Preemergent Bittercress Control on a Gravel Groundcover[1]

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Abstract

Bittercress (*Cardamine hirsuta*) is a problem weed year round in Southeastern U.S. container nurseries. It readily establishes itself on gravel production surfaces and in containers, producing seeds in 4 to 5 weeks. Gravel has limited adsorption sites for herbicides, and higher use rates are required for control. Many preemergent herbicides provide short-term (3 month) control of bittercress. Sprayable formulations provided more persistent control than granular formulations. Factor (prodiamine) and Goal (oxyfluorfen) controlled bittercress for 8 months at 2× normal rates under nursery conditions of daily irrigation. Half-lives of Factor and Goal were 3 and 1 month, respectively. Extraction of herbicides from the gravel indicated that bittercress was controlled by 0.31 ppm of both herbicides.

Index words: container nursery production, herbicide formulation, herbicide half-life, herbicide persistence, preemergent herbicide, weed control.

Chemicals used in this study: Dimension (dithiopyr), *S,S*-dimethyl 2-(difluoromethyl)-4-(2-methylpropyl)-6-(trifluoromethyl)-3,5-pyridinedicarbothioate; Factor (prodiamine), 2,4-dinitro-N^3, N^3-dipropyl-6-(trifluoromethyl)-1,3-benzenediamine; Gallery (isoxaben), *N*-[3-(1-ethyl-1-methylpropyl)-5-isoxazolyl]-2,6-dimethoxybenzamide; Goal (oxyfluorfen), 2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl)benzene; Pendulum 2G (pendimethalin), *N*-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine; Predict (norflurazon), 4-chloro-5-(methylamino)-2-(3-(trifluoromethyl)phenyl)-3(2*H*)-pyridazinone; Princep Liquid (simazine), 6-chloro-*N,N'*-diethyl-1,3,5-triazine-2,4-diamine; Prowl EC (pendimethalin), given above; RegalKade (prodiamine), given above; Ronstar (oxadiazon), 3-[2,4-dichloro-5-(1-methylethoxy)phenyl]-5-(1,1-dimethylethyl)-1,3,4-oxadiazol-2-(3*H*)-one; Rout (oxyfluorfen + oryzalin), oxyfluorfen = given above, oryzalin = 4-(dipropylamino)-3,5-dinitrobenzenesulfonamide; Snapshot 2.5 TG (trifluralin + isoxaben), trifluralin = α,α,α-trifluoro-2,6-dinitro-*N,N*-dipropyl-4-(trifluoromethyl)benzenamine, isoxaben = given above; Surflan A.S. (oryzalin), given above.

Significance to the Nursery Industry

To achieve 6 to 8 months of bittercress control on gravel production areas, growers should apply sprayable formulations of the preemergent herbicides Factor and Goal. Two × normal rates appear to be sufficient for long term control. Princep was not effective in controlling bittercress in gravel production beds and because of possible contamination of groundwater should not be used for this purpose.

Introduction

Gravel is a common production surface at container plant nurseries, often overlaid on plastic or fabric. Under daily irrigation conditions, the gravel layer becomes a moist, nutrient-enriched environment that is favorable for weed seed germination. Weed seedling emergence is further enhanced as the gravel provides points of contact for seed during germination (13). Weed control on gravel production beds is necessary to reduce the spread of weedy species to container plants where they may compete for water and nutrients and are unacceptable in sales (6). Weeds also serve as secondary hosts for insects and pathogens (7) and have been found to be a source of nematode innoculum to container plants (9).

Bittercress (*Cardamine hirsuta* L.), a member of the *Brassicaceae* (Mustard) family, is a major weed problem at container nurseries in the Southeastern United States. The plant behaves as a winter annual in the wild but will germinate year-round under production conditions of daily irrigation and regular fertilization in the nursery environment. Establishment is possible in containers from gravel production beds and peripheral areas at nurseries. Bittercress plants mature, flower, develop siliques and release seeds in as short a period as 4 to 5 weeks. Each plant can produce up to 5000 seeds that are forcefully propelled for a distance of up to 1 m (42 in) (2). Significant infestations may occur in a short period of time.

Preemergent herbicides are used to control bittercress in containers, and large amounts of a broadcast or spray applied material falls on the gravel surface. Gravel was found to retain more herbicide than plastic or fabric groundcovers up to 19 days after application (8), but as gravel has fewer adsorption sites for herbicide than container media, preemergent weed control is thought to be relatively short. Control may also be related to the formulation of the herbicide. Granular products may release the active ingredient over a longer period of time than sprayable formulations (12).

The objective of this research was to evaluate the efficacy of preemergent herbicides on controlling bittercress in a gravel production bed. Granular and sprayable formulations of herbicides were compared and amounts of herbicides adsorbed to the gravel over time were quantified.

Materials and Methods

Herbicide evaluation. Research was conducted at the Clemson/Carolina Nurseries Cooperative Research Center in Moncks Corner, SC. In the initial study, twelve herbicide products were evaluated at 4× normal use rate (Table 1). Increased rates were selected as longevity of control was desired. Plots [0.9 m × 0.9 m (3 ft × 3 ft)] in which coarse gravel (10% ≈ 12 cm^3, 53% ≈ 30 cm^3, 37% ≈ 50 cm^3; bulk

[1]Received for publication September 18, 2000; in revised form April 20, 2001. Technical contribution no. 4677 from South Carolina Agricultural Experiment Station.

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Table 1. **Bittercress control on gravel, 1995 study, at 1, 3, 7 and 8 months after preemergent herbicide application.**

Herbicide	Formulation	Rate		Months after treatment			
				1	3	7	8
		kg ai/ha	lb ai/A	% Bittercress control			
Factor WDG65 (prodiamine)	Sprayable	4.4	4.0	100	100	100	95
RegalKade (prodiamine)	Granular	4.4	4.0	100	100	90	85
Rout (oxyfluorfen + oryzalin)	Granular	13.2	12.0	100	100	87	30
Dimension GR (dithiopyr)	Granular	4.4	4.0	100	100	100	85
Snapshot 2.5 TG (trifluralin + isoxaben)	Granular	11.0	10.0	100	100	0	7
Prowl EC (pendimethalin)	Sprayable	8.8	8.0	100	100	82	32
Pendulum 2G (pendimethalin)	Granular	8.8	8.0	100	100	82	65
Gallery DF (isoxaben)	Sprayable	4.4	4.0	100	85	0	0
Gallery DF on fertilizer (isoxaben)	Granular	4.4	4.0	100	100	35	15
Goal T/O GR (oxyfluorfen)	Granular	8.8	8.0	100	100	87	60
Goal EC (oxyfluorfen)	Sprayable	8.8	8.0	100	100	100	82
Ronstar (oxadiazon)	Sprayable	8.8	8.0	100	100	85	15
LSD (P = 0.05)				0	12	31	33

density = 2 g cm^{-3}; pH 7.9) had been installed to a depth of 5.1 cm (2 in), were replicated twice and treated on October 24, 1995. Prior to treatment and container plant placement the area was sprayed with Finale (glufosinate) to kill existing weeds. Granular formulations were applied with a shaker can and the sprayable formulations were applied with a CO_2 backpack sprayer equipped with 8006 nozzles calibrated to deliver 374 liters/ha (40 gal/A). Containers of actively growing bittercress were placed on the perimeter of all plots (7 per plot) to provide a constant source of seed. Daily irrigation provided 2.5 cm (1 in) of water and fertilization on the gravel beds and was of the same frequency and intensity as in beds housing container grown plants. Bittercress control was rated visually every month on a scale of 0 to 100 with 0 = no control and 100 = complete control.

Sprayable herbicide evaluation. Bittercress weed control of eight sprayable herbicides (Table 2) was evaluated in the second study. Gravel plots [0.9 m × 1.5 m (3 ft × 5 ft)] were replicated four times and treated in October 1996. Herbicides were applied at 2× and 4× normal rates with a backpack sprayer as above. Pretreatment weed control and bittercress seed source was also as described above. Bittercress control was rated visually each month from 3 to 8 months after treatment.

Factor and Goal evaluation. In the third study, efficacy of two herbicides, Factor and Goal, that had effectively controlled bittercress in earlier studies, was evaluated with the addition of an antitranspirant (Table 3). Plots [2 m × 2 m (6.6 ft × 6.6 ft)] were sprayed on August 28, 1997. Treatments were Factor 65WDG and Goal at 2× normal rates with and without 10% ClearSpray (W. A. Cleary Chemical Corp., 178 Ridge Road, Suite A, Dayton, NJ 08810). Included were an untreated control and a ClearSpray only treatment. Treatments were applied with a CO_2 back-pack sprayer equipped with 8006 nozzles, calibrated to deliver 935 liters/ha (100 gal/A) at 40 psi. Spray volume was increased to provide greater penetration of the herbicide into the gravel layer. Pots containing bittercress were placed on the perimeter of the experimental plots to provide a constant supply of seed during the trial. There were three replications of each treatment. Bittercress control was rated visually monthly through 8 months on a scale of 0 (no control) to 100 (complete control).

Samples of gravel from depths of 0–2.5 cm (0–1 in) and 2.5–5.0 cm (1–2 in) were taken immediately after application and at 3, 5, and 7 months after application from all plots. Gravel samples were dried at 100C (212F) for 24 hr prior to extraction. Fifty gm of dried gravel were placed in an amber jar (50 ml) with 30 ml MeOH and shaken at 60 rpm for 1 hr in a 58C (136F) water bath to extract herbicides. The solution was filtered through Whatman #5 filter papers and 0.2 µm nylon membrane filters using Buckner funnels and further filtered through 0.2 µm acrodiscs. The herbicide/MeOH extract was placed in a test tube and evaporated to a volume of 10 ml under a steady stream of nitrogen. Two ml of the solution was evaporated to dryness under nitrogen. One ml of acetonitrile:water (65:35) was used to reconstitute dried samples. Prior to placement in autosampler vials, samples were filtered through 0.2 µm acrodisc. Analysis was performed utilizing a Hewlett Packard 1090 HPLC fitted with a C_{18} reverse phase column (Rexchrom S3–100–ODS, 3 µm, 100A). Solvent system was acetonitrile (with 0.1% phosphoric acid): water (with 2% acetonitrile and 0.1% phosphoric acid), 65:35, over 20 minutes at a flow rate of 0.5 ml/min, 100% acetonitrile for 20–25 min, and 65:35 starting solvent from 25–30 min. Injection volume was 50 µl, and each sample was injected twice and quantified by comparison to herbicide standards (20 µg/ml). The diode array detector was set at 220 nm. Percent recoveries were 75 and 56 percent for Factor and Goal, respectively. Limits of detection for both herbicides were 40 ppb.

Data from the studies were subjected to ANOVA and means were separated using least significant differences at P = 0.05.

Results and Discussion

Herbicide screening. Excellent bittercress control (100%) was observed from all treatments at three months after treatment (MAT) except Gallery DF (isoxaben), which only provided 85% control (Table 1). At 7 MAT, control had declined to unacceptable levels for Snapshot 2.5 TG (trifluralin + isoxaben), Gallery DF and Gallery DF coated fertilizer. Treatments providing marginal control (80–90%) were Rout (oxyfluorfen + oryzalin) (87%), Prowl EC (pendimethalin)

Table 2. Bittercress control on gravel with sprayable formulations of herbicides at 2× and 4× label rates, at 3, 4, 5, 6 and 8 months after herbicide application in 1996.

	Rate		Months after treatment				
			3	4	5	6	8
Herbicide	kg ai/ha	lb ai/A	% Bittercress control				
Factor WDG65 (prodiamine)	2.2	2.0	100	97	95	85	57
	4.4	4.0	100	100	97	92	88
Goal 2EC (oxyfluorfen)	4.4	4.0	100	99	91	62	27
	8.8	8.0	100	100	100	90	43
Ronstar WP (oxadiazon)	4.4	4.0	100	96	84	45	0
	8.8	8.0	100	97	92	69	0
Predict (norflurazon)	5.5	5.0	95	89	52	25	0
	11.0	10.0	97	96	87	50	17
Princep 4L (simazine)	4.4	4.0	92	80	82	45	0
	8.8	8.0	92	71	66	35	20
Dimension 1EC (dithiopyr)	2.2	2.0	100	100	96	81	0
	4.4	4.0	100	100	100	95	50
Pendulum WDG (pendimethalin)	4.4	4.0	100	96	81	47	0
	8.8	8.0	100	100	95	75	27
Surflan A.S. (oryzalin)	4.4	4.0	92	86	46	22	0
	8.8	8.0	94	87	30	20	0
LSD (P = 0.05)			5	16	29	38	33

(82%), Pendulum 2G (pendimethalin) (82%), Goal T/O GR (oxyfluorfen) (87%) and Ronstar (oxadiazon) (85%). Factor (prodiamine), RegalKade (prodiamine), Dimension (dithiopyr) and Goal EC (oxyfluorfen) provided excellent control (90%+). The sprayable forms of oxyfluorfen and prodiamine provided 100% weed control through 7 MAT but only 87% and 90% control were noted for their granular formulations. Factor, RegalKade, Dimension and Goal EC controlled bittercress >80% at 8 MAT but only Factor, RegalKade and Dimension controlled bittercress ≥80% at 8.5 MAT (257 days).

Sprayable herbicides evaluation. Sprayable treatments which provided excellent long term control of bittercress in 1995 were further evaluated in 1996 along with additional preemergent herbicides available in sprayable formulations (Table 2). Herbicides were applied at 2× and 4× normal rates. All herbicides controlled bittercress at 3 MAT (Table 2). Surflan (oryzalin) (both rates), Predict (norflurazon) (2×) and Princep (simazine) (4×) were ineffective (<80%) at 5 months. Both rates of Factor and Dimension controlled bittercress (>80%) at 6 MAT, as did Goal at 4× rate. However, only Factor (4×) effectively (88%) controlled bittercress at the end of the study, eight months after application.

Factor/Goal bittercress control. The third study continued the evaluation of Factor and Goal for preemergent control of bittercress in gravel beds. Sprayable formulations of the herbicides were applied at 2× normal rates with and without the addition of an antitranspirant (ClearSpray). Factor and Goal provided >95% control of bittercress at 7 MAT and >88% at 8 MAT (Table 3). The addition of the antitranspirant did not enhance efficacy of Factor. Control from Factor + CS was lower at 6, 7 and 8 MAT than from Factor alone.

Table 3. Bittercress control at 3, 4, 6, 7 and 8 months after herbicide application in 1997–98.

	Rate		Months after treatment				
			3	4	6	7	8
Herbicide	kg ai/ha	lb ai/A	% Bittercress control				
Factor (prodiamine)	2.2	2	97	97	97	95	92
Factor + 10% ClearSpray	2.2	2	83	77	17	17	7
Goal (oxyfluorfen)	4.4	4	100	100	100	100	88
Goal + 10% ClearSpray	4.4	4	100	100	100	100	70
10 % Clearspray			10	10	10	10	10
Control			0	0	0	0	0
LSD P = 0.05			14.9	20.5	26.4	26.7	18.7

Table 4. Factor, Factor plus ClearSpray (CS), Goal and Goal plus ClearSpray concentrations (mg herbicide/kg gravel) from the surface (0–2.5 cm) and underlying (2.5–5 cm) layers of gravel at 0, 3, 5 and 7 months after treatment (MAT).

	0 MAT		3MAT		5 MAT		7 MAT		
	0–2.5	2.5–5	0–2.5	2.5–5	0–2.5	2.5–5	0–2.5	2.5–5	LSD $P = 0.05$
Treatment	mg/kg								
Factor	2.02	0	0.75	0.75	0.38	0.28	nd[z]	nd	0.28
Factor + CS	5.02	0	0.16	0.10	0.09	0.21	nd	nd	0.68
LSD $P = 0.05$	2.18	0	0.33	0.52	0.17	0.25			
Goal	17.6	0	1.41	1.32	0.81	0.31	0.31	0.19	3.89
Goal + CS	24.7	0	8.04	0.56	0.57	0.14	1.23	0.57	7.75
LSD $P = 0.05$	17.83	0	8.81	0.77	0.54	0.54	1.39	0.39	

[z]Not detected.

Factor + CS provided 17% control at 6 MAT and 7% at 8 MAT compared to 97% and 92% with Factor. Goal + ClearSpray (CS) provided 100% control at 7 MAT decreasing to 70% control at 8 MAT, similar to control from Goal of 100% and 88%, respectively.

Samples were taken from the gravel beds and analyzed for herbicide content on the day of application and at 3, 5, and 7 MAT. Herbicide extraction of the gravel indicated that Factor was present at a higher concentration in the + CS (ClearSpray) treatment than in the Factor alone treatment in the top 2.54 cm (1 in) of gravel immediately following application (Table 4). The antitranspirant may have competed with the herbicide for the limited binding sites on the gravel surface resulting in more extractable herbicide. Factor was not detected in the 2.5–5.0 cm (1–2 in) layer of gravel on the day of application. At three months after application, the concentration in both Factor treatments was lower than initial concentrations with herbicide detection in both the top and second layers indicating downward movement. Amounts detected in the + CS treatment were lower than the Factor alone treatment perhaps indicating that ClearSpray enhanced losses of the herbicide by preventing adsorption and thus inhibited the effectiveness of Factor. At 5 MAT, concentrations were ≈ 50% lower than in the 3 MAT sampling in both Factor treatments, and the Factor treatment had a greater level of extractable herbicide than the Factor + CS treatment in the top layer of gravel. Concentrations were similar among treatments in the bottom gravel layer at 5 MAT. Factor was not detected in either treatment at 7 MAT.

Goal was detected at much higher concentrations than Factor following treatment (Table 4), likely the result of higher application rates. In the + CS treatment, over 24 mg/kg were detected in the top 0–2.5 cm (0–1 in) gravel layer and, similarly to Factor, lower, but not significantly, amounts were detected in the Goal alone (17 mg/kg). No Goal was detected in the 2.5–5.0 cm (1–2 in) gravel layer immediately after treatment. At 3 MAT, Goal was found in both layers in both treatments at lower concentrations than on the day of application (half-life estimated at approximately two months). Amounts were similar in the + CS treatment to the – CS treatment in the top and bottom layers of gravel. Goal continued to be detected from both layers in both treatments at five and seven months after application at similar concentrations. Results are similar to those reported in a study on residues of oxyfluorfen from organic soils in which 4.5 mg/kg was detected in the top 5 cm (2 in) of soil after an application of 720 g/ha, and residues migrated to lower soil layers over time (5).

Factor was applied at one half the rate of Goal, but concentrations detected on the gravel immediately after application were <20% of those detected for Goal. Goal is more strongly adsorbed on soils than Factor (K_{oc} 100,000 and 7000, respectively), but Factor is much less soluble in water than Goal (0.01 and 0.1 ppm, respectively) (1). A smaller proportion of Factor may have been available for adsorption to the limited binding sites on the gravel surface. Approximately 50% of the Factor detected on the day of application was detected at 3 MAT and 25% was found at 5 MAT, indicating a half-life of approximately 3 months. Published half-life for prodiamine has been reported at 70–120 days (1). The slow rate of dissipation of Factor over 5 months reflects the low solubility of the chemical and may be responsible for the long term (8 MAT) weed control. Factor is known to persist longer than other dinitroaniline herbicides (4). In a sandy loam soil, concentrations of Factor which inhibited 50% root elongation in members of the *Cruciferaea* family ranged from <10 to >128 mg/kg, and shoot growth was inhibited 50% at concentrations of 2–25 mg/kg (3). The lower concentrations which provided weed control in our study may be a result of the lack of organic matter in the gravel layer which would allow the herbicide to be more readily available to enter solution. In the Factor + CS treatment, amounts detected at 3 and 5 MAT were <4% of the amount on the day of application. The antitranspirant, a plastic polymer, may have remained functional throughout the early months of the study acting as a coating on the gravel and preventing adsorption of the herbicide and allowing for faster losses from site of application. Half-life of Factor + CS is ≈ 1.5 months, less than half of that for the Factor alone. The smaller concentrations in the top layer of gravel at 3 and 5 MAT in the + CS treatment resulted in unacceptable weed control. However, bittercress control was still acceptable in the Factor treatment at 7 MAT although extractable and detectable concentrations were not found. ClearSpray clearly inhibited the effectiveness of Factor.

Goal concentrations declined to <8% of amount detected on day of application at 3 MAT, <5% at 5 MAT and <2% at 7 MAT. Estimated half-life of the herbicide from this study is ≈ 1 month and is in accordance with other studies (1). Dissipation rate was faster than with Factor as expected based on herbicide solubilities. However, weed control remained excellent through 7 MAT. Goal was effective in controlling bittercress at concentrations <0.31 ppm. The addition of the antitranspirant did not reduce persistence of the herbicide on the gravel or adversely affect weed control. Movement of the herbicide from the top layer to the second layer was also unaffected by the ClearSpray.

Both Factor and Goal are effective in inhibiting bittercress seed germination in soilless container medias (10, 11). This research indicates that both herbicides are also effective in controlling bittercress seed germination in a gravel production surface for more than 8 months in the Southeast. Losses of both herbicides occur quickly from a gravel surface and both herbicides migrate over time to lower profiles. However, effective control of bittercress is apparently possible with very small concentrations of Factor and Goal. The addition of the antitranspirant resulted in a decrease in weed control when combined with Factor but did not affect the efficacy of Goal.

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