

Potential for Phytotoxicity of Pendulum 2G
(Pendimethalin) on
Coral Bells (*Heuchera sanguinea* 'Firefly')

By

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Project: Interregional Research Project #4
Project Number 24705A – September 30, 2005

Donors/Supporters:
Suncrest Nursery, Watsonville CA

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PR.NO. :	24703
TRIAL:	
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IR-4 ORNAMENTAL DATA REPORTING FORM

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Location of Trial	University of California, Davis CA
TRIAL TYPE: (field, container, greenhouse, etc)	Field Container
Chemical - Common Name	Pendimethalin
- Formulation	Granular, 2%
- Batch Number	
- Product	Pendulum 2G
- EPA Registration Number	241-375
- Manufacture	BASF
USE INFORMATION	
- Plant Common Name	Coral Bells
- Plant Scientific Name	<i>Heuchera sanguinea</i> 'Firefly'
- Pest (s)	Weeds
Soil Type or Type of Potting Mix: UC Mix	a)%Sand: 35 b)%Silt: c)%Clay: d)%OM: 65 e)%pH: 6.5
Enter each DATE for:	Seedling: Emergence: Transplanting: 7/29/05
Enter each SPACING for:	Plant or Pot: 6 inches Row: 6 inches
Enter each SIZE for:	Pot: 1-gallon Plot: 50 sq ft
Experimental Design:	Randomized complete block (3 blocks X 3 reps)
Number of Reps:	9 reps total for each treatment

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APPLICATION PARAMETERS¹

Type of Application: (aerial, ground, foliar, drench, ppi, chemigation, broadcast, directed, etc)	Broadcast over the top
Number of Applications:	2, 30 days apart
Application Type:	Shaker container
Nozzle Type/Size:	
Nozzle Pressure:	
Delivery Rate:	
Calibration Date(s):	

APPLICATION SUMMARY

APPLICATION DATE	RATES (a.i./A) (Be sure to provide units)	Brief Description of Growth Stage (Dormant, New Growth Present, Bud, etc)
August 5, 2005	0, 2, 4, 8 lb. a.i./A	Vegetative, actively growing
September 2, 2005	0, 2, 4, 8 lb. a.i./A	Vegetative, actively growing

1 RAINFALL/IRRIGATION RECORDS: INCLUDE RAINFALL/IRRIGATION INFORMATION (printouts, IR-4 forms, etc.)

See Table 1 for environmental conditions. The plants were watered by hand daily with tap water.

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OTHER PESTICIDES, FERTILIZER, LIME AND ADJUVANTS USED:

PRODUCT	AMOUNT	DATE
Osmocote 19-6-12	0.5 tsp per 6-inch pot	8/12/2005
Pounce	0.16 oz/2 gal	8/26/2005
Marathon II	2.4 oz/2 gal	8/26/2005

NARRATIVE SUMMARY OF METHODS AND RESULTS:

Materials and Methods

Plant Material and Culture. Liners of *Heuchera sanguinea* 'Firefly' were received from Suncrest Nursery on July 26, 2005. These were transplanted to 1-gallon pots containing UC Mix on July 29, 2005 and grown on in a greenhouse for 6 days. The 8-week experiment took place in an outdoor nursery and began on August 5, 2005. Environmental conditions during the experiment are summarized in Table 1. Osmocote (19-6-12) controlled release fertilizer was added on August 12, 2005 at the rate of 1 teaspoon per 1-gallon pot. The plants were watered by hand daily during the 8-week experiment. Applications of pesticides as part of a normal pest management program were made as needed (see above).

Experimental Procedure. Thirty-six plants were randomly chosen and individually tagged for treatment with 0 (Control), 2 (1X), 4 (2X), or 8 (4X) lb. ai/A Pendulum 2G with 9 replicates per treatment. These dosages were prescribed in IR4 Ornamental Protocol 05-001 dated 1/05 (Appendix A). The plants received the first granular application on August 5, 2005 and the second application 4 weeks later on September 2, 2005. The plants were arranged in a randomized complete block design with 3 blocks and 3 treatment replicates per block (Figure 1). Phytotoxicity ratings and plant height and width measurements were taken at day 0, 3, 7, 14, 28, 31, 35, 42 and 56. Visual phytotoxicity evaluations were based on a numerical rating scale ranging from 0 (no injury) to 10 (complete kill) (Table 2). Plant height (cm) was measured from the container soil surface to the top of the leaf canopy.

Plant width (cm) was measured twice along perpendicular lines at the widest part of the plant, resulting in W_1 and W_2 . For each observation a canopy volume index was calculated so as to be able to determine if canopy volume was affected by the application of Pendulum 2G. The calculation was made as $H*W_1*W_2$, where H is the height and W_1 and W_2 are two width measurements. The usefulness of this index is based on the fact that many of the models for such a volume calculation are of the form $a*H*W_1*W_2$. The constant "a" depends on the assumption of the shape of the canopy. Since analyses of variance are scale-independent, the conclusion will thus be for the volume of the plant canopy.

Statistical Analysis. The data were analyzed using Proc GLM of the Statistical Analysis System (SAS). The phytotoxicity and change in mean value from the starting plant height, width and volume index were analyzed for significant differences using t-tests.

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Results

The *Heuchera* plants had some initial blemishes which accounted for non-zero phytotoxicity index values at the start of the trial (Table 3, Figure 2, Appendix B). As the control plants grew new leaves these phytotoxic index values decreased resulting in negative mean values at all observations later in the trial for phytotoxicity increase over the values at day 0.

No significant differences in phytotoxicity index increases were noted at any of the observations during the 8 week trial (Table 3, Figure 2, Appendix B). The actual phytotoxicity index means were below 2 at all times, dropping lower than the initial phytotoxicity index rating by week 8 even in all the treatments.

Increases in height ranged from around 2.9 to 4.8 cm in the various treatments (Table 4, Figures 2 and 3, Appendix B). While the plants in the 4X treatment had the smallest increase in height, the plants in the 2x treatment had the highest mean. While Pendulum was found to have a significant effect on height increase, there is no logical trend in this effect and we cannot conclude that Pendulum resulted in deleterious effects on height. No width increase and volume index increase effects were noted.

Discussion

In this trial with *Heuchera* we found no phytotoxicity due to Pendulum. We also found no conclusive evidence for growth suppression.

GOOD RESEARCH PRACTICE STATEMENT:

I acknowledge that I have read and followed the IR-4 Research protocol and completed this trial following good agricultural practice, or reported any deviations (note any changes from authorized protocol in narrative).

SIGNATURE (PRINCIPAL INVESTIGATOR) _____

Date Completed:

If submitted, using e-mail, please provide e-mail address and send confirming receipt.

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Table 1. Environmental conditions during the experiment to evaluate the phytotoxicity of Pendulum 2G on *Heuchera sanguinea* 'Firefly'.

Date	Sol Rad (Ly/day)	Max Air Temp (°F)	Min Air Temp (°F)	Avg Air Temp (°F)	Avg Vap (mBars)	Avg wSpd (MPH)	Precip (in)	CIMIS ETo (in)	Avg Rel Hum (%)	Dew Pt (°F)
7/29/2005	633	96.2	59.6	75.6	13.4	5.5	0	0.28	44	52.4
7/30/2005	655	98.2	59.3	77.2	14.4	4.6	0	0.27	45	54.3
7/31/2005	675	99.4	57.7	77.5	14.6	4.3	0	0.28	45	54.6
8/1/2005	689	100.7	57.1	77	12.2	5.4	0	0.29	38	49.8
8/2/2005	665	93.3	53.8	72.6	13.3	4.3	0	0.26	49	52.1
8/3/2005	661	94.4	53.4	74.1	13.6	4.6	0	0.27	47	52.8
8/4/2005	654	97.8	56.7	76.3	14.2	3.7	0	0.26	46	53.9
8/5/2005	658	100.1	58.8	78.2	14.1	3.6	0	0.26	43	53.7
8/6/2005	647	102.6	57	77.7	13.8	4.2	0	0.27	42	53.1
8/7/2005	636	101.3	59.8	78.8	14.2	4	0	0.27	42	53.9
8/8/2005	573	92.2	59.6	73.8	14.9	4.8	0	0.23	52	55.2
8/9/2005	641	99	57.6	75.5	14.8	4.4	0	0.26	49	55.1
8/10/2005	650	94.6	55.8	74.5	14	4.2	0	0.26	48	53.6
8/11/2005	640	97.7	53.2	76	13	3.6	0	0.26	43	51.6
8/12/2005	640	97.6	57.4	75.5	13.8	4.8	0	0.27	46	53.1
8/13/2005	552	81.6	53.7	66.6	13.5	5.7	0	0.2	61	52.6
8/14/2005	613	84.7	54.3	67.1	14.2	5.9	0	0.23	62	53.8
8/15/2005	546	81.1	56.4	69	13.9	6.6	0	0.23	57	53.3
8/16/2005	579	94	62.3	76.1	14.7	4.8	0	0.25	48	54.9
8/17/2005	608	89.8	55.7	70.6	13.7	5.8	0	0.25	54	53
8/18/2005	611	79.8	54.4	65.1	14.1	8.9	0	0.23	67	53.7
8/19/2005	609	83.1	52.7	65.9	13.6	5.9	0	0.22	63	52.8
8/20/2005	608	88.8	51.3	69.7	13.1	3.9	0	0.22	53	51.8
8/21/2005	613	91.9	53.5	71.2	13.5	4.2	0	0.24	52	52.6
8/22/2005	609	95.3	50.1	73.3	13.6	4	0	0.24	48	52.7
8/23/2005	609	95.1	54.7	72.3	13	5.6	0	0.25	48	51.6
8/24/2005	607	89.2	52.9	70.7	12.4	6.9	0	0.26	48	50.2
8/25/2005	601	90.2	53.1	70.8	10.1	4.5	0	0.24	39	44.8
8/26/2005	605	95.2	52.2	73.3	9.6	4.4	0	0.25	34	43.5
8/27/2005	585	97.8	54.5	76.4	11.2	4	0	0.25	36	47.5
8/28/2005	601	98.4	56.8	77	11.2	4.6	0	0.26	35	47.6
8/29/2005	588	90.6	55.5	72.8	11.4	4.2	0	0.23	41	47.9
8/30/2005	587	92.9	65.4	78.3	7.6	11.9	0	0.36	--	--
8/31/2005	580	98.2	59.2	77.1	8.7	4.9	0	0.26	27	40.9
9/1/2005	568	91.7	52.8	71.2	12.4	4.6	0	0.23	47	50.2
9/2/2005	574	87.5	51.9	67.6	12.9	4.8	0	0.21	56	51.4
9/3/2005	568	87.5	50.8	67.2	12.8	5.7	0	0.22	56	51.1
9/4/2005	552	82.5	52	66.2	12.8	5	0	0.19	58	51
9/5/2005	554	87.4	50.2	68.8	11.8	3.5	0	0.2	49	49
9/6/2005	551	86.4	51.4	66.7	11.9	4.9	0	0.21	53	49.2
9/7/2005	544	84.2	48.4	64.6	12.3	4.8	0	0.19	59	50
9/8/2005	536	77.5	50.3	64	12.4	7	0	0.2	61	50.3
9/9/2005	524	73.7	53.5	62.1	12.9	9.6	0	0.19	68	51.2
9/10/2005	481	76.4	49.9	62	11.7	5.6	0	0.17	62	48.8
9/11/2005	531	76.2	45.3	61.4	11.1	4.1	0	0.17	60	47.3
9/12/2005	520	78.2	44	61.3	10.7	2.3	0	0.16	58	46.3
9/13/2005	521	78.5	42.8	60.6	10.7	4	0	0.17	59	46.4
9/14/2005	505	76.3	46.7	60.6	11.9	4.5	0	0.16	66	49.1
9/15/2005	506	81.1	46.3	62.6	11.8	3.5	0	0.16	61	48.9
9/16/2005	491	79.9	52.2	63.6	12.2	6.9	0	0.18	61	49.7
9/17/2005	486	78.1	48.7	63.4	11.9	4.4	0	0.17	60	49.1
9/18/2005	491	83.8	46.2	65.7	9.5	3.7	0	0.18	44	43.3
9/19/2005	495	89.7	46.9	68.1	9.3	3.5	0	0.19	39	42.5
9/20/2005	458	89.6	51.4	70.3	10.5	6.2	0	0.2	42	45.8
9/21/2005	464	86.5	54.6	67.8	12.4	4.3	0	0.17	54	50.3
9/22/2005	492	87.1	48.2	66.1	10.8	4	0	0.18	49	46.5
9/23/2005	480	80.1	53.1	65.7	9.8	9.1	0	0.23	45	44.1

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Table 2. Numerical plant damage rating scale used for phytotoxicity determinations.

Rating	Description of plant damage
0	No damage
1	No visible damage but unintended (non-permanent) impact
2	Slight leaf/tissue damage (curling leaves, necrosis, etc.)
3	Marginal chlorosis on some leaves (damage on up to 10% of plant)
4	10% – 20% of plant damaged
5	Significant damage to much of plant (30% - 40%)
6	40% – 60% of plant damaged
7	Chlorosis or necrosis on most of plant (60% - 70%)
8	Abscised leaves, branch dieback
9	Tissue severely damaged (80% - 100% of plant)
10	Complete kill

Table 3. Phytotoxicity ratings over 8 weeks for *Heuchera sanguinea* ‘Firefly’ treated with 0 (Control), 2 (1X), 4 (2X), or 8 (4X) lb. ai/A Pendulum 2G, applied at weeks 0 and 4. Different letters within a column indicate significant differences between treatments (P < 0.05). “Yes”/”No” refer to significant treatment effects at the 5% level. Means ± SE (n = 9)

Phytotoxicity Effect of Pendulum on Heuchera								
Phytotoxicity Index Increase from beginning of trial until:								
Treatment	Day 3	(NA)	1 week	no	2 weeks	no	4 weeks	no
0X	0.00 ± 0.00	a	0.00 ± 0.17	a	-0.22 ± 0.15	a	-0.44 ± 0.18	a
1X	0.00 ± 0.00	a	0.00 ± 0.00	a	0.00 ± 0.29	a	-0.22 ± 0.32	a
2X	0.00 ± 0.00	a	0.11 ± 0.11	a	0.00 ± 0.24	a	-0.22 ± 0.28	a
4X	0.00 ± 0.00	a	0.00 ± 0.00	a	0.11 ± 0.20	a	-0.33 ± 0.17	a
Phytotoxicity Index increase from beginning of trial until:								
Treatment			5 week	no	6 weeks	no	8 weeks	yes
0X			-0.89 ± 0.20	a	-0.78 ± 0.15	a	-0.89 ± 0.20	a
1X			-0.44 ± 0.34	a	-0.78 ± 0.32	a	-0.78 ± 0.22	a
2X			-0.67 ± 0.24	a	-0.89 ± 0.20	a	-1.00 ± 0.17	a
4X			-0.44 ± 0.24	a	-0.67 ± 0.33	a	-1.22 ± 0.15	a

Table 4. Plant height, width and volume changes over 8 weeks for *Heuchera sanguinea* ‘Firefly’ treated with 0 (Control), 2 (1X), 4 (2X), or 8 (4X) lb. ai/A Pendulum 2G, applied at weeks 0 and 4. Different letters within a column indicate significant differences between treatments (P < 0.05). “Yes”/”No” refer to significant treatment effects at the 5% level. Means ± SE (n = 9)

Growth Effect of Pendulum on Heuchera							
Increase by week 8 of:							
Treatment	Height (cm)	yes	Average Width (cm)	no	Volume Index	yes at 10%	
0X	3.83 ± 0.46	ab	12.81 ± 0.67	a	6257.56 ± 661.85	a	
1X	3.50 ± 0.65	b	13.22 ± 0.93	a	6860.11 ± 795.98	a	
2X	4.83 ± 0.30	a	14.83 ± 1.44	a	8700.11 ± 1455.96	a	
4X	2.94 ± 0.55	b	12.42 ± 1.17	a	6082.56 ± 1053.62	a	

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Figure 1. *Heuchera sanguinea* 'Firefly' plants were arranged in a randomized complete block design with 3 blocks and 3 treatment replicates per block for the experiment to evaluate the phytotoxicity of Pendulum 2G.

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Species: *Heuchera* -- Material: Pendulum

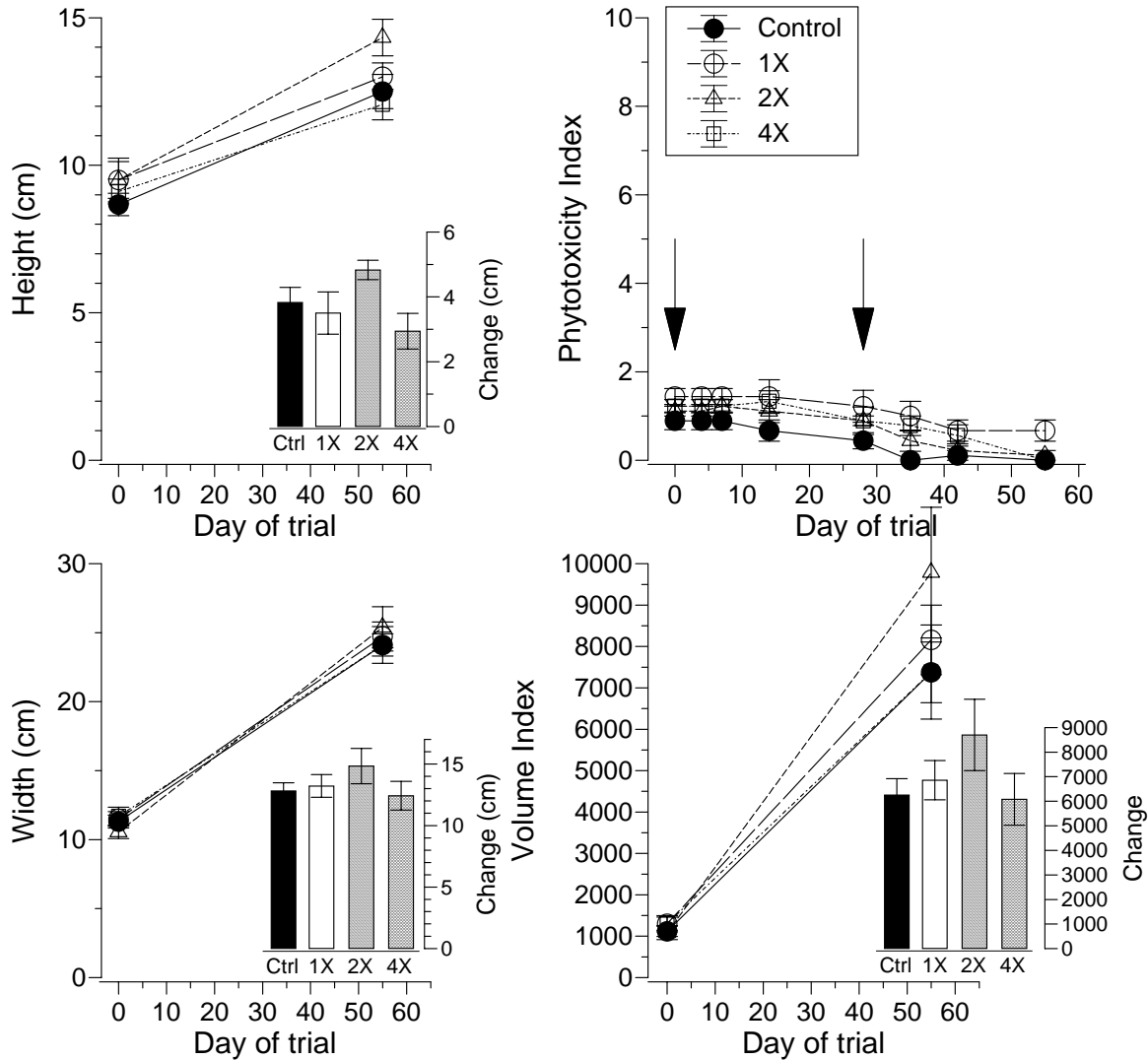


Figure 2. Summary of results for *Heuchera sanguinea* 'Firefly' treated with 0 (Control), 2 (1X), 4 (2X), or 8 (4X) lb. ai/A Pendulum 2G, applied at weeks 0 and 4 (arrows). Both means and cumulative changes over time are plotted for phytotoxicity index, plant height, plant width and plant volume index. Histograms show changes over the 8-week trial period. SE bars shown. (n = 9)

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Block A



Block B



Block C

CONTROL 1X 2X 4X

Figure 3. *Heuchera sanguinea* 'Firefly' plants 8 weeks after treatment with 0 (Control), 2 (1X), 4 (2X), or 8 (4X) lb. ai/A Pendulum 2G, applied at weeks 0 and 4.

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Appendix A

Phytotoxicity to herbaceous perennial plants with pre-emergent applications of Pendulum, Pennant Magnum, and Snapshot

Ornamental Protocol Number: 05-001

Objective: Determine phytotoxicity of Pendulum, Pennant Magnum, and Snapshot to unlabelled perennial plants commonly grown in nurseries.

Experimental Design:

Plot Size: Must be adequate to reflect actual use conditions.

Replicates: Minimum of 3 replications (preferably 4) with 3 pots per replicate

Application Instructions: Two applications made approximately 4 weeks apart with the first application within 7 days of potting. Plant materials must have broken dormancy prior to first application. For liquid applications, use a minimum of 20 gal per acre. Applications should be made over the top of the plants using application equipment consistent with conventional commercial equipment. Please see table below for instructions for post-application irrigation.

Plant Materials: See attached list of plant materials. Plants grown in field containers are preferred to in-ground.

Evaluations: Record phytotoxicity on a scale of 0 to 10 (0 = No phytotoxicity; 10 = Complete kill) at 3, 7, 14, and 28 days after each application. If phytotoxicity is observed in treated plants, take pictures comparing treated and untreated plant material.

Recordkeeping: Keep detailed records of weather conditions including temperature and precipitation, soil-type or soil-less media, application equipment, application volume per acre, irrigation, liner size, plant height & width, and plant growth stage at application and data collection dates.

Treatments:

Product	Rate	Post-Application Irrigation Instructions
Pendulum 2G (pendimethalin)	2.0 lb ai/A	Follow with sufficient overhead irrigation to wash Pendulum from the foliage to reduce the chance of injury
	4.0 lb ai/A	
	8.0 lb ai/A	
Pennant MAGNUM 7.62EC (s-metalochlor)	2.5 lb ai/A	Follow with sufficient overhead irrigation to wash Pennant Magnum from the foliage to reduce the chance of injury
	5.0 lb ai/A	
	10.0 lb ai/A	
Snapshot 2.5TG (isoxaben+trifluralin)	2.5 lb ai/A	Follow with sufficient overhead irrigation to wash Snapshot from the foliage to reduce the chance of injury
	5.0 lb ai/A	
	10.0 lb ai/A	
Untreated	--	--

For labels, materials, and any required adjuvants contact:

Pendulum - BASF, Kathie Kalmowitz, 919-785-9659, email: kalmowk@basf-corp.com

Pennant Magnum - Syngenta, Dave Ross, 336-632-6411, david.ross@syngenta.com

Snapshot - Dow AgroSciences, Mike Melichar, 317-337-4982, mwmelichar@dow.com

Reports:

Report must include a brief summary paragraph of results, a summary table with appropriate statistical analyses, a section on experimental design and materials and methods, with raw data and recordkeeping information as listed above included as appendices. If pictures were taken, please include them.

An electronic report is preferred but not required. If the report is provided electronically, the basic report can be sent in MS Word or WordPerfect, the recordkeeping information as pdf or other electronic documents, and the raw data in MS Excel or other suitable program such as ARM.

Please direct questions to: Cristi Palmer, IR-4 HQ, Rutgers University, 681 US Hwy 1 S, North Brunswick, NJ 08902-3390, Phone 732-932-9575 x629, palmer@aesop.rutgers.edu OR Ely Vea, 308 Aston Forest Lane, Crownsville, MD 21032, Phone & FAX#: 410-923-488, E-mail: evvea@comcast.net.

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Appendix B

Phytotoxicity Report Form for Pendulum on Heuchera																	
Treatment	Block	Rep	Phytotoxicity at week									Plant Size at week 0			Plant Size at week 8		
			day			day			Height (cm)	Width1 (cm)	Width 2 (cm)	Height (cm)	Width1 (cm)	Width 2 (cm)			
			0	3	1	2	4	3							5	6	8
Control	A	1	2	2	2	2	1		0	1	0	9	9.5	8.5	12	22	20
Control	A	2	1	1	1	1	1		0	0	0	8.5	11.5	9	10	23	22
Control	A	3	0	0	0	0	0		0	0	0	7	11	10	10	25	24
Control	B	1	1	1	1	0	0		0	0	0	9.5	12.5	13	14	30	29
Control	B	2	1	1	1	1	1		0	0	0	10	14	7.5	13	26	20
Control	B	3	1	1	1	1	1		0	0	0	9	11.5	14.5	12.5	26	23
Control	C	1	0	0	1	0	0		0	0	0	8	12	10	14	27	24
Control	C	2	1	1	0	0	0		0	0	0	10	14.5	12	15	24	22
Control	C	3	1	1	1	1	0		0	0	0	7	12	10.5	12	24	23
Mean			0.9	0.9	0.9	0.7	0.4		0.0	0.1	0.0	8.7	12.1	10.6	12.5	25.2	23.0
1X	A	1	1	1	1	1	2		2	2	1	10	14.5	11	12	24.5	24
1X	A	2	1	1	1	1	1		1	1	1	12	14	10.5	13	26	24
1X	A	3	2	2	2	2	2		1	1	2	11	10	15.5	14	25	24
1X	B	1	1	1	1	1	0		0	0	0	10	12	9	13	27	26
1X	B	2	2	2	2	1	0		0	0	0	10	10.5	12	15	31	28
1X	B	3	1	1	1	0	0		0	0	0	10	13	12.5	14	28	24
1X	C	1	2	2	2	2	2		1	0	1	7	9	9	14	24	23
1X	C	2	2	2	2	4	3		3	1	1	6	8.5	10	11	18	17.5
1X	C	3	1	1	1	1	1		1	1	0	9.5	14	12	11	27	24
Mean			1.4	1.4	1.4	1.4	1.2		1.0	0.7	0.7	9.5	11.7	11.3	13.0	25.6	23.8
2X	A	1	1	1	1	1	1		0	0	0	7	9	11	12	22	21
2X	A	2	1	1	1	0	0		0	0	1	6	9	11	12	23	23
2X	A	3	1	1	1	2	0		0	0	0	10	9.5	9	13	26	24
2X	B	1	1	1	1	1	0		0	0	0	11	8	9	15.5	32	28
2X	B	2	2	2	2	2	2		1	0	0	9	12	12	14	25	22
2X	B	3	1	1	1	1	2		1	1	0	10.5	14	8.5	15	26	21
2X	C	1	1	1	1	0	0		0	0	0	13	14	12.5	17.5	33	33
2X	C	2	1	1	1	1	1		0	0	0	11	12	9	16	30	29
2X	C	3	1	1	2	2	2		2	1	0	8	9.5	11	14	20	19
Mean			1.1	1.1	1.2	1.1	0.9		0.4	0.2	0.1	9.5	10.8	10.3	14.3	26.3	24.4
4X	A	1	1	1	1	2	1		1	1	0	8	11	9.5	12	23	21
4X	A	2	1	1	1	1	1		0	0	0	8.5	14	13	10	24	22
4X	A	3	1	1	1	1	1		0	1	0	8.5	9.5	8	10.5	22	19
4X	B	1	2	2	2	2	1		1	0	0	10	11.5	8.5	13	28	26
4X	B	2	1	1	1	1	1		2	2	0	7.5	10	12	12	20	18
4X	B	3	2	2	2	2	1		1	0	0	9	12	10	10.5	24	22
4X	C	1	1	1	1	2	1		1	0	0	11	13.5	16	14	32	29
4X	C	2	1	1	1	1	1		1	1	0	11	15	12.5	12	23	22
4X	C	3	1	1	1	0	0		0	0	0	8.5	12.5	12	14.5	31	28
Mean			1.2	1.2	1.2	1.3	0.9		0.8	0.6	0.0	9.1	12.1	11.3	12.1	25.2	23.0