greenhouse experiment tested the efficacy of these herbicide formulations applied at various rates as well as commercially formulated oryzalin (Surflan 4AS). There was no difference between the two exchange resins and Surflan at 90 days after treatment (DAT), however at 120 DAT both exchange resins had significantly lower weed control than Surflan. The MN400 resin provided less weed control than other treatments at both 90 and 120 DAT, except for Surflan at 120 DAT where no difference occurred.

INTRODUCTION

The container nursery industry currently uses broadcast applications of granular herbicide for preemergent weed control. This application method may result in significant amounts of herbicides falling between containers as nontarget loss. Growers make an average of three applications per year with losses up to 80% per application (Gilliam et al., 1992), depending on application equipment, container spacing, and crop canopy (Porter and Parish 1993). Other techniques have been evaluated to reduce chemical losses in container production, including herbicide-coated fertilizers (Keel et al., 1998), geotextile disks (Appleton and Derr, 1990), and slow-release herbicide tablets (Gorski et al., 1989). The long-term objective of this research is to develop and evaluate new controlled-release herbicide formulations,

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Table 1. Effects of extended delivery herbicide formulations on crabgrass control.

		Crabgrass dry weight (g)	
Herbicide	Rate (lb ai ac^{-1})	90 DAT[z]	120 DAT
MN400 - oryzalin	4	9.08	2.78
	8	2.53	0.72
	12	3.4	2.47
	16	1.08	3.66
	20	1.21	0.57
	24	0.52	0.98
	28	0.54	1.32
	32	0.23	0.1
		L***Q***[y]	NS
A300 - oryzalin	4	1.6	2.95
	8	0.43	0.37
	12	0.93	0.25
	16	1.88	0.65
	20	0.67	1.12
	24	1.16	0.15
	28	0.48	0.3
	32	0.4	0.19
		NS	L**Q*
A400 - oryzalin	4	2.27	0.84
	8	3.64	2.96
	12	1.98	0.87
	16	1.42	1.59
	20	0.26	0.45
	24	0.12	0.3
	28	0.15	0.12
	32	0.72	0.07
		L*	L*
Surflan	2	0.87	3.9
	4	0.36	1.68

Control	8.77	4.21
Contrast:		
MN400 vs. A300	(2.51 vs. 0.97) ***[x]	(2.78 vs. 1.24) **
MN400 vs. A400	(2.51 vs. 1.41) ***	(2.78 vs. 1.49)
*A300 vs. A400	(0.97 vs. 1.41) NS	(1.24 vs. 1.49) NS
MN400 vs. Surflan	(2.51 vs. 0.64) ***	(2.78 vs. 3.63) NS
A300 vs. Surflan	(0.97 vs. 0.64) NS	(1.24 vs. 3.63) **
A400 vs. Surflan	(1.41 vs. 0.64) NS	(1.41 vs. 3.63) **

[z]Days after treatment.
[y]L or Q represents linear or quadric responses within a herbicide, *, ** and *** represents significance as alpha = 0.05, 0.01, and 0.001.
[x]Contrast means in parenthesis followed by significance.

which if effective would be applied directly to each container annually at potting, thus eliminating nontarget losses associated with current application techniques. The short-term objective was to screen and evaluate various carriers for their potential to provide a vehicle for extended delivery of herbicides.

MATERIALS AND METHODS

Experiment 1. Three commercially available polymeric resins were chosen for laboratory evaluation as herbicide carriers: Two of the resins were Purolite® A300 and A400 anion exchange resins, both were made of a polymer matrix structure of polystyrene cross linked with divinylbenzene. The functional groups for A300 and A400 are type I quaternary ammonium and dimethylethanolamine respectively, both resins have chloride as the ionic form. The other resin was Purolite® MN400 sorbent resin made of cross linked polystyrene. It has trimethylamine as a functional group and has a very high internal surface area of 800 to 1000 m^2g^{-1}. All resins were spherical in shape and were between 0.5 and 1.1 mm in diameter. Lab testing began the summer of 1999. Oryzalin, a commonly use DNA herbicide, was chosen as the herbicide to conduct our initial testing. Oryzalin disassociates at a pH above 8.5 rendering it more negatively charged and giving it a greater affinity for adsorption onto the exchange resins. Resins were placed into a 10,000-ppm solution of oryzalin at a ratio of resin:oryzalin solution (1 : 5, v/v), ^{14}C-oryzalin was added to facilitate detection. The resin:oryzalin mixture was then placed on a flat-bed shaker for 24 h. Effective concentrations obtained were 50 mg g^{-1} (5% ai), 60 mg g^{-1} (6% ai), and 80 mg g^{-1} (8% ai) for the A300, A400, and MN400 resins, respectively. Herbicide-resin formulations were placed into 60 ml (4 oz) cylindrical separatory funnels and 3 ml (0.2 oz) of water were added daily. Water was allowed to remain in the funnels for 30 min. before leaching. Funnels were opened and allowed to drain into glass beakers for 5 min. A 0.2 ml (0.013 oz) sub-sample was removed from each beaker and placed into 20 ml (1.33 oz) scintillation vials along with 15 ml (1 oz) of scintillation cocktail. Vials were placed into a Beckman LS 3800 liquid scintillation analyzer and assayed for ^{14}C concentration.

Experiment 2. On April 4, 2000, 198 2-liter (trade gallon) pots were filled with 6:1 pine bark: sand substrate (v/v) amended on a m^{-3} (yd^{-3}) basis of 2.3 kg (5 lb) dolomitic limestone, 6.4 kg (14 lb) Osmocote 17N-7P-12K and 0.7 kg (1.5 lb) Micomax per cubic yard. Containers were placed in the greenhouse under overhead irrigation at the Patterson greenhouse complex in Auburn, Alabama. Each of the three resins were applied at rates of 4.2 (4), 8.4 (8), 12.6 (12), 16.7 (16), 20.9 (20), 25.1 (24), 29.3 (28), and 33.4 (32) kg ai ha^{-1} (lbs ai ac^{-1}). In addition Surflan 4AS was applied at 2.1 (2) and 4.2 (4) kg ai ha (lbs ai ac^{-1}), and an untreated control was maintained. Each individual container received its application of experimental herbicide formulations by the use of a shaker can to ensure uniform application and distribution. Surflan 4AS treatments were applied with a backpack sprayer with a flat fan nozzle applied at 20-40 psi using a spray volume of 374 l ha^{-1} (40 gal ac^{-1}). Crabgrass (*Digitaria sanguinalis*), a summer annual grass sensitive to DNA herbicide, was chosen as our weed species. Containers were over seeded with crabgrass (20 seeds per container) one irrigation event after herbicide application. Weeds were sprayed with 2% glyphosate to runoff one day prior to harvesting weeds. Containers were reseeded monthly after harvesting throughout the experiment. Data collected included number of seed germinated and monthly weed top dry weight.

RESULTS AND DISCUSSION

Experiment 1. After 21 days of leaching, A400 had the highest release rate having released a total of 8.2% of the oryzalin followed by A300 at 5.1% and MN400 at 1.4% (Fig. 1). Between 21 days and the end of the experiment (57 leaching events), release rates were similar among the resins. After 57 leaching events the MN400, A300, and A400 resins had released a total of 3.3%, 8.7%, and 11.3% respectively. This test was repeated and similar trends were observed (data not shown). These data offer exciting possibilities for the extended delivery of herbicides since oryzalin was still being released from the carrier after 57 leaching events. The A400 resin while having the highest release rate during the first 21 days, still retained over 88% of its active ingredient after 57 days. This higher rate of initial release may benefit in providing an initial higher concentration of herbicide to the container surface, while the later decreased release rate could provide a maintenance level of herbicide for extended weed control.

Experiment 2. The resins evaluated in the laboratory were prepared for a greenhouse evaluation. There was a linear response with release rate for the A400 resin 90 and 120 days after treatment (DAT) (Table 1), with greater weed control increasing with increasing rate. The A400 resin with its high initial release of oryzalin followed with a more uniform release over time, resulting in extended weed control beyond the 90 DAT normally obtained with granular herbicides in container crops. There was a significant quadratic response with the MN400 resin at 90 DAT and the A300 120 DAT. For example, both the MN400 and A300 had very poor control at these dates with the lowest rate while weed control increased with increasing rates. These data correspond with laboratory results which showed lower levels of oryzalin initially being released. Contrast analysis was conducted to determine differences between formulations across all rates (Table 1). There was no difference between the two exchange resins and Surflan at 90 DAT; however, at 120 DAT both exchange resins had significantly lower weed dry weights than Surflan.

For example, the A300 and A400 had 62% and 63% lower weed dry weight than Surflan; indicating extended control with the experimental formulations. The MN400 resin provided less weed control than other resins at both 90 and 120 DAT and was similar to Surflan at 120 DAT. It was apparent that the exchange resins were releasing oryzalin to the target areas providing weed control beyond current industry standard applications. These tests indicate the potential these resins have to provide extended herbicide delivery. However; longer-term weed efficacy tests and plant tolerance tests need to be conducted.

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