Pre and Post Application Moisture Levels and Formulation Affect Preemergence Control of Spotted Spurge (*Chamaesyce maculata*) and Hairy Bittercress (*Cardamine hirsuta*) with Flumioxazin©[1]

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Two experiments were conducted to evaluate pre and post application moisture levels effect on preemergence control of spotted spurge (*Chamaesyce maculata*) and hairy bittercress (*Cardamine hirsuta L.*) with flumioxazin in two different formulations. BroadStar™ 0.25G was applied as granular, and SureGuard 51 WDG (water dissoluble granular) was sprayed. In Experiment 1, three pre-moisture substrate levels (wet, medium, and dry) were treated with BroadStar and SureGuard® at 0.25 and 0.375 lb ai/A on 7 Sept. 2010. Four irrigation volumes were applied immediately after herbicides application, including 0.6, 1.3, 2.5, and 5.1 cm (0.25, 0.50, 1, and 2 in.). Each pot was overseeded with 25 spotted spurge seed the next day. Results showed that both main effects, formulation and herbicide rate, had significant influence on spotted spurge control. The only significant two-way interaction was formulation × rate. Granular was less effective than spray formulation, and low rate was less effective than high rate. Conversely, spray formulation provided 100% control at both 0.25 and 0.375 lb ai/A. In Experiment 2, the experiment was repeated with hairy bittercress on 1 March 2011. Each pot was overseeded with 25 hairy bittercress seed 1 week after treatment. Results showed formulation significantly influenced weed control; irrigation was slightly significant at 2 weeks after seeding; pre-moisture and herbicide rate did not influence bittercress germination number. The only two-way interaction of formulation × irrigation was slightly significant. When irrigation volume was 0.6 cm (0.25 in.), granular formulation had lower control of hairy bittercress germination at 2 weeks after seeding. Spray formulation at both rates provided excellent control of hairy bittercress.

INTRODUCTION

Preemergence herbicides have to be activated by water. For most herbicides, irrigation [0.6 to 1.3 cm (0.25–0.5 in.)] is needed after treatment. Based on previous studies, moisture is one factor affecting the absorption of herbicides by germinating weeds (Menges, 1963). Previous researches in the 1960s demonstrated how irrigation volume affects effectiveness of preemergence herbicides with different ingredient and volatility (Knake et al., 1967). As pointed out by Audus (1964), the relationship between soil moisture and absorption of herbicides into the soil ex-

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change complex may affect the availability of herbicides for uptake by the plant. Other research with diuron on cotton (*Gossypium hirsutum L.*) showed that diuron was more toxic under high moisture conditions than under low moisture conditions (Upchurch, 1957). In a study on foxtail control with 25%, 31%, and 37% moisture (Stickler et al., 1969), the effectiveness of atrazine and ethyl N,N-dipropylthiocarbamate (EPTC) increased with increasing soil moisture. In reviewing the literature, little or no research has been conducted since cited research from the 1960s. Nursery production had changed dramatically since the 1960s. Potting media in the 1960s had high soil content; today most media are completely soilless. Growers need solid information about how to best manage moisture levels for the best weed control. Therefore, the objective of this research was to evaluate the influence of pre-application moisture levels and the initial post-application irrigation levels on the preemergence control of spotted surge (*Chamaesyce maculata*) and hairy bittercress (*Cardamine hirsuta L.*) with flumioxazin.

MATERIALS AND METHODS

Experiment 1. On 3 Sept. 2010, trade-gallon pots were filled with pine bark and sand (6 : 1, v/v) substrate previously mixed with 15 lb/yd^3 of Polyon (17–5–11) control-released (7–8 months) fertilizer, 5 lb/yd^3 of dolomitic limestone, and 1.5 lb/yd^3 Micromax. Pots were separated into three moisture levels and container weights and container metric water content for each moisture level were measured with 10 samples for each moisture level before herbicides were applied. We used a Decagon® Soil Moisture Sensor to measure volumetric water content. For low moisture, no water was applied 4 days before treatment. The average weight of whole pot was 1.18 kg, and water content was 20%. For medium moisture, no water was applied 1 day before treatment. The average weight of whole pot was 1.36 kg, and water content was 26%. For high moisture, all pots were watered to saturation immediately before treatment. The average weight of whole pot was 1.60 kg, and water content was 34%. On 7 Sept. 2010, herbicides were applied to the pot surface. Treatments included BroadStar™ 0.25G at 0.250 and 0.375 lb ai/A and SureGuard® 51WDG at 0.250 and 0.375 lb ai/A. Both herbicides have the same active ingredient: flumioxazin. BroadStar was applied with a hand-shaker, and SureGuard was applied by an enclosed-cabinet sprayer which has been calibrated to deliver at 30 GPA (gallon per acre) with Teejet 8002 flat fan nozzle. After treatment, 4 overhead irrigation volumes were applied, including 0.6, 1.3, 2.5, and 5.1 cm (0.25, 0.5, 1, and 2 in.). Each pre-moisture level received four herbicides treatments and four irrigation volumes with six replications per treatment. Nontreated control group was also included. All pots were completely randomized and maintained outdoor with 1.3-cm (0.5-in.) overhead-irrigation daily. Spotted spurge was overseeded 25 per pot the next day (8 Sept. 2010) after treatment. Weeds number was counted weekly and fresh weight was collected at 9 weeks after seeding (10 Nov. 2010). Data subject to ANOVA and variable means separated using Duncan's multiple range test at $P \geq 0.05$.

Experiment 2. A similar experiment was conducted on 25 Feb. 2011 with hairy bittercress. Pots were filled with the same substrate as in Experiment 1. Container weights and container metric water content were measured before herbicides were applied on 1 March 2011: low pre-moisture 1.58 kg, 16%; medium pre-moisture

1.73 kg, 22%; and high pre-moisture 1.88 kg, 30%. Herbicide treatments, irrigation treatments, and experimental designs were identical to that previously described for the spotted spurge experiment. Bittercress was over seeded 25 per pot at 1 week after treatment. Weed numbers were counted weekly. Fresh weights were collected at 10 weeks after seeding (10 May 2011). Pairwise comparisons were performed for each growth stage using a generalized linear model using Duncan's Multiple Range Test at P≥0.05.

RESULTS

Experiment 1. For spotted spurge emergence counts at 2, 6, and 9 weeks after seeding (Table 1), all three evaluations were influenced by the main effects of formulation and rate. The main effect irrigation was slightly significant at 6 weeks after seeding. Conversely, the main effects pre-application media moisture and post-application irrigation volumes were not significant. Only herbicide formulation affected spotted spurge fresh weights at 9 weeks after seeding. For the two-way interactions, the interaction of herbicide formulation × rate was also significant for weed counts. Conversely, all other two-way interactions were not significant. No two-way interaction affected spotted spurge fresh weight. Individual means of formulation and rate review showed the spray was consistently more effective than granular. There was no significant difference between the two rates of spray formula on spotted spurge germination and fresh weight (Table 2). Because the spray formula is so effective, even low rate (0.25 lb ai/A) can also achieved almost 100% control. In contrast, for the granular formulation, low rate achieved 73.9% control, and high rate achieved 82.4% control.

Table 1. ANOVA of spotted spurge (*Chamaesyce maculata*) data (Fall 2010).

	Weed counts (WAS[Z])			
Source of variation	2	6	9	F.W.[Y]
Main effects	---probability---			
Formulation (form.)	<0.0001[X]	<0.0001	<0.0001	<0.0001
Rate	0.02	0.01	0.02	0.14
Pre moisture (moist.)	0.70	0.57	0.61	0.33
Post irrigation (irrig.)	0.24	0.06	0.11	0.47
Two-way interactions				
form.*rate	0.02	0.02	0.02	0.15
form.*moist.	0.70	0.47	0.78	0.32
form.*irrig.	0.24	0.07	0.09	0.46
rate*moist	0.81	0.96	0.95	0.91
rate*irrig.	0.56	0.42	0.64	0.89

[Z]WAS = weeks after spotted spurge was seeded.
[Y]F.W. = fresh weight of spotted spurge at 9 WAS.
[X]P-value form general linear model of the weekly data.

Table 2. Pertinent treatment means for spotted spurge (*Chamaesyce maculata*) (Fall 2010).

Experimental variable		Weed counts /pot (WAS[Z])			F.W.[Y] (g/pot)
Fomulation	Rate (lb ai/A[W])	2	6	9	(% control[U])
Spray[X]	0.250	0.00a[V]	0.01a	0.04a	0.02 (99.9)a
spray	0.375	0.00a	0.00a	0.04a	0.00 (100.0)a
Mean		0A	<0.01A	0.04A	<0.01 (100.0) A
granular	0.250	1.00a	1.54a	1.84a	9.90 (73.9)a
granular	0.375	0.51b	0.90b	1.16b	6.69 (82.4)b
Mean		.76B	1.22B	1.51B	8.43 (77.8)B
Non-treated control		7.83	8.17	8.33	38.00 (0.0)

[Z]WAS = weeks after spotted spurge was seeded.
[Y]F.W. = fresh weight of spotted spurge at 9 WAS.
[X]spray = SureGuard; gran. = granular = BroadStar.
[W]lb ai/A = pounds active ingredient per acre.
[V]Means separated using Duncan's multiple range test at P = 0.05; lower cases within formulation; upper cases mean comparison.
[U]% control = 100 - (weed fresh weight/ control fresh weight)*100.

Experiment 2. For hairy bittercress emergence weed count, formulation was always a highly significant main effect (Table 3). Irrigation was slightly significant in weed count at 2 and 10 weeks after seeding. The main effects of both rate and moisture were not significant. Only the two-way interaction of formulation × irrigation was significant on germination. For all response variables (Table 4), the spray formulation was more effective than the granular formulation. Post-application irrigation levels had no effect on efficacy of the spray formulation. All spray formulation treatments achieved about 100% control with four post-irrigation levels. Conversely, with the granular formulation at 2 weeks after seeding, irrigation at 0.6 cm (0.25 in.) was less effective than the higher irrigation levels. There results indicated the importance of adequate irrigation to activate BroadStar; however, at 6 and 10 weeks, the weed counts in different irrigation volumes were not significantly different. For the fresh weight, irrigation at 0.6 cm (0.25 in.) provided 92.4% control, which was similar to irrigation at 5.1 cm (2 in.) of 91.3%. Irrigation at 1.3 cm (0.5 in.) provided 96.6% control, which was similar to irrigation at 2.5 cm (1 in.) –96.8%. Therefore, the irrigation treatments at 0.6 cm (0.25 in.) and 5.1 cm (2 in.) were less effective than irrigation at 1.3 cm (0.5 in.) and 2.5 cm (1 in.).

DISCUSSION

In summary, formulation was always the most highly significant main effect in both spotted spurge and hairy bittercress control, while pre-moisture substrate levels

Table 3. ANOVA of hairy bittercress (*Cardamine hirsuta* L.) data (Spring 2011).

	Weed counts /pot (WAS[Z])			
Sourse of variation	2	6	10	F.W.[Y]
Main effect	------probability------			
Formulation (form.)	<0.0001[X]	<0.0001	<0.0001	<0.0001
Rate	0.58	0.34	0.34	0.08
Moisture (moist.)	1.00	0.76	0.87	0.29
Irrigation (irrig.)	0.06	0.09	0.06	0.43
Two-way interaction				
form.*rate	0.58	0.47	0.46	0.12
form.*moist.	0.52	0.58	0.81	0.24
form.*irrig.	0.05	0.06	0.04	0.33
rate*moist.	0.63	0.58	0.90	0.26
rate*irrig.	1.00	0.73	0.62	0.44

[Z]WAS = weeks after hairy bittercress was seeded.
[Y]F.W. = fresh weight of hairy bittercress at 10 WAS
[X]P-value form general linear model of the weekly data.

were not significant at any time. Spray formulation of flumioxazin always provided excellent control at all irrigation levels and rates. The effectiveness of granular formulation increased with the increasing rate. However, post-irrigation volume did affect hairy bittercress emergence with the granular formulation. Irrigation volume at 1.3 cm (0.5 in.) and 2.5 cm (1 in.) provided better control than irrigation at 0.6 cm (0.25 in.) and 5.1 cm (2 in.). When preemergence herbicide flumioxazin is applied, the media moisture before treatment does not affect the herbicide effectiveness. However, irrigation at 1.3 cm (0.5 in.) to 2.5 cm (1 in.) is recommended to activate the granular formulation of flumioxazin.

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Table 4. Pertinent treatment means for hairy bittercress (*Cardamine hirsuta* L.) (Spring 2011).

Experimental variable		Weed counts (WAS[z])			F.W.[y] (g/pot)
Fomulation	Irrigation (inch)	2	6	10	(% control[v])
spray[x]	0.25	0.00a[w]	0.00a	0.00a	0.00 (100.0)a
spray	0.50	0.00a	0.00a	0.00a	0.00 (100.0)a
spray	1.00	0.00a	0.03a	0.03a	0.59 (99.5)a
spray	2.00	0.00a	0.00a	0.00a	0.00 (100.0)a
Mean		0.00A	<0.01A	<0.01A	0.15 (99.9)A
gran.	0.25	0.78a	0.36a	0.47a	8.63 (92.4)b
gran.	0.50	0.17b	0.11a	0.11a	3.84 (96.6)a
gran.	1.00	0.25b	0.06a	0.11a	3.64 (96.8)a
gran.	2.00	0.22b	0.39a	0.47a	9.80 (91.3)b
Mean		0.35B	0.23B	0.29B	6.47 (94.3)B
Non-treated control		11.17	15.67	16.50	113.22 (0.0)

[z] WAS = weeks after hairy bittercress was seeded.
[y] F.W. = fresh weight of hairy bittercress at 10 WAS.
[x] spray = SureGuard; gran. = granular = BroadStar.
[w] Means separated using Duncan's multiple range test at P = 0.05; lower cases within formulation; upper cases mean comparison.
[v] % control = 100- (weed fresh weight/ control fresh weight)*100.