



<http://ir4.rutgers.edu/Ornamental/ornamentalSummaryReports.cfm>

**IR-4 Ornamental Horticulture Program
d-limonene Crop Safety**

**Authors: Ely Vea and Cristi Palmer
Date: August 19, 2014**

Acknowledgements

**Diane Infante
Lori Harrison
Kathleen Hester**

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Abstract

From 2012 to 2013, IR-4 completed 19 trials on Avenger Ag (d-limonene). The data contained in this report was generated to register uses of active ingredient on and around ornamental horticulture plants with broadcast applications, including over the top of established plants. The Avenger Ag rates in this testing program were at 14 and 28 % v/v as the 1X and 2X rates. It had been applied to 11 plant genera or species. Results showed Avenger Ag causing no injury when applied to these crops in the dormant stage of growth. Of these genera and species, none exhibited no or minimal transient injury after the second application at both rates. Six (6) crops showed significant injury after the second application. Of the six (6) crops that still need additional information, there is one (1) species in which one trial did not show significant injury at 1X and 2X rates.

Introduction

Control of broadleaved weeds and sedges in the production of woody and herbaceous perennials can be problematic because nurseries grow many different types of plants and not all genera or species are listed on labels. These weeds can also be difficult to control in landscape settings for the same reason. Five herbicides, acetic acid (WeedPharm), d-limonene (Avenger Ag), oregano oil (Bryophyter), pelargonic acid (Scythe), and ammonium nonanoate (Emery Agro / Racer), were chosen for research activities into level of crop safety with over the top applications.

Materials and Methods

In the 2012 and 2013 protocols, two applications of Avenger Ag were made approximately 8 weeks apart, with the first made under winter conditions and the second application when crop demonstrated active growth. In some trials (CA, GA, NC and VA), applications were made when plants were already growing. The application rates were 14 and 28 % v/v, plus a water treated control. A minimum of four plants (replicate treatments) were required with many researchers exceeding this minimum. Phytotoxicity was recorded on a scale of 0 to 10 (0 = No phytotoxicity; 10 = Complete kill) at 1, 2, and 4 weeks after each application. Some researchers also included readings at 6 or 8 weeks after the initial and second applications. For more detailed materials and methods, please see protocols at <http://ir4.rutgers.edu/Ornamental/Ornamentals.cfm>.

Avenger Ag was supplied to researchers (See list of researchers in Appendix 1) by Cutting Edge Formulations, Inc.

Results and Summary

Phytotoxicity

Based on the type and nature of injury seen with Avenger Ag applications in the conducted research, tested plant species were placed into four categories: 1) no significant phytotoxicity or growth differences from the untreated check or any injury was transitory, 2) no or minimal transitory injury seen at the 1X rate, but the 2X rate did cause significant phytotoxicity, 3) significant injury sufficient to recommend growers not utilize this product, and 4) more data is needed to make informed recommendations.

Avenger Ag caused sufficient injury on six genera/species to recommend growers not utilize Avenger Ag as an over-the-top treatment on actively growing plants for liverwort control (Table 3). For seven genera/species, more information is needed because only 1 or 2 trials were conducted to date (Table 4). Of the six (6) crops that still need additional information, there is one (1) species in which one trial did not show significant injury at 1X and 2X rates.

Please see Table 5 for a list of individual trial summaries on Avenger Ag.

Table 1. List of Avenger Ag treated crops with no or minimal transitory injury.

None

Table 2. List of Avenger Ag treated crops with no or minimal transitory injury seen at the 1X rate, but the 2X rate did cause significant phytotoxicity

None

Table 3. List of Avenger Ag treated crops exhibiting significant injury.

Alchemilla erythropoda
Dryopteris erythrosora
Hydrangea macrophylla

Liriope sp
Ophiopogon japonicas
Rhododendron x indica

Table 4. List of Avenger Ag treated crops where more information is needed.

Delosperma sp.
Hemerocallis sp.
Heuchera sp.

Hosta sp.
*Osmunda regalis*¹
Sedum sp.

¹ Little to no injury observed in one or two container trial(s).

Table 5. Detailed Summary of Crop Safety Testing with Avenger Ag (d-limonene)

Notes: Table entries are sorted by crop Latin name. Only those trials with research reports received by 8/01/14 are listed below. Table entries with blank results have been received but not yet cataloged in the database.

PR#	Product (Active Ingredients)	Crop	ProductionSite	Researcher	State	Year	ApplicationType	Results
31117	Avenger Ag (d-limonene)	Lady's-Mantle (Alchemilla sp.) A. erythropoda 'Alma'	Greenhouse	Senesac	NY	2013	Over the top	Minor to severe damage with the highest damage occurring at the 28% concentration without irrigation. The least amount of injury occurred at 14% concentration with irrigation.
30749	Avenger Ag (d-limonene)	Delosperma sp. (Delosperma sp.) 'Cooper's Ice'	Greenhouse	Wilen	CA	2012	Over the top	Significant injury with 14 and 28 % v/v, more injury at high rate; good liverwort control.
30749	Avenger Ag (d-limonene)	Delosperma sp. (Delosperma sp.) D. cooperi 'Fire Spinner'	Greenhouse	Derr	VA	2012	Over the top	Minor injury with 14 % v/v w/ or w/o irrigation; unacceptable initial injury only with high rate (28 % v/v) w/o irrig, but plants quickly outgrew injury. Acceptable liverwort control with low rate w/o irrigation and high rate w/ or w/o irrig.
30749	Avenger Ag (d-limonene)	Delosperma sp. (Delosperma sp.) D. nubigenum 'Basutoland'	Greenhouse	Senesac	NY	2012	Over the top	Minor injury with 14 % with irrig. after 2nd applic., moderate w/o and at 28 % v/v, w/ and w/o irrig.; excellent liverwort control with 2 applications.
30750	Avenger Ag (d-limonene)	Fern, Autumn & Wood (Dryopteris sp.) D. erythrosora	Greenhouse	Neal	NC	2012	Over the top	Good liverwort control but unacceptable injury with 14 and 28% v:v applied twice and irrigated 15 or 2 hr post application.
30750	Avenger Ag (d-limonene)	Fern, Autumn & Wood (Dryopteris sp.) D. erythrosora	Greenhouse	Senesac	NY	2012	Over the top	Moderate to severe injury of evergreen/past season foliage with 14 % and 28 % v/v applied twice, no injury of new growth; excellent liverwort control with 2 applications.
30753	Avenger Ag (d-limonene)	Daylily (Hemerocallis sp.) 'Mini Pearl'	Greenhouse	Senesac	NY	2012	Over the top	Low injury with 14 % w/ or w/o irrig. after 2nd applic., moderate with 28 %; excellent liverwort control with 2 applications.
30754	Avenger Ag (d-limonene)	Coral Bells, Alumroot (Heuchera sanguinea) 'Big Top Gold'	Greenhouse	Czarnota	GA	2012	Over the top	No injury w/ or w/o irrig. with 14 % v/v, moderate with complete recovery with 28 % v/v only w/o irrig; good to excellent liverwort control for 2 WAT.
30754	Avenger Ag (d-limonene)	Coral Bells, Alumroot (Heuchera sanguinea) H. micrantha 'Purple Palace'	Greenhouse	Wilen	CA	2012	Over the top	Inadequate crop safety with 14 and 28 % v/v; good liverwort control.
30754	Avenger Ag (d-limonene)	Coral Bells, Alumroot (Heuchera sanguinea) H. villosa 'Caramel'	Greenhouse	Senesac	NY	2012	Over the top	Low injury w/ or w/o irrig. with 14 % v/v, moderate with 28 % v/v applied twice; excellent liverwort control with 2 applications.
30757	Avenger Ag (d-limonene)	Hosta (Hosta sp.) 'Blue Hawaii'	Greenhouse	Derr	VA	2013	Over the top	Low injury with 14 and 28 % v/v w/ irrigation, unacceptable injury at both rates w/o irrig. Low injury and high liverwort control only from high rate w/ irrig.

PR#	Product (Active Ingredients)	Crop	ProductionSite	Researcher	State	Year	ApplicationType	Results
30757	Avenger Ag (d-limonene)	Hosta (Hosta sp.) 'Gold Standard'	Greenhouse	Senesac	NY	2012	Over the top	Low injury with 14 % w/ irrig. after 2nd applic., moderate with 28 %; excellent liverwort control with 2 applications.
30756	Avenger Ag (d-limonene)	Hydrangea (Hydrangea sp.) H. macrophylla 'Blue Danube'	Greenhouse	Senesac	NY	2012	Over the top	Moderate to severe injury with 14 % and 28 % v/v w/ or w/o irrig. after 2nd applic.; excellent liverwort control with 2 applications.
30624	Avenger Ag (d-limonene)	Lilyturf, Creeping (Liriope sp.) L. muscari 'Variegata'	Greenhouse	Neal	NC	2012	Over the top	Good liverwort control but unacceptable injury with 14 and 28% v:v applied twice and irrigated 15 or 2 hrpostapplication.
30758	Avenger Ag (d-limonene)	Mondo Grass, Lilyturf, Ker-Gawl (Ophiopogon sp.) O. japonicus 'Dwarf Black'	Greenhouse	Senesac	NY	2013	Over the top	Minor to severe damage with the highest damage occurring at the 28% concentration without irrigation. The least amount of injury occurred at 14% concentration with irrigation. The low rate with and without irrigation and the high rate with irrigation were
30758	Avenger Ag (d-limonene)	Mondo Grass, Lilyturf, Ker-Gawl (Ophiopogon sp.) O. japonicus 'Nana'	Greenhouse	Wilen	CA	2013	Over the top	Unacceptable injury with 14 and 28 % v/v; excellent liverwort control.
31873	Avenger Ag (d-limonene)	Fern, Royal (Osmunda regalis)	Greenhouse	Derr	VA	2013	Over the top	Unacceptable injury with 14 and 28 % v/v w/o irrigation, acceptable injury at both rates with irrig. Low injury and high liverwort control only from high rate w/ irrig.
30759	Avenger Ag (d-limonene)	Azalea (Rhododendron sp.) R. × indica 'Judge Solomon'	Greenhouse	Gilliam	AL	2012	Over the top	Good to excellent control of liverwort, but unacceptable injury (die back, burnt leaves and defoliation) at 14 and 28 v/v conc. with and w/o immediate irrigation.
30761	Avenger Ag (d-limonene)	Stonecrop (Sedum sp.) S. spurium 'John Creech'	Greenhouse	Senesac	NY	2013	Over the top	Minor to severe damage with the highest damage occurring at the 28% concentration without irrigation. The least amount of injury occurred at 14% concentration with irrigation. The low rate with and without irrigation and the high rate with irrigation were

Label Suggestions

For Avenger Ag, data suggest no change in its current label recommendations to avoid contact with desirable plants.

Appendix 1: Contributing Researchers

Dr. Mark Czarnota	University of Georgia Department of Horticulture 1109 Experiment St. Griffin, GA 30223
Dr. Jeffrey Derr	Hampton Roads Ag. Exp. Station 1222 Diamond Springs Road, Virginia Beach, VA 23244
Dr. Hannah Mathers	The Ohio State University Dept. Hort. and Crop Science 2001 Fyffe Ct. Columbus, OH 23210
Dr. Joe Neal	North Carolina State University Department of Horticultural Science 262 Kilgore Hall Box 7609, NCSU Raleigh, NC 27694-7609
Dr. Andy Senesac	Long Island Horticultural Research Laboratory 39 Sound Avenue Riverhead, NY 11901
Dr. Cheryl Wilen	University of California, San Diego 4444 Overland Ave., Bldg. 2 San Diego, CA 92123