Effect of Pre and Post Moisture Level on Preemergence Control of Hairy Bittercress (*Cardamine hirsuta* L.) with Flumioxazin[1]

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Abstract

Moisture is an important component to activate preemergence herbicides; however, this aspect had not been investigated in soilless substrate. The objective of this study was to evaluate the influence of pre-application moisture levels and post-application irrigation levels in the preemergence control of hairy bittercress with flumioxazin in a pine bark substrate. Three similar experiments were conducted over a 13-month period. Treatments were a factorial arrangement at the following variables: three pre-application moisture levels (dry, medium and wet), two flumioxazin formulations (granular and spray), two flumioxazin rates [0.28 and 0.42 kg ai·ha^{-1} (0.250 and 0.375 lb ai·A^{-1})] and four levels of single-event, post-application irrigation [0.6, 1.3, 2.5 and 5.1 cm (0.25, 0.50, 1.00 and 2.00 in)]. Treated pots were overseeded with 25 hairy bittercress at 1 week after flumioxazin application. Pre-application moisture did not affect the flumioxazin efficacy at any time and treatment. The spray formulation (SureGuard) provided maximum fresh weight control (≥ 99%) in weed counts up to 12 weeks after application, regardless of rate, pre-moisture level or post-irrigation level. The granular formulation (BroadStar) was less effective than spray formulation, and efficacy was improved with the higher rate and higher levels of post-application irrigation (Experiments 1 and 3).

Index words: container substrate, moisture, irrigation, preemergence weed control.

Species used in this study: hairy bittercress (*Cardamine hirsuta* L.).

Chemicals used in this study: BroadStar (flumioxazin), 2-[7-fluoro-3,4-dihydro-3-oxo-4-(2-propynyl)-2H-1,4-benzoxazin-6-yl]-4,5,6,7-tetrahydro-1H-isoindole-1,3(2H)-dione; SureGuard (flumioxazin), 2-[7-fluoro-3,4-dihydro-3-oxo-4-(2-propynyl)-2H-1,4-benzoxazin-6-yl]-4,5,6,7-tetrahydro-1H-isoindole-1,3(2H)-dione.

Significance to the Nursery Industry

For preemergence control, one important component of herbicide activation is moisture. Growers are generally instructed to apply irrigation after application of preemergence herbicides. However, little or no research has been conducted in soilless substrates evaluating effects of moisture levels. Data are needed to guide growers on how to optimize moisture levels for the best weed control with flumioxazin. Therefore, this research evaluated the effects of pre-application moisture levels, post-application irrigation levels and flumioxazin rates in two different formulations — granular (BroadStar® 0.25G) and spray (SureGuard® 51WDG) — on preemergence control of hairy bittercress. Pre-moisture level of the substrate had no effect on flumioxazin efficacy. SureGuard provided excellent control (≥ 99%) of hairy bittercress regardless of post-application irrigation level and rate. BroadStar needed both the higher rate and higher irrigation levels to provide acceptable control.

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Introduction

Weed control is one of the biggest problems for nursery managers. With increasing labor cost, hand-weeding is becoming more expensive (6). Research reported that hand weeding 1,000 pots cost as much as $1,376 over a four-month period based on the minimum wage ($5.15) in the 1990s (5), which had increased to $1,937 based on the minimum wage in 2011 ($7.25). Growers are becoming increasingly aware of labor saved by the application of preemergence herbicide, and typically make 3 to 6 preemergence herbicides applications annually (6). Hairy bittercress (*Cardamine hirsuta* L.) has been reported as one of top 10 weeds in container-grown crops particularly in the southeastern United States (7, 11). It is an annual broadleaf (dicot) weed, emerging from early spring to the end of fall. Each seedpod produces 20 to 50 seeds, and 600 to 5,000 seeds can be produced by one plant.

Soil moisture is an important factor affecting the absorption of herbicides by germinating weeds (10), because water can dissolve granular herbicides, move the herbicides into substrate to enhance herbicide-substrate contact and allow herbicides to contact the roots of target weed plants. Research in 1960s showed irrigation volume affected effectiveness of many preemergence herbicides (9). As pointed out by Audus (1), the relationship between soil moisture and absorption of herbicides into the soil exchange complex may affect the availability of herbicides for uptake by the plant. Research with diuron on cotton (*Gossypium hirsutum* L.) showed that diuron was more effective under high post-moisture conditions than under low moisture condition (15). In a study on giant foxtail (*Setaria faberii* Hermm.) control with 25, 31 and 37% soil moisture (14), the effectiveness of both atrazine and EPTC (ethyl N, N-dipropylthiocarbamate) increased with increasing soil moisture. In a more recent study, research indicated that 5.1 cm (2.0 in) of preplant irrigation with pronamide reduced weed density compared with the no preplant irrigation (13).

Flumioxazin inhibits protoporphyrinogen oxidase, which is an enzyme involved in chlorophyll synthesis (12). Flumioxazin is absorbed by both roots and foliage of targeted weeds and has both preemergence and postemergence activity, but it is used predominately for preemergence weed control (8). Flumioxazin is reported to control many broadleaf weed species when applied as a preemergence in field crops (4). A study in 2010 reported that 90% hairy bittercress control was obtained with the spray formulation in container substrate with 0.37 kg ai·ha^{-1} (0.33 lb ai·A^{-1}) of flumioxazin applied alone (16). Herbicide products used in this research were BroadStar® 0.25G (3) and SureGuard® 51WDG (2). Both products have flumioxazin as the only active ingredient, but the formulation is different. BroadStar is a granular formulation with 0.25% active ingredient. This product was first registered in 2003 for use in container and field grown woody shrubs, trees and groundcovers, and provides 8 to 12 weeks of preemergence control. In 2009 a new coating was added to BroadStar to prevent foliar damage from over-top application. Some growers have observed less post herbicidal activity with the new formulation. SureGuard is a water dispersible granular formulation containing 51% active ingredient. This product was registered for directed application in container and field grown conifers and deciduous trees.

Previous research about the effect of moisture on weed control was conducted in field studies, and results differed among different herbicides. Pine bark is the primary substrate used for container production of nursery crops and little research has been conducted evaluating the influence various moisture levels have on preemergence weed control in nursery production. The objective of this study was to evaluate the influence of flumioxazin formulation, pre-application moisture and post-application irrigation on preemergence control of hairy bittercress in container substrate.

Materials and Methods

Experiment 1. This study was conducted at the Paterson greenhouse complex of Auburn University, AL. On February 25, 2011, 2.8 liter (trade gal) pots were filled with pine bark and sand (6:1 by vol) substrate previously mixed with 9.3 kg·m^{-3} (15 lb·yd^{-3}) of 17-5-11 Polyon® (Harrell's Fertilizer, Sylacauga, AL) control-released (7–8 months) fertilizer, 3.1 kg·m^{-3} (5 lb·yd^{-3}) of dolomitic limestone and 0.9 kg·m^{-3} (1.5 lb·yd^{-3}) Micromax® (Scott's Co., Maryville, OH). Pots were separated into three moisture levels, i.e. low, medium, and high. Container weights and container volumetric water contents for each moisture level were measured with 10 samples for each moisture level before herbicides were applied. A Soil Moisture Sensor (Decagon Drive Inc., Pullman, WA) was used to measure volumetric water content (VWC). For low moisture, no water was applied 4 days before treatment; average pot weight was 1.6 kg (3.5 lb), and water content was 16%. For medium moisture, no water was applied 1 day before treatment; average pot weight was 1.7 kg (3.7 lb), and water content was 20%. For high moisture, pots were watered to saturation immediately before treatment; average pot weight was 1.9 kg (4.2 lb), and water content was 27%. Flumioxazin treatments were applied on March 1, 2011. Treatments included BroadStar® (Valent, Walnut Creek, CA) at 0.28 and 0.42 kg ai·ha^{-1} (0.250 and 0.375 lb ai·A^{-1}) and SureGuard® (Valent, Walnut Creek, CA) at 0.28 and 0.42 kg ai·ha^{-1} (0.250 and 0.375 lb ai·A^{-1}). BroadStar was applied with a hand-shaker. SureGuard was applied by an enclosed-cabinet sprayer calibrated to deliver 281 liters·ha^{-1} (30 gal·A^{-1}) with a single Teejet 8002VS flat fan nozzle at 193 kPa (28 psi).

This experiment was conducted as a factorial treatment arrangement: three pre-application moisture levels (dry, medium and wet), two flumioxazin formulations (granular and spray), two flumioxazin rates [0.28 and 0.42 kg ai·ha^{-1} (0.250 and 0.375 lb ai·A^{-1})] and four post-application, single-event irrigation levels [0.6, 1.3, 2.5 and 5.1 cm (0.25, 0.50, 1.00 and 2.00 in)]. With an additional non-treated control, there were 49 treatments in total. This study was a completely randomized design with 6 replicates per treatment. After herbicides application (March 7, 2011) and 1 day after completion of the single-event irrigation, a 1.3 cm (0.50 in) per day irrigation schedule was started. This schedule was maintained for the duration of the experiment. Pots were seeded with 25 hairy bittercress seeds 1 week after completion of the single-event irrigation. Number of hairy bittercress seedlings was counted weekly for 10 weeks after seeding (WAS). Hairy bittercress fresh weights were collected at 10 WAS (May 10, 2011). Fresh weight percentage control was determined as a percentage of the non-treated control group at 10 WAS with following equation: fresh weight percentage control = 100 – (treated fresh weight / non-treated control fresh weight) × 100.

Data were subjected to analysis of variance (ANOVA), which reflected the factorial treatment arrangement. Data were pooled over non-significant experimental variables. Treatment means for experimental variables that were significant as either main effect, or as two-way interactions were separated by Duncan's multiple range test at the 0.05 level.

Experiment 2. Experiment 2 was a repeat in time of experiment 1. Pots were filled April 1, 2011. Container weights and container volumetric water content were as follows: low moisture [1.5 kg (3.3 lb) and 16%], medium moisture [1.6 kg (3.5 lb)] and 22%, high moisture [1.7 kg (3.7 lb) and 30%]. Herbicides treatments were applied April 7, 2011. Pots were overseeded April 14, 2011. Because the weather warmed in May, fresh weights were collected 8 WAS (June 10, 2011).

Experiment 3. Experiment 3 was also a repeat in time of Experiment 1. Pots were filled December 5, 2011. Container weights and container volumetric water content were as follows: low moisture [1.3 kg (2.9 lb) and 19%], medium moisture [1.4 kg (3.1 lb) and 23%], high moisture [1.5 (3.3 lb) kg and 27%]. Herbicides were applied December 8, 2011. Pots were overseeded December 15, 2011. Pots were maintained outside until December 31, 2011, at which time pots were moved into a greenhouse to prevent frost damage until this experiment was terminated. Hairy bittercress fresh weights were collected 11 WAS (March 1, 2012).

Results and Discussion

Experiment 1. March 2011. Weed counts were consistently influenced only by the main effect of flumioxazin formulation (Table 1). Conversely, weed counts were not influenced by the main effects of rate, pre-application moisture and post-application irrigation. Bittercress fresh weight was also only influenced by the main effect of formulation. Only the

Table 1. Response of hairy bittercress (*Cardamine hirsuta* L.) to the main effects of all experimental variables and their two-way interactions[z]. (Expt. 1)

Source of variation	Weed counts/pot (WAS[y]) 2	6	10	F.W.[x]
	probability			
Main effects				
Formulation (form.)	<0.01	<0.01	<0.01	<0.01
Rate	0.58	0.34	0.34	0.08
Moisture (moist.)	1.00	0.09	0.06	0.29
Irrigation (irrig.)	0.06	0.76	0.87	0.43
Two-way interactions				
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]Analysis of variance performed using general linear model of SAS; effects are considered significant if $P \leq 0.05$.

[y]WAS=weeks after seeding. Additional counts were taken at 1, 3, 4, 5, 7, 8 and 9 WAS. However, results were equivalent to the data presented.

[x]F.W.=fresh weight of bittercress at 10 WAS.

two-way interaction of formulation and post-irrigation were significant at 2 and 10 WAS. Consequently, data were pooled over formulation and post-irrigation variable for further analysis (Table 2).

Between the two flumioxazin formulations, weed counts with the spray formulation were consistently and significantly lower than with the granular formulation. The spray formulation obtained higher (99.9%) average fresh weight control than the granular (94.3%). Within the spray formulation, irrigation consistently had no effect on both weed counts and fresh weight, since almost no hairy bittercress emergence was observed. All spray formulation treatments achieved about 100.0% control regardless of herbicides rate, pre-application moisture and post-irrigation level. Wehtje (16) reported 90% bittercress control was obtained with SureGuard at 0.37 kg ai·ha^{-1} (0.33 lb ai·A^{-1}), applied in March with 0.6 cm (0.25 in) irrigation daily. Within granular formulation, irrigation at 0.6 cm was less effective than the higher irrigation levels at 2 WAS. At 6 and 10 WAS, irrigation at 0.6 and 5.1 cm (0.25 and 2.00 in) had higher weed counts, but the results were not significantly different from irrigation at 1.3 and 2.5 cm (0.50 and 1.00 in). For fresh weights, irrigation at 0.6 cm (0.25 in) provided 92% control of bittercress, which was similar to irrigation at 5.1 cm (2.00 in) (91%). Irrigation at 1.3 and 2.5 cm (0.50 and 1.00 in) both provided 97% control; therefore, the irrigation treatments at 0.6 and 5.1 cm (0.25 and 2.00 in) were less effective than irrigation at 1.3 and 2.5 cm (0.50 and 1.00 in).

Table 2. Response of hairy bittercress (*Cardamine hirsuta* L.) to the interaction of formulation and post-irrigation[z]. (Expt. 1)

Experimental variables: Fomulation	Irrigation (cm)	Weed counts/pot (WAS[y]) 2	6	10	F.W.[x] (g·pot^{-1}) (% control[u])
spray[w]	0.6	0.0a[v]	0.0a	0.0a	0.0 (100.0)a
spray	1.3	0.0a	0.0a	0.0a	0.0 (100.0)a
spray	2.5	0.0a	0.3a	0.3a	0.6 (99.5)a
spray	5.1	0.0a	0.0a	0.0a	0.0 (100.0)a
Mean		0.0A	0.0A	0.0A	0.2 (99.9)A
gran.	0.6	0.8a	0.4a	0.5a	8.6 (92.4)b
gran.	1.3	0.2b	0.1a	0.1a	3.8 (96.6)a
gran.	2.5	0.3b	0.1a	0.1a	3.6 (96.8)a
gran.	5.1	0.2b	0.4a	0.5a	9.8 (91.3)b
Mean		0.4B	0.2B	0.3B	6.45 (94.3)B
Non-treated control		11.2	15.7	16.5	113.2 (0.0)

[z]Analysis of variance performed using general linear model of SAS; effects are considered significant if $P \leq 0.05$.

[y]WAS = weeks after seeding. Additional counts were taken at 1, 3, 4, 5, 7, 8 and 9 WAS. However, results were equivalent to the data presented.

[x]F.W. = fresh weight of bittercress at 10 WAS.

[w]spray = SureGuard; gran. = granular = BroadStar.

[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.

Table 3. Response of hairy bittercress (*Cardamine hirsuta* L.) to the main effects of all experimental variables and their two-way interactions[z]. (Expt. 2)

Source of variation	Weed counts/pot (WAS[y]) 2	5	8	F.W.[x]
	probability			
Main effects				
Formulation (form.)	<0.01	<0.01	<0.01	<0.01
Rate	0.07	0.01	0.02	0.03
Moisture (moist.)	0.77	0.66	0.68	0.61
Irrigation (irrig.)	0.07	0.70	0.12	0.57
Two-way interactions				
form. × rate	0.06	0.01	0.03	0.03
form. × moist.	0.77	0.66	0.72	0.61
form. × irrig.	0.07	0.70	0.15	0.57
rate × moist.	0.77	0.55	0.81	0.37
rate × irrig.	0.54	0.74	0.99	0.78

[z]Analysis of variance performed using general linear model of SAS; effects are considered significant if $P \leq 0.05$.

[y]WAS = weeks after seeding. Additional counts were taken at 1, 3, 4, 6 and 7 WAS. However, results were equivalent to the data presented.

[x]F.W. = fresh weight of bittercress at 8 WAS.

Experiment 2. April 2011. Weed counts were consistently influenced by the main effect of formulation (Table 3). The main effect of rate was also frequently significant (i.e. 5 and 8 WAS). Conversely, the main effect of pre-moisture and post-irrigation consistently did not influence counts. Only the two-way interaction of formulation and rate significantly influenced counts frequently (i.e. 5 and 8 WAS). Fresh weight was influenced by the main effects of both formulation and rate, and by the two-way interaction of formulation and rate. Consequently, data were pooled over pre-moisture level and post-irrigation level for future analysis.

Examination of the formulation and rate variables (Table 4) revealed that between the two formulations, counts were significantly lower with the spray. All spray treatments achieved almost 100% control regardless of rate. With the granular formulation, the 0.42 kg ai·ha^{-1} (0.375 lb ai·A^{-1}) rate

Table 4. Response of hairy bittercress (*Cardamine hirsuta* L.) to the interaction of formulation and rate [z]. (Expt. 2)

Experimental variables		Weed counts/pot (WAS[y])			
Fomulation	Rate (kg ai·ha^{-1})	2	5	8	F.W.[x] (g·pot^{-1}) (% control[u])
spray[w]	0.28	0.0a[v]	0.0a	0.0a	0.0 (99.9)a
spray	0.42	0.0a	0.0a	0.0a	0.0 (100.0)a
Mean		0.0A	0.0A	0.0A	0.0 (100.0)A
gran.	0.28	0.6a	0.9a	1.6a	12.7 (69.7)a
gran.	0.42	0.3b	0.4b	0.8b	6.9 (83.5)b
Mean		0.4B	1.7B	1.2B	9.8 (76.6)B
Non-treated control		5.8	8.7	8.7	42.0 (0.0)

[z]Analysis of variance performed using general linear model of SAS; effects are considered significant if $P \leq 0.05$.

[y]WAS = weeks after seeding. Additional counts were taken at 1, 3, 4, 6 and 7 WAS. However, results were equivalent to the data presented.

[x]F.W. = fresh weight of bittercress at 8 WAS.

[w]spray = SureGuard; gran. = granular = BroadStar.

[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.

Table 5. Response of hairy bittercress (*Cardamine hirsuta* L.) to the main effects of all experimental variables and their two-way interactions[z]. (Expt. 3)

	Weed counts/pot (WAS[y])			
Source of variation	2	6	11	F.W.[x]
	probability			
Main effects				
Formulation (form.)	<0.01	<0.01	<0.01	<0.01
Rate	0.09	<0.01	<0.01	<0.01
Moisture (moist.)	0.82	0.56	0.80	0.36
Irrigation (irrig.)	0.25	0.35	<0.01	0.59
Two-way interactions				
form. × rate	0.09	<0.01	<0.01	<0.01
form. × moist.	0.81	0.47	0.84	0.37
form. × irrig.	0.24	0.30	<0.01	0.58
rate × moist.	0.34	0.94	0.56	0.88
rate × irrig.	0.40	0.01	0.05	0.17

[z]Analysis of variance performed using general linear model of SAS; effects are considered significant if $P \leq 0.05$.

[y]WAS = weeks after seeding. Additional counts were taken at 1, 3, 4, 5, 7, 8, 9 and 10 WAS. However, results were equivalent to the data presented.

[x]F.W. = fresh weight of bittercress at 11 WAS.

was more effective in reducing both counts and fresh weight than the 0.28 kg ai·ha^{-1} rate (0.250 lb ai·A^{-1}).

Experiment 3. December 2011. Weed counts were consistently influenced by the main effect of formulation, which was the same as the prior two experiments (Table 5). The main effects of rate and irrigation also affected weed counts, but not consistently. Conversely, the main effect of pre-moisture consistently did not influence either weed counts or fresh weights. The two-way interactions of formulation by rate, formulation by post-irrigation and rate by post-irrigation were frequently, but not consistently significant. The two-way interactions including pre-moisture were never significant. Fresh weights were only influenced by the main effect of formulation and rate, and the two-way interaction of formulation and rate, which result was similar with the second experiment. Therefore, data were pooled so as to examine the effects of the formulation, rate, and irrigation variables (Table 6).

Within the spray formulation treatments, 100% hairy bittercress control was obtained, regardless of the herbicide rate and the post-irrigation level (Table 6). Conversely, within the granular formulation, rate had an effect. Treatments with higher rate consistently had lower weed counts and fresh weights than treatments with lower rate. Post-irrigation did not affect the granular formulation at 0.28 kg ai·ha^{-1} (0.250 lb ai·A^{-1}). For granular formulation at higher rate, post-irrigation at 0.6 cm (0.25 in) had higher weed counts than the other irrigation levels after 2 WAS (i.e. from 6 to 11 WAS). Fresh weights were decreased when irrigation increased, and fresh weight control was increased (Fig. 1). Irrigation at 5.1 cm (2.0 in) obtained 77.5% hairy bittercress fresh weight control, which significantly higher than irrigation at 0.6 cm (0.25 in, 63.5%).

In summary, the spray formulation provided maximum control of weed counts and fresh weight, regardless of rate, pre-moisture level or post-irrigation level. Conversely, the granular formulation was less effective. BroadStar at 0.42 kg ai·ha^{-1} (0.375 lb ai·A^{-1}) generally provided better hairy bittercress control than BroadStar at 0.28 kg ai·ha^{-1} (0.250 lb ai·A^{-1}). Pre-application moisture at dry, medium and wet level did not affect flumioxazin efficacy across all three experiments. Granular formulation efficacy tended to be improved by additional post-application irrigation levels in cooler season (i.e. experiments 1 and 3). We speculated that the coating that is placed on the outer surface of the new BroadStar formulation is removed faster during the warmer temperature of summer (April 2011).

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Table 6. Response of hairy bittercress (*Cardamine hirsuta* L.) to formulation, rate and post-irrigation [z]. (Expt. 3)

Experimental variables			Weed counts/pot (WAS[y])			
Fomulation	Rate (kg ai·ha^{-1})	Irrigation (cm)	2	6	11	F.W.[x] (g·pot^{-1}) (% control[u])
spray[w]	0.28	0.6	0.0a[v]	0.0a	0.1a	0.0 (100.0)a
spray	0.28	1.3	0.0a	0.3a	0.0a	0.0 (100.0)a
spray	0.28	2.5	0.0a	0.0a	0.1a	0.0 (100.0)a
spray	0.28	5.1	0.0a	0.0a	0.2a	0.0 (100.0)a
Mean			0.0B	0.1C	0.1C	0.0 (100.0)C
spray	0.42	0.6	0.0a	0.0a	0.0a	0.0 (100.0)a
spray	0.42	1.3	0.0a	0.0a	0.0a	0.0 (100.0)a
spray	0.42	2.5	0.0a	0.1a	0.0a	0.0 (100.0)a
spray	0.42	5.1	0.0a	0.0a	0.2a	0.0 (100.0)a
Mean			0.0B	0.0C	0.1C	0.0 (100.0)C
gran.	0.28	0.6	0.1a	5.9a	6.3a	27.9 (72.1)a
gran.	0.28	1.3	0.6a	6.6a	4.9a	26.2 (65.1)a
gran.	0.28	2.5	0.4a	7.2a	6.1a	34.2 (54.4)a
gran.	0.28	5.1	0.1a	7.1a	5.6a	29.7 (60.4)a
Mean			0.3A	6.7A	5.7A	29.5 (60.7)A
gran.	0.42	0.6	0.1a	7.2a	6.6a	27.4 (63.5)a
gran.	0.42	1.3	0.1a	4.1b	2.5b	20.4 (72.8)ab
gran.	0.42	2.5	0.1a	2.4b	2.1b	11.8 (84.3)ab
gran.	0.42	5.1	0.1a	3.7b	2.4b	8.8 (88.3)b
Mean			0.1B	4.3B	3.4B	16.9 (77.5)B
Control			0.3	12.5	11.2	75.0 (0.0)

[z]Analysis of variance performed using general linear model of SAS; effects are considered significant if $P \leq 0.05$.

[y]WAS = weeks after seeding. Additional counts were taken at 1, 3, 4, 5, 7, 8, 9 and 10 WAS. However, results were equivalent to the data presented.

[x]F.W. = fresh weight of bittercress at 11 WAS.

[w]spray = SureGuard; gran. = granular = BroadStar.

[v]Means separated using Duncan's multiple range test at $P = 0.05$; lower cases within formulation; upper cases mean comparison.

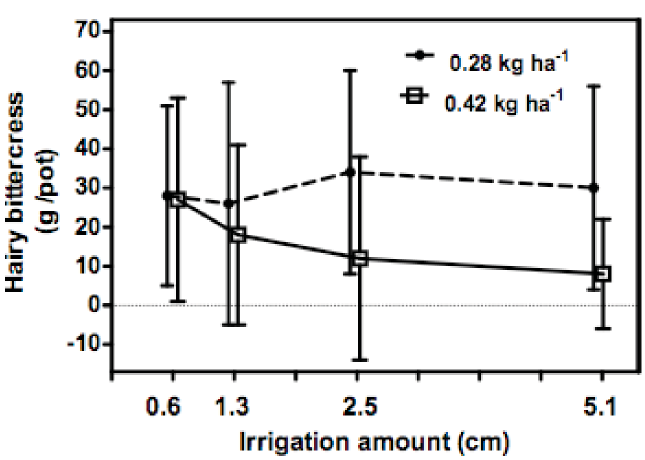

Fig. 1. Response of hairy bittercress (*Cardamine hirsuta* L.) to granular formulation of flumioxazin and post-application irrigation levels, error bars equivalent to standard errors. (Expt. 3)

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