Weed Control

Mengmeng Gu

Section Editor

Can Indaziflam be Used in Greenhouse Production of Annuals?

Lucy Edwards, Charles H. Gilliam, S. Christopher Marble

Department of Horticulture, 101 Funchess Hall
Auburn University, AL

lee0003@auburn.edu

Index Words: over-the-top, herbicide, PRE-emergent

Significance to Industry: Due to liability associated with high value crops there are no labeled herbicides for enclosed structures, such as greenhouses. Reluctance to establish such a product arises from the high volatility risk and small market. Indaziflam SC is a PRE herbicide recently labeled for directed application in ornamental nursery production (outdoor pads, shadehouses, and hoophouses). Exhibiting excellent weed control, indaziflam is unique because it has a low volatility index, providing potential use in other production areas. This study demonstrated the effects of indaziflam on the gravel and directly over plants in greenhouses using sensitive crops.

Nature of Work: Indaziflam is classified as an alkylazine herbicide, inhibiting crystalline cellulose deposition in the cell wall affecting wall formation, cell elongation and division (1). Though previous evaluations of indaziflam have mainly focused on weed control in turfgrass, indaziflam is labeled for use in nursery production (2, 3, 4). Growers continually struggle with maintaining a weed free environment. The presence of weeds significantly effects a plant's growth and marketability (5). Container production is less mechanized than other agricultural sectors, causing hand labor to be major cost factor. Recent legislation in immigration reform has resulted in many growers to lose a large amount of their labor force (6), making weed control inside enclosed structures more difficult. To avoid risking crop injury from herbicide volatility, growers must remove their crops from the structure and apply a broad-spectrum POST product, or pay for the labor to hand weed. It would be beneficial to find herbicides that provide PRE and POST emergent weed control in greenhouse production. The objective of this study was to evaluate indaziflam as a PRE emergent herbicide for use in greenhouse production.

Materials and Methods : Two similar but separate experiments were conducted at the Paterson Greenhouse Complex, Auburn University, AL. The following procedures apply to both experiments: Fifteen ground beds [2.9 m by 2.9 m by 0.36 m (9.5 ft by 9.5ft by 1.17 ft)] with metal support walls and a gravel floor were used as the experimental site. Mini-greenhouses (MG) [2.44 cm (8.0 ft) by 2.44 cm (8.0 ft) by 46 in. tall] were constructed of 1.3 cm (0.05 in) PVC pipe and covered with Klerk's K-1 white 70% co-poly for each ground bed. Five MG were randomly selected to have a window made of clear plastic and contained thermometers in order to monitor the temperature throughout the study.

Indaziflam (Indaziflam SC, Bayer Environmental Science, Research Triangle Park, NC 27709) was applied at two rates including the manufacturers labeled rate [40 g ai·ha^{-1} (3.48 oz ai·ac^{-1})] (1×) and twice the labeled rate [80 g ai·ha^{-1} (6.92 oz ai·ac^{-1})] (2×). Three treatments were applied at each rate: treated gravel only in ground bed (GO-MG); over-the-top of plants on gravel inside the ground beds (OTT-MG); over-the-top of plants outside the ground beds on adjacent gravel (OTT-OMG). Two non-treated control treatments were maintained: plants placed on the non-treated gravel inside the ground beds (C-MG); and plants placed outside the ground beds on adjacent non-treated gravel without cover (C-OMG).

Indaziflam was applied using a CO_2-backpack sprayer fitted with an 8004 flat fan nozzle (TeeJet Technologies, Wheaton, IL 60187) at 172.4 kPa (25 psi) calibrated to deliver an application volume of 187 L ha^{-1} (20 gpa). Treatments placed in ground beds (OTT-MG, G-MG, C-MG) were covered with MG immediately after application. After application and plant placement, all treatments were covered with shade cloth (30%). Ground beds received irrigation via 2.5 gpm popup sprinkler [1.3 cm/day (0.5 in/day)]. Plants outside ground beds received overhead irrigation via impact sprinklers. Three days after initiation, MG covers were removed and plants were placed under a shade cloth (30%) structure, receiving overhead irrigation (impact sprinkler) [1.3 cm/day (0.5 in/day)]. Data collected included injury ratings on 1 to 10 scale (1 = no injury and 10 = dead plant) at 3, 10, 24, and 30 DAT. Fresh weights (FW) were taken at 30 DAT. All data were subjected to Duncan's Multiple Range Test ($p \leq 0.05$) (SAS® Institute version 9.2, Cary, NC).

Experiment 1. Plug trays (200 count) of 'Dreams White' petunia (*Petunia × hybrida* Juss. 'Dreams White') were potted into 36 cell packs on May 17, 2011 using a pinebark:sand (6:1, v:v) mix amended with 8.31 kg·m^{-3} (14 lbs·yd^{-3}) 15.0N-2.64P-9.96K (15-6-12) Polyon (Harrell's Fertilizer, Inc., Lakeland, FL) control release fertilizer, 3.0 kg·m^{-3} (5 lbs·yd^{-3}) dolomitic limestone, and 0.9 kg·m^{-3} (1.5 lbs·yd^{-3}) Micromax (The Scott's Company, Marysville, OH) prior to potting. On May 31, 2011, impatiens (*Impatiens walleriana* Hook. f. 'Xtreme Orange') were received in four inch pots from a local supplier and were not transplanted. Each treatment consisted of three replications, with 15 sub-replications for petunia and 10 sub-replications for impatiens. On June 7th, 2011 treatments were applied as previously described.

Experiment 2. Due to an addition in replications, one-half of impatiens (*Impatiens walleriana* Hook. f. 'Xtreme Orange')and petunia (*Petunia × hybrida* Juss. 'Dreams Neon Rose') from plug trays (200 count) were potted into 36 cell packs on May 15, 2012; the second half were potted on May 18, 2012 using substrate previously stated. Each treatment consisted of three replications, with 24 sub-replications. On June 12th, 2012 treatments were applied as previously described.

Results and Discussion

Experiment 1. Impatiens exhibited little to no injury in C-MG, C-OMG, and G-MG, regardless of the rate (Table 1). Impatiens receiving OTT-MG exhibited injury at 3 DAT

(3.7 and 2.7 at 1× and 2×, respectively). No injury was observed on impatiens treated OTT-OMG at 3 DAT; however, injury ratings steadily increased throughout the study. Impatiens treated over-the-top (OTT-MG, OTT-OMG) were severely injured or completely dead by 30 DAT, regardless of herbicide rate. Impatiens FW also indicate that over-the-top treatments were severely injured or dead, while G-MG had similar FW to the control treatments.

Petunia treated G-MG (both rates) had similar injury ratings to C-MG and C-OMG (1.0) (Table 2). Petunia treated OTT-MG had higher injury ratings than any other treatment at 3 DAT (3.0 and 3.3 at 1× and 2× rates, respectively). By 30 DAT, petunia treated OTT-MG (4.7) and OTT-OMG (4.7) at the 2× rate had higher injury ratings than those at the 1× rate. FW indicate similarities to impatiens where those treated G-MG at both rates were similar to C-MG and C-OMG. FW data indicates over-the-top application of indaziflam is not recommended.

Experiment 2. Impatiens treated OTT-MG (3.0, both rates) had the highest injury ratings followed by OTT-OMG (2.0, both rates). Similar to Exp. 1, impatiens exhibited no injury in C-MG, C-OMG, and G-MG treatments (Table 1). By 30 DAT, impatiens receiving over-the-top treatment (OTT-MG, OTT-OMG) were completely dead (injury ratings 10.0). FW for all over-the-top treated impatiens had a mean of 0.0.

Petunia receiving G-MG exhibited no injury throughout the study (Table 2). OTT treated plants exhibited injury throughout the test. At 3 DAT, all OTT plants showed signs of injury. By 30 DAT, the majority of petunias in over-the-top treatments were stunted or dead while the controls (C-MG, C-OMG) and G-MG exhibited no injury. FW show that petunia treated G-MG were similar in size or larger than C-MG and C-OMG.

The objective of the experiment was to determine if indaziflam can be used safely as a PRE emergent in greenhouse production. Our experiments were conducted in mini-greenhouses under a worst-case scenario where air temperatures rose to 100-108˚F with no ventilation for 3 days. Under these extreme conditions, treatments where gravel only was sprayed with indaziflam had little to no injury, while OTT treatments had severe injury by 30 DAT. Petunia exhibited signs of rejuvenation, but the impatiens and tomato did not show any signs of regrowth. FW data verify that the gravel only and control treatments showed no signs of injury or stunted growth; while treatments sprayed OTT caused major plant injury.

Literature Cited

1. Anonymous. 2009. Bayer CropScience Presents New Herbicidal Active Ingredient Indaziflam. http://www.bayercropscience.com/bcsweb/cropprotection.nsf/id/. F730899 C884F 24ADC1257558003E5E76. Accessed: February 2, 2012.
2. Brosnan, J.T., P.E. McCullough, and G.K. Breeden. 2011. Smooth crabgrass control with indazilam at various spring timing. Weed Tech. 25:363-366.

3. Brosnan, James T., Gregory K. Breedon, Patrick E. McCullough, and Gerald M. Henry. 2012. Pre and post control of annual bluegrass (*Poa annua*) with indaziflam. Weed Tech. 26:48-53.
4. Brosnan, James T. and Gregory K. Breeden. 2012. Application placement affects postemergence smooth crabgrass (*Digitaria ischaemum*) and annual bluegrass (*Poa annua*) control with indaziflam. Weed Tech. 26:661-665.
5. Fretz, T.A. 1972. Weed competition in container grown Japanese holly. HortScience 7:485-486.
6. Johnson, K.R., 2011. Sweet home Alabama? Immigration and civil rights in the “new”South. http://www.stanfordlawreview.org/online/sweet-home-alabama. Accessed: April 5, 2013.

Table 1. 'Extreme Orange' impatiens injury ratings and fresh weights following Indaziflam applications in greenhouse situations, Experiments 1 and 2.

		Injury Ratings[z]					
Application		3 DAT[y]		30 DAT		Shoot Fresh Weights (g)[x]	
Placement[w]	Rate[v]	EXP. 1	EXP. 2	EXP. 1	EXP. 2	EXP. 1	EXP. 2
G-MG	1×	1.0c[u]	1.0c	1.0b	1.0b	109.9a	15.9b
G-MG	2×	1.0c	1.0c	1.0b	1.0b	97.0ab	17.7a
OTT-MG	1×	3.7a	3.0a	9.7a	10.0a	0.1c	0.0d
OTT-MG	2×	2.7b	3.0a	9.7a	10.0a	1.3c	0.0d
OTT-OMG	1×	1.0c	2.0b	9.7a	10.0a	0.2c	0.0d
OTT-OMG	2×	1.0c	2.0b	10.0a	10.0a	0.0c	0.0d
C-MG	NA	1.2c	1.0c	1.0b	1.0b	96.0b	16.0ab
C-OMG	NA	1.0c	1.0c	1.0b	1.0b	112.2a	13.8c

[z]Injury ratings based on a scale of 1 to 10, 1 = no injury, 10 = dead plant.

[y]DAT = days after treatment.

[x]Shoot fresh weights were taken at 30 DAT for each experiment and are presented in grams.

[w]G-MG = herbicide applied to gravel with plants placed on gravel inside mini-greenhouses immediately following application; OTT-MG = herbicide applied over-the-top of plants on gravel ground beds and then placed inside mini-greenhouses immediately following application; OTT-OMG = plants treated over-the-top and not placed inside mini-greenhouses; C-MG = non-treated control placed in gravel ground beds inside mini-greenhouses; C-OMG = non-treated control placed outside of gravel ground beds and not placed inside mini-greenhouses.

[v]1× = 40 g ai·ha-1 (0.04 lbs ai·ac-1); 2×= 80 g ai·ha-1 (0.07 lbs ai·ac-1).

[u]Means within column followed by the same letter are not significantly different based on Duncan's Multiple Range Test ($p = \leq 0.05$).

Table 2. 'Dreams White' and 'Dreams Rose' Petunia injury ratings and fresh weights following Indaziflam applications in greenhouse situations, Experiments 1 and 2.

Application Placement[w]	Rate[v]	Injury Ratings[z] 3 DAT[y] EXP. 1	Injury Ratings[z] 3 DAT[y] EXP. 2	Injury Ratings[z] 30 DAT EXP. 1	Injury Ratings[z] 30 DAT EXP. 2	Shoot Fresh Weights (g)[x] EXP. 1	Shoot Fresh Weights (g)[x] EXP. 2
G-MG	1×	1.0b[u]	1.0b	1.7c	1.0d	16.3a	7.0c
G-MG	2×	1.3b	1.0b	1.7c	1.0d	16.3a	12.2a
OTT-MG	1×	3.0a	2.3a	4.0b	4.3c	7.4b	4.3d
OTT-MG	2×	3.3a	2.3a	5.7a	8.0a	2.0b	1.0e
OTT-OMG	1×	1.3b	2.0a	4.3b	6.7b	7.0b	2.3e
OTT-OMG	2×	1.3b	2.0a	5.7a	7.7ab	3.0b	1.3e
C-MG	NA	1.0b	1.0b	1.3c	1.0d	22.9a	9.8b
C-OMG	NA	1.0b	1.0b	1.0c	1.0d	19.5a	8.8bc

[z]Injury ratings based on a scale of 1 to 10, 1 = no injury, 10 = dead plant.

[y]DAT = days after treatment.

[x]Shoot fresh weights were taken at 30 DAT for each experiment and are presented in grams.

[w]G-MG = herbicide applied to gravel with plants placed on gravel inside mini-greenhouses immediately following application; OTT-MG = herbicide applied over-the-top of plants on gravel ground beds and then placed inside mini-greenhouses immediately following application; OTT-OMG = plants treated over-the-top and not placed inside mini-greenhouses; C-MG = non-treated control placed in gravel ground beds inside mini-greenhouses; C-OMG = non-treated control placed outside of gravel ground beds and not placed inside mini-greenhouses.

[v]1× = 40 g ai·ha-1 (0.04 lbs ai·ac-1); 2×= 80 g ai·ha-1 (0.07 lbs ai·ac-1).

[u]Means within column followed by the same letter are not significantly different based on Duncan's Multiple Range Test ($p = \leq 0.05$).

Weed Control in Kentucky Native Wildflower Field Nurseries and Gardens

Winston Dunwell, Carey Grable, and Dwight Wolfe

University of Kentucky Research and Education Center
1205 Hopkinsville St, Princeton, KY 42445

wdunwell@uky.edu

Index Words: *Hymenocallis caroliniana, Sanguinaria canadensis, Solidago shortii*, Spiderlily, Short's Goldenrod, Solar Cascade Goldenrod, prairie trillium, recurved trillium, Snapshot®, Trifluralin, Isoxaben

Significance to the Industry: Kentucky native wildflowers not common to the landscape create weed control challenges. Snapshot® control of winter weeds, chickweed and henbit, and yellow nutsedge in plantings of Kentucky natives could increase native plant use in landscape, increase the longevity of wildflower plantings and reduce maintenance related to hand-weeding.

Nature of Work: Wildflower gardens in west Kentucky are frequently abandoned due to weed establishment. Many wildflowers die down during the growing season reducing weed-controlling ground cover and allowing weed seed to establish in bare ground. The objective of this study was to determine if recurved trillium, Solar Cascade goldenrod, bloodroot and spiderlily would be tolerant of Snapshot® 2.5TG.

To reduce maintenance in wildflower gardens control of difficult to hand-weed chickweed and persistent henbit and nutsedge is beneficial. Snapshot® 2.5 TG (Dow Agrosciences, LLC) is a combination of Trifluralin 2.0% (MOA Group 3 (2), Dinitroanilines family) for grass and broadleaf weed control and Isoxaben 0.5% (benzamide herbicide family, MOA 21 (2)) for broadleaf weed control. Snapshot® has been shown to control winter weeds and yellow nutsedge (1, 3, 4). Snapshot® 2.5TG had been used successfully in annual and perennial plantings at the University of Kentucky Research and Education Center in Princeton, but the wildflowers in this study were not on the label, injured or may be used on, plant lists.

A landscape bed that had been infested with common chickweed (*Stellaria media* (L.) Vill.), Henbit (*Lamium amplexicaule* L.), and yellow nutsedge (Cyperus esculentuss L.) was sprayed with Roundup Pro® (Glyphosate) at 4% (0.5 oz. per gallon) October 8, 2012 and tilled and planted with divisions of recurved trillium, Solar Cascade goldenrod, bloodroot and spiderlily bulbs on October 23, 2012. Plants were not randomized within the randomized Snapshot® 2.5TG treated plots.

November 8, 2012 Snapshot® 2.5TG was applied by handheld shaker to randomly selected plots at the 150 lbs per acre rate. Weeds were counted in a square foot of each plot on April 5, 2013. Observations of plant health were done on July 31, 2013.

Results: Snapshot® controlled weeds as indicated in previous research (Figure 1). No discernible injury was observed on the native plants. The bloodroot and trillium foliage had died to the ground but the roots were still alive and appeared healthy at observation. The Spider lily was in bloom and the Solar Cascade goldenrod had grown normally and had flower buds. One Solar Cascade was lost in a non-treated plot from an unknown cause. The bloodroot and trillium appeared be stressed in the full-sun plots and will be moved to shaded plots for future experiments. This study did indicate that recurved trillium, Solar Cascade goldenrod, bloodroot and spiderlily are tolerant of Snapshot® 2.5TG applied as a fall-applied herbicide treatment. A second trial will be done to ensure these results are accurate and repeatable.

Literature Cited

1. Judge, Caren A., Joseph C. Neal and Robert E. Wooten. 2005. Preemergence Control of Winter Weeds in Overwintering Ornamental Crops. Proc. Southern Nurs. Assoc. Res. Conf. 50:432-434
2. Oklahoma State University Extension. 2013. Herbicide Mode of Action Table. http://pested.okstate.edu/pdf/herbicide%20moa.pdf
3. Neal, Joseph C. and Andrew F. Senesac., 1990 Summer Annual and Winter Annual Weed Control in Field Soil and Soilless Media with Gallery (Isoxaben). J. Environ. Hort. 8(3), 124-127.
4. Setyowati, N., L. A. Weston and R. E. McNiel. 1995. Evaluation of Selected Preemergence Herbicides in Filed-Grown Landscape Crops in Kentucky. J. Environ. Hort. 13: 196-202.

Phytotoxicity on Containerized Ornamentals from Several Herbicides at Three Nurseries in Michigan

Hannah Mathers and Luke Case

Department of Horticulture and Crop Science
The Ohio State University, Columbus, OH 43210

case.49@osu.edu

Index words: Preemergence herbicides, ornamentals

Significance to the industry: On-site herbicide trials are an effective approach to educating nursery growers. Many growers continue to use handweeding as their primary weed control, and if they do use herbicides, the same herbicide is used continuously. Crop and weed species are key to proper herbicide selection, but many crops are still not labeled or it is unknown how they will respond to certain combinations. These trials were funded by USDA specialty crop block grants and IR-4 to identify herbicides for containerized ornamentals that are important for nursery production in Michigan and to let growers see first-hand the results.

Nature of Work: Three cooperating nurseries located near Grand Haven, MI were selected as sites for the container trials, which included Berryhill Family of Nurseries (BFN, formerly Zelenka Nursery), Spring Meadow Nursery, Inc., and Northland Farms Nursery, LLC. The trade and common names and manufacturers of the herbicides used are as follows: Tower (dimethenamid-p) + Pendulum (pendimethalin, BASF Corp.), FreeHand (dimethenamid-p + pendimethalin, BASF Corp.), Biathlon (oxyfluorfen + prodiamine, OHP, Inc.), F6875SC (sulfentrazone +prodiamine, FMC), Gallery (isoxaben, Dow Agro Sciences + Barricade (prodiamine, Syngenta), and Indaziflam G (Bayer Corp.). Phytotoxicity evaluations were performed at 1 WA1T (week after first treatment), 2 WA1T, 4 WA1T, 1 WA2T (weeks after second treatment), 2 WA2T, and 4WA2T. Visual ratings were performed on a scale of 0-10 with 0 being no phytotoxicity, 10 being dead, and ≤3 commercially acceptable. All liquid treatments were applied with a CO_2 backpack sprayer with a spray volume of 20 gal/ac using nozzles delivering 0.15 gal/ min/ nozzle and the nozzle spacing at 12 inches.

Herbicides selected for the containerized portion included: Indaziflam (Bayer Corp.) at 0.11, 0.22, and 0.44 lb. ai/ac on daylily and rose; Tower + Pendulum Aquacap at 21 oz./ac + 2qt/ ac on daylily, azalea, and viburnum; Gallery + Barricade 4FL at 1.0 lb. ai/ac + 0.66 lb. ai/ac on daylily, euonymus, elderberry and coneflower; FreeHand at 2.65, 5.3, and 10.6 lb. ai/ac on elderberry, barberry, viburnum, azalea and coneflower; Biathlon at 2.75 lb. ai/ac on azalea, coneflower, daylily and viburnum and F6875 at 0.375, 0.75, 1.5 lb. ai/ac on barberry, euonymus and daylily.

For the containerized portion at BFN, species selected included: daylily, (*Hemerocallis* 'Stella d'Oro'), elderberry (*Sambucus nigra* Blacklace™), barberry (*Berberis thunbergii* 'Crimson Pygmy'), purple coneflower (*Echinacea purpurea* 'Purple Magnus'), and euonymus (*Euonymus* f*ortunei* 'Emerald & Gold'). The species selected for the field trial at BFN included common lilac (*Syringa* 'Common Purple') and compact euonymus (*Euonymus alatus* 'Compacta'). For the containerized portion at Northland Farms, species selected included daylily (*Hemerocallis* 'Stella d'Oro'), elderberry (*Sambucus nigra* Blacklace™), barberry (*Berberis thunbergii* 'Crimson Pygmy'), purple coneflower (*Echinacea purpurea* 'Purple Magnus'), and euonymus (*Euonymus* f*ortunei* 'Emerald & Gold'). Species selected at Spring Meadow included rose (*Rosa* 'Home Run RED'), barberry (*Berberis thunbergii* Sunjoy® Gold Beret *'Talago'),* azalea *Azalea* Bloom-a-thon® Pink Double and viburnum (*Viburnum* Red Balloon™ 'Redell'). The containerized trials were initiated on March 27, 2012 at all locations. Treatments were reapplied at 6 weeks after original treatments were applied. Treatments were watered in within 4 hours of application. Pot sizes were one-gallon trade (#1) pots at BFN and Northland Farms and at Spring Meadow 4 inch pots were used. At BFN and Northland Farms, treatments consisted of four replications with three subsamples/replication; at Spring Meadow, there were ten replications/treatment. Trials were set up in a completely randomized design at each location.

Results and discussion: Biathalon, F6875, and indaziflam are three herbicides that are new to the nursery industry and have not been used extensively by Michigan nursery growers. There is also much to be learned about FreeHand on containerized ornamentals (1). Tower + Pendulum was also included in the trials as a liquid alternative to FreeHand, which contain the same active ingredients. At BFN phytotoxicity occurred with *Berberis* 'Crimson pygmy' with F6875 1 and 2 WA1T at the 2X and 4X rate; however, the plants recovered from the injury by the end of the trial (Table 1). Injury also occurred on *Echinacea* 'Purple Magnus' with FreeHand at BFN and at Northland Farms (Tables 1 and 2). Previous research has shown that FreeHand can cause injury to other perennials (2). At Northland Farms the injury was just above commercially acceptable at the 4X rate 4WA2T (Table 2). At BFN the injury occurred after the second application at the 4X rate and at that time was just above commercially acceptable (Table 1). However, on August 9 of the BFN *Echinacea* at a workshop tour indicated the stunting effect of the FreeHand had continued for 3 months after the trial ended with severe root stunting also occurring, which growers got to see firsthand. Damage also occurred to *Echinacea* with Gallery + Barricade at Northland Farms (Table 2). Although the plants were starting to grow out of the injury at 4WAT, the second application increased the injury through to the end of the trial (Table 2). *Hemerocallis* was injured at BFN with Biathlon, Tower + Pendulum, Indaziflam at all rates and F6875 at all rates (Table 1). Hemerocallis was also injured at Northland Farms with Indaziflam at the 4X rate (Table 2). The injury from Biathlon, Tower + Pendulum and F6875 at 1 and 2X was transitory and no injury was present by the end of the trial at BFN (Table 1). However, the injury from indaziflam at all rates and F6875 at the 4X rate persisted (Table 1). Damage also occurred on azalea and viburnum at Spring Meadow from Tower + pendulum (Table 3). The damage on azalea was worse than on viburnum.

Literature cited

1. Lurvey, E., K. Hester, and C.L. Palmer. 2012. IR-4 ornamental horticulture program Dimethenamid-p + pendimethalin crop safety. http://ir4.rutgers.edu/ir4_pdf/default.aspx?pdf=http://ir4.rutgers.edu/Ornamental/SummaryReports/BAS659GDataSummary2012.pdf. Accessed July 25, 2013.
2. Senesac, A. 2010. Response of field and container-grown herbaceous ornamentals to FreeHand (dimethenamid-p + pendimethalin). Proc. of Northeast Weed Sci. Soc. 64:99.

Table 1. Phytotoxicity from various herbicides on several ornamental species located at Berryhill Family of Nurseries near Grand Haven, MI.

Sambucus 'Blacklace'

Treatment	Rate/ac	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T	4 WA2T
FreeHand	150 lb	0.0	0.0	0.0	0.0	2.2 **	0.0
FreeHand	300 lb	0.3	0.2	0.0	1.8 **	2.6 **	0.0
FreeHand	600 lb	0.3	0.2	0.5	0.0	0.4	0.0
Untreated	--	0.2	0.3	0.0	0.0	0.0	0.0

Berberis 'Crimson pygmy'

Treatment	Rate/ac	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T	4 WA2T
F6875	0.375 lb ai	1.9 **	1.1 **	--	1.2	0.4	0.3
F6875	0.75 lb ai	3.0 **	2.5 **	--	1.6 **	1.0 **	0.3
F6875	1.5 lb ai	3.7 **	3.5 **	--	2.8 **	2.4 **	0.6
Untreated	--	0.0	0.0	--	0.5	0.2	0.2

Echinacea 'Purple Magnus'

Treatment	Rate/ac	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T	4 WA2T
Biathalon	100 lb	1.4	2.0 **	1.0	1.8	2.5 **	2.9 **
FreeHand	150 lb	0.8	0.7	0.2	1.1	1.1	3.1 **
FreeHand	300 lb	0.4	0.2	0.6	1.2	2.3 **	2.0
FreeHand	600 lb	1.3 *	0.5	0.5	3.3 **	3.3 **	3.2 **
Untreated	--	0.5	0.4	0.8	1.5	0.8	0.9

Euonymus 'Emerald and Gold'

Treatment	Rate/ac	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T	4 WA2T
Gallery + Barricade	1 lb ai + 0.66 lb ai	0.0	0.0	1.0	0.0	0.2	3.0 **
F6875	0.375 lb ai	0.2	0.3	0.2	0.6 **	0.8	0.0
F6875	0.75 lb ai	0.0	0.2	0.6	0.2	0.3	0.0
F6875	1.5 lb ai	0.4	0.1	0.5	1.5 **	1.6 **	0.3
Untreated	--	0.2	0.1	0.8	0.0	0.0	0.1

Table continued on next page.

Table 1 (continued). Phytotoxicity from various herbicides on several ornamental species located at Berryhill Family of Nurseries near Grand Haven, MI.

Hemerocallis 'Stella d'oro'

Treatment	Rate/ac	1 WAT		2 WAT		4 WAT		1 WA2T		2 WA2T		4 WA2T	
Biathalon	100 lb	1.9	**	3.9	**	3.8	**	0.5		0.8	**	1.9	**
Tower + Pendulum	21 fl oz + 2 qt	5.4	**	5.0	**	3.9	**	0.5		1.5	**	0.3	
Gallery + Barricade	1 lb ai + 0.66 lb ai	0.6		0.3		0.0		0.0		0.2		0.4	
Indaziflam	200 lb	0.8		3.3	**	3.1	**	0.0		0.1		1.5	**
Indaziflam	400 lb	1.5	**	3.7	**	3.3	**	1.8	**	2.3	**	3.5	**
Indaziflam	800 lb	1.5	**	3.7	**	3.8	**	3.0	**	3.7	**	4.0	**
F6875	0.375 lb ai	5.5	**	4.9	**	3.8	**	1.4	**	1.7	**	2.5	**
F6875	0.75 lb ai	5.9	**	5.2	**	3.7	**	2.6	**	2.9	**	2.9	**
F6875	1.5 lb ai	7.1	**	5.6	**	5.3	**	3.9	**	5.1	**	5.7	**
Untreated	--	0.4		0.0		0.0		0.0		0.0		0.5	

z = WAT: weeks after first treatment; WA2T: weeks after second treatment

y = Phytotoxicity visual ratings based on a 0-10 scale with 0 being no phytotoxicity and 10 death with ≤3 commercially acceptable

x = Treatment means followed by *,** are significantly different from the control, based on Dunnett's t-test (α = 0.10 and 0.05, respectively)

Table 2. Phytotoxicity from various herbicides on several ornamental species located at Northland Farms near Grand Haven, MI.

Sambucus 'Blacklace'

Treatment	Rate/ac	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T	4 WA2T
FreeHand	150 lb	0.0	0.3	0.2	0.3	0.0	0.7
FreeHand	300 lb	0.0	0.1	0.3	0.7	2.8 **	0.4
FreeHand	600 lb	0.0	0.1	1.3 **	2.0 **	2.3 **	2.3 **
Gallery + Barricade	1 lb ai + 0.66 lb ai	0.0	0.8 **	1.1 *	0.0	3.0 **	0.9
Untreated	--	0.0	0.1	0.0	0.0	0.0	0.0

Echinacea 'Purple Magnus'

Treatment	Rate/ac	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T	4 WA2T
Gallery + Barricade	1 lb ai + 0.66 lb ai	4.4 **	4.4 **	3.5 **	6.8 **	7.7 **	4.2 **
FreeHand	150 lb	0.5	0.5	1.0	1.2	2.3 **	2.0 **
FreeHand	300 lb	0.8 **	1.0	2.3 **	1.8 **	4.6 **	2.3 **
FreeHand	600 lb	0.3	1.0	2.4 **	1.6 **	2.4 **	3.2 **
Untreated	--	0.0	0.2	0.1	0.1	0.0	0.0

Euonymus 'Emerald and Gold'

Treatment	Rate/ac	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T	4 WA2T
F6875	0.375 lb ai	0.4	0.3	0.3	0.0	0.0	0.0
F6875	0.75 lb ai	0.4	0.5	0.6	0.3	0.0	0.0
F6875	1.5 lb ai	1.1 **	1.6 **	1.3 **	1.5 **	0.0	0.0
Gallery + Barricade	1 lb ai + 0.66 lb ai	0.2	0.2	0.5	0.2	0.0	0.0
Untreated	--	0.2	0.2	0.1	0.0	0.0	0.0

Hemerocallis 'Stella d'oro'

Treatment	Rate/ac	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T	4 WA2T
Indaziflam	200 lb	0.2	3.2 **	2.7 **	1.6	1.0	1.4
Indaziflam	400 lb	0.0	3.4 **	2.2 **	2.5 **	2.7 **	2.8 **
Indaziflam	800 lb	0.5	4.3 **	2.8 **	3.7 **	4.4 **	5.0 **
Gallery + Barricade	1 lb ai + 0.66 lb ai	0.5	1.1	0.2	0.4	0.8	0.0
Untreated	--	0.4	0.3	0.2	0.3	0.0	0.0

z = WAT: weeks after first treatment; WA2T: weeks after second treatment

y = Phytotoxicity visual ratings based on a 0-10 scale with 0 being no phytotoxicity and 10 death with ≤3 commercially acceptable

x = Treatment means followed by *,** are significantly different from the control, based on Dunnett's t-test (α = 0.10 and 0.05, respectively)

Table 3. Phytotoxicity from various herbicides on several ornamental species located at Spring Meadow Nursery near Grand Haven, MI

Berberis thunbergii SUNJOY Gold Beret ('Talago')							
Treatment	Rate/ac	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T	4 WA2T
FreeHand	150 lb	0.0	0.8	1.3	0.7	1.3	2.8 **
Untreated	--	0.0	1.5	1.9	1.0	0.8	0.0
Rosa x HOME RUN RED ('WEKcisbako')							
Treatment	Rate/ac	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T	4 WA2T
Indaziflam	200 lb	0.7	3.1	2.4	0.9	0.0	0.2
Untreated	--	0.3	3.4	2.5	0.4	0.0	0.2
Viburnum x RED BALLOON ('Redell')							
Treatment	Rate/ac	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T	4 WA2T
Biathalon	100 lb	0.0	0.3	0.0	0.0	0.0	0.0
Tower + Pendulum	21 fl oz + 2 qt	2.8 **	3.7 **	3.7 **	3.6 **	3.8 **	2.9 **
FreeHand	150 lb	0.3	0.0	0.0	0.2	0.0	0.0
Untreated	--	0.0	0.2	0.0	0.4	0.0	0.5
Azalea 'BLOOM-A-THON Pink Double'							
Treatment	Rate/ac	1 WAT	2 WAT	4 WAT	1 WA2T	2 WA2T	4 WA2T
Biathalon	100 lb	0.1	0.0	0.0	0.0	0.0	0.0
Tower + Pendulum	21 fl oz + 2 qt	0.0	3.7 **	3.9 **	4.1 **	4.1 **	4.9 **
FreeHand	150 lb	0.0	0.3	0.0	0.1	0.0	0.0
Untreated	--	0.3	0.0	0.0	0.0	0.0	0.0

z = WAT: weeks after first treatment; WA2T: weeks after second treatment
y = Phytotoxicity visual ratings based on a 0-10 scale with 0 being no phytotoxicity and 10 death with ≤3 commercially acceptable
x = Treatment means followed by *,** are significantly different from the control, based on Dunnett's t-test (α = 0.10 and 0.05, respectively)

Soluble Phenol Extraction and Weed Suppression from Selected Wood Mulches

Craig Oetting[1], William E. Klingeman[1,*], Adam Taylor[2], Kevin Hoyt[3],
Annette Wszelaki[1] and Phil Flanagan[1]

[1]University of Tennessee, Department of Plant Sciences, Knoxville, TN 37996-4561,
[2]University of Tennessee, Department of Forestry, Wildlife and Fisheries,
Knoxville, TN 37996-4563,
[3]University of Tennessee Forest Resources AgResearch and Education Center,
Oak Ridge, TN 37830

wklingem@utk.edu

Index Words: IPM, ornamental crops, phenolic compounds, phytotoxicity, weed management

Significance to Industry: Bioactive chemical compounds that protect trees from plant pathogens, insects, and fungal decomposition have been shown in some studies to limit weed seed germination and subsequent weed growth. Mulch benefits from select tree species may be extended when top-dressed on ornamental containers and landscape beds, particularly if soluble extracts leach from wood mulches to restrict substrate breakdown and weed competition. Lab and field-based demonstrations using solution extracts and mulch top-dressing from eastern red cedar, black walnut, and white oak wood chips did not support consistent or lasting inhibition of weed seed germination and did not diminish crop plant aesthetics and growth. Durability and decomposition demonstrations are ongoing with these mulch options, yet may represent the greatest value-added benefits for use of these renewable resources in sustainable landscape settings.

Nature of Work: The commercial wood products industry in the southeastern U.S. produces waste-wood chips, planer shavings, and sawdust from black walnut, oak, pine, and cedar that are periodically available in large quantities. These commercial byproducts are normally used in the manufacture of paper or burned as a low-cost fuel. However, solid wood, foliage, and extracts from select tree species can be naturally rich in bioactive chemical compounds that protect trees from plant pathogens, insects, and fungi (3). Many tree species also generate allelopathic principals that can reduce weed seed germination and growth (3, 5, 6, 7). Such wood by-products could become value-added when used alone as mulch (2, 7) or in combination with existing weed control practices thereby increasing effectiveness of weed management in cropping systems. Our own preliminary research supported potential value of top-dressing ornamental plants with black walnut (*Juglans nigra*), eastern red cedar (*Juniperus virginiana*), and ailanthus (*Ailanthus altissima*) wood chips compared with commercially available pine bark (*Pinus taeda*). Annual bedding plants grown with a 0.5-in deep mulch layer of wood from these tree species experienced reduced germination of over-seeded teaweed (*Sida spinosa*), redroot pigweed (*Amaranthus retroflexus*) and common purslane (*Portulaca oleracea*) after 28 DAT and did not reduce plant growth and aesthetic condition of annual vinca and impatiens (data not shown). If demonstrated to be practical commercially or in residential landscapes, such benefits could provide a higher-value market for wood processors and yield an incentive to deliver continuous supplies for commercial nurseries and organic/sustainable markets.

Commercial millworks within the region provided eastern red cedar, black walnut, and white oak waste wood chips. Because of its importance to the forest products industry in the southeastern U.S., white oak (*Quercus alba*) was tested instead of *Ailanthus*, which is an invasive and weedy pest species. Pine bark nuggets were purchased at a local garden center, commercial pine bark substrate was purchased from a regional distributor and commercial landscape hardwood mulch was obtained at a local firm. Water soluble constituents in woods, in a related project, fractions were collected across 3 temperatures and exposure durations from cedar, oak, and walnut wood chips for comparison with fractions from commercial pine bark nursery substrate and pine bark nuggets (3). Only 25C and 45C data are presented (Figure 1). Filtered 5 ml extracts (Whatman 802 (15 µm) Reeve Angel filters, GE Healthcare, Waukesha, WI) were collected after 24 hr submersion at 35^oC (95^oF) and 45^oC (113^oF), and were used to assay germination among 25 redroot pigweed (Herbiseed, Berkshire, ENG) and *Lactuca sativa* 'Green Ice' lettuce seeds (Park Seed Co., Hodges, SC) that were lined on heavy weight seed germination paper (Anchor Paper Co., St. Paul, MN). The experiment included 9 replicates per species. Weed and lettuce seed germination were tallied at 5DAT and root and shoot growth measurements were taken (Figures 2-4).

Ornamental plant sensitivity to potential wood mulch exudates was assessed using 6 replicates each of 'Noble Upright' *Ilex crenata*, 'Red Heart' *Hibiscus syriacus*, and 'Red Trailing Queen' Coleus (*Solenostemon scutellarioides*) plants that were transplanted into Classic 1200 (11.4 L) nursery containers in a 100 percent aged pine bark substrate (TH Blue, Inc., Eagle Springs, NC) and grown outdoors for 8 wk. About 100 each of redroot pigweed (*Amaranthus retroflexus*) and common purslane (*Portulaca oleracea*) seeds were overseeded onto the pinebark substrate in all pots at time of planting. Pots were next top-dressed to 3 inch (7.6 cm) depth with either eastern red cedar, white oak, black walnut wood chips, large (>1 inch [2.5 cm]) pine nuggets, commercial pine bark substrate (positive control) or quartered, black plastic, Pond Logic BioBall pond filter units (negative control) (Airmax Ecosystems, Romeo, MI). Weed counts were taken at 7 DAT (data not shown) and 33 DAT, with weed biomass collected on 33 DAT (weed growth in holly are presented) (Figure 5). Ornamental plant growth indices, representative leaf areas (10 leaves per plant), and total stem dry mass were measured at 56 DAT, with only holly data presented (Figure 6).

A field demonstration plot was also established into which 3-gal (11.4 L) 'Little Lime' hydrangea were planted and mulched with either eastern red cedar, white oak, black walnut wood chips, large (>1 inch [2.5 cm]) pine nuggets, commercial hardwood mulch (positive control) or commercial hardwood mulch over three layered sheets of newspaper. Each of five replicated treatment plots and four bare ground plots (1 m square) were over seeded with 0.25g each of purslane and redroot pigweed seed (yielding 657±24 and 551±9 seeds, respectively [n=5 counts]), 0.75g of lambsquarters (1035±6 seeds) and 2.0g (835±2 seeds) of teaweed seeds. Weed cover (percentage of plot) was assessed 28DAT for all species. Data are presented for smooth pigweed and teaweed, which were the only seed that germinated in the field (Figures 7, 8). Subsidence and decomposition of these wood mulch products are currently being assessed in the field as a measure of potential landscape performance and wood mulch durability (data not shown).

Results and Discussion: Spectrophotometric analyses of extractions using Folin-Ciocalteau reagent (1) confirmed that both hardwood tree species contained high levels of total phenolic compounds within woody tissues, and that these compounds were readily mobilized following exposure to water (Figure 1). Hypothetical “summer” container temperatures (45^{o}C) facilitated significantly greater release of total phenolic compounds from all wood substrates (indicated by asterisks), except from pine bark nuggets, compared with container temperatures that are more characteristic during spring season transplanting (25^{o}C [77^{o}F]). High temperatures also yielded the largest proportion of water soluble phenolics that could be recovered following a 24-hr submersion in 50:50 methanol:water (v/v) solution after 72-hr exposure to water alone (Figure 1).

Regardless, germination of pigweed seeds did not differ from exposure to treatments of total phenolic compounds made soluble in 35F extractions. Germination of lettuce was reduced when exposed to oak and commercial pine bark extracts compared with distilled water, red cedar, and walnut extracts (Figure 2). Lettuce root growth also reflected influence of 35F wood extract samples but these effects were not observed following exposure to 45F extracts, nor in root or shoot growth of pigweed at either temperature (Figures 3,4). More seeds of both plant species germinated by 5 DAT after exposure to 45F extracts and only pigweed germination was reduced across all treatments compared to DI Water alone. These results are not explained by levels of total phenolic compounds recovered from woods (Figure 1).

When wood substrates or bioball filters were top-dressed onto weed-seeded nursery containers, higher counts of common purslane and redroot pigweed were recovered among containers with only commercial pine bark. Though fewer weeds persisted by 33DAT in containers, the largest redroot pigweed and common purslane plants were recovered from pine bark nugget and eastern red cedar top-dressed containers, respectively (Figure 5), indicating capability of weeds to grow aggressively once they successfully germinate and become established. This result, paired with the reduction in germination and weed dry mass observed in containers top-dressed with inert, black, plastic bioball filter pieces (Figure 5), suggests that reduction in light exposure to seeds or alteration of the container environment may be more relevant to seed germination than release of phenolic compounds from tree substrates.

For the ornamental crops growing in these containers, growth indices, mean leaf area and total plant shoot weights did not differ among treatments for both 'Red Heart' hibiscus and 'Red Trailing Queen' coleus (*P*-value range: 0.13 to 0.69)(data not shown). Mean leaf area of 'Noble Upright' holly remained consistent across treatments (P = 0.49). Both growth indices ($P < 0.01$) and total shoot weight ($P < 0.01$) differed between treatments. Reductions in these parameters were observed for holly exposed to Eastern red cedar, white oak and pine bark nugget treatments, compared to black walnut wood chips and commercial pine bark alone (Figure 6). It is probable that holly growth parameters were limited more by competition with redroot pigweed and common purslane plants persisting in these treatments, rather than exposure to phenolics (Figure 5). It is also notable that none of the ornamentals tested, including holly (Figure 6), showed growth or total shoot weight reductions with exposure to phenolic extracts that were leached from black walnut wood chips by 33 DAT. Regardless, future availability of black walnut is a concern because, although it remains a common landscape plant and valuable timber tree, this species is threatened in portions of the eastern U.S. by Thousand Canker Disease (*Geosmithia morbida*), which is vectored by the walnut twig beetle (*Pityophthoris juglandis*).

Bioactive phenolic compounds in woods that are soluble in water can become active in the weed seedling root zone. However, applying excessive irrigation to nursery containers, particularly later in the growing season, can be expected to wash bioactive compounds out of the container substrate thus limiting the duration of their effectiveness. Following 28 and 56 DAT in replicated demonstration landscape beds, the least teaweed (Figure 7) and redroot pigweed (Figure 8) growth were observed in plots with three sheets of newspaper overlapped beneath commercial hardwood mulch. All wood substrates also out-performed the commercial hardwood mulch alone applied to a 2-inch depth on top of bare soil. Though eastern red cedar extracts did not yield lasting inhibition of weed seed germination, cedar wood chip mulch did provide a thorough and stable plot covering, which would limit light transmission to seeds and produced an aesthetically pleasing aroma when stepped on. The aesthetic scent was largely gone by 56 DAT.

Acknowledgements: Support for this research and demonstration project was provided with funding from the USDA-AMS and Tennessee Department of Agriculture's Specialty Crops Block Grant Program, and also The University of Tennessee Institute of Agriculture.

Literature Cited:

1. Ainsworth, E.A. and K.M. Gillespie. 2007. Estimation of total phenolic content and other oxidation substrates in plant tissues using Folin–Ciocalteu reagent. Nature Protocols 2: 875-877.
2. Cochran, D.R., C.H. Gilliam, D.J. Eakes, G.R. Wehtje, P.R. Knight, and J. Olive. 2009. Mulch depth effects weed germination. J. Environ. Hort. 27(1): 85-90.

3. Duryea, M.L. R.J. English and L.A. Hermansen. 1999. A comparison of landscape mulches: chemical, allelopathic, and decomposition properties. J. Arboriculture 25(2): 88-97.
4. Ferguson, J., B. Rathinasabapathi and C. Warren. 2008. Southern redcedar and southern magnolia wood chip mulches for weed suppression in containerized woody ornamentals. HortTechnology 18: 266-270.
5. Heisey, R.M. and T.K. Heisey. 2003. Herbicidal effects under field conditions of *Ailanthus altissima* bark extract, which contains ailanthone. Plant and Soil 256: 85-99.
6. Rathinasabapathi, B., J. Ferguson, and M. Gal. 2005. Evaluation of allelopathic potential of wood chips for weed suppression in horticultural production systems. HortScience 40: 711-713
7. Richardson, B., C.H. Gilliam, G. Fain and G.R. Wehtje. 2008. Nursery container weed control with pinebark mini-nuggets. J. Environ. Hort. 26(3): 144-148.

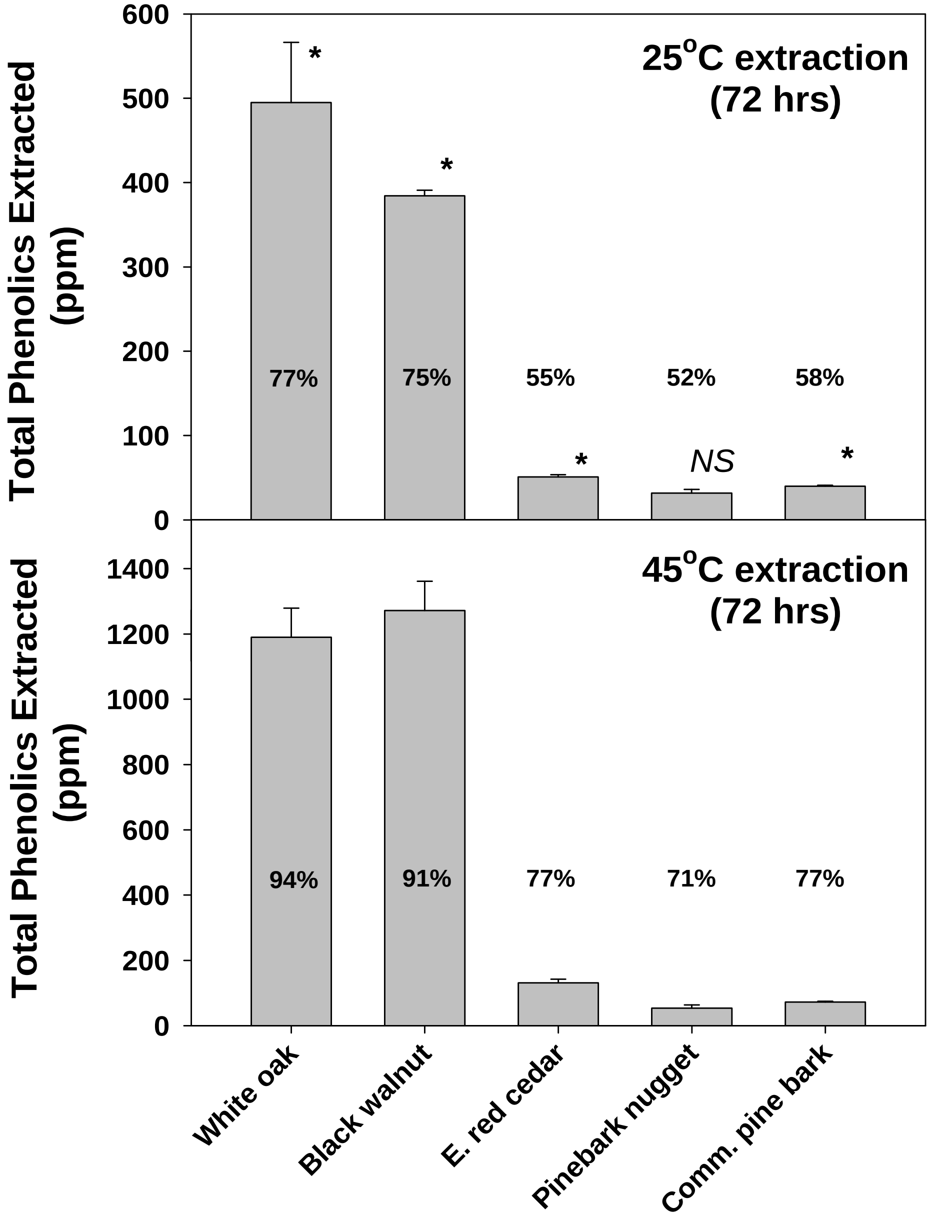

Figure 1. Total phenolics extracted with water (at 25 [top] and 45C [bottom]) after 72 hr using Folin-Ciocalteau reagent with spectrophotometer readings (765 nm)(Ainsworth and Gillespie 2007) and compared with proportion recovered with 50:50 methanol: water solution. Extractions levels differed between temperatures (3 replicates per substrate) where indicated by asterisk (*; P < 0.05).

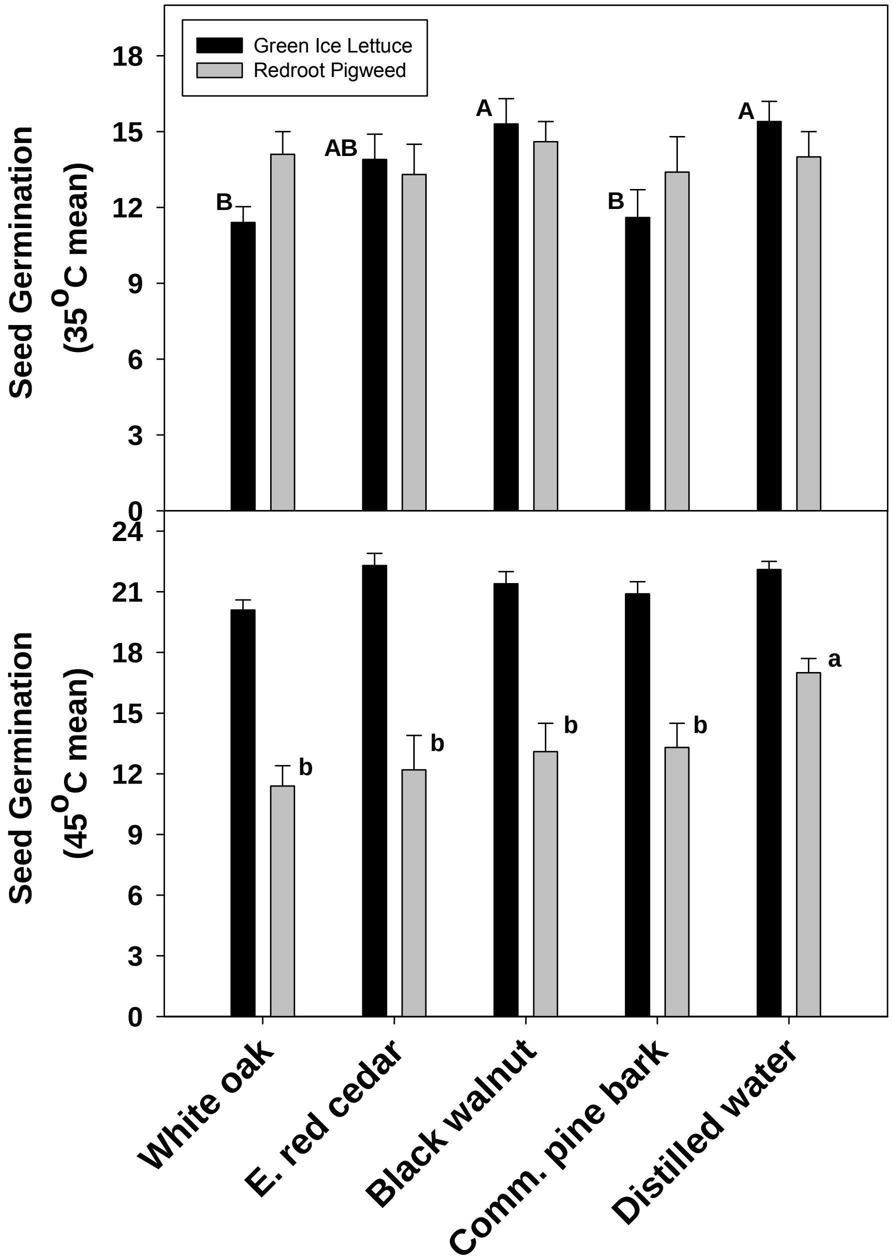

Figure 2. 'Green Ice' lettuce (black) and redroot pigweed (grey) seed germination following 5DAT exposure to 35C (top) 45C (bottom) biomulch solution extracts. Germination means only differed between treatments 5DAT and only for 'Green Ice' lettuce at 35C (upper case) and redroot pigweed at 45C (lower case) (*P* = 0.05).

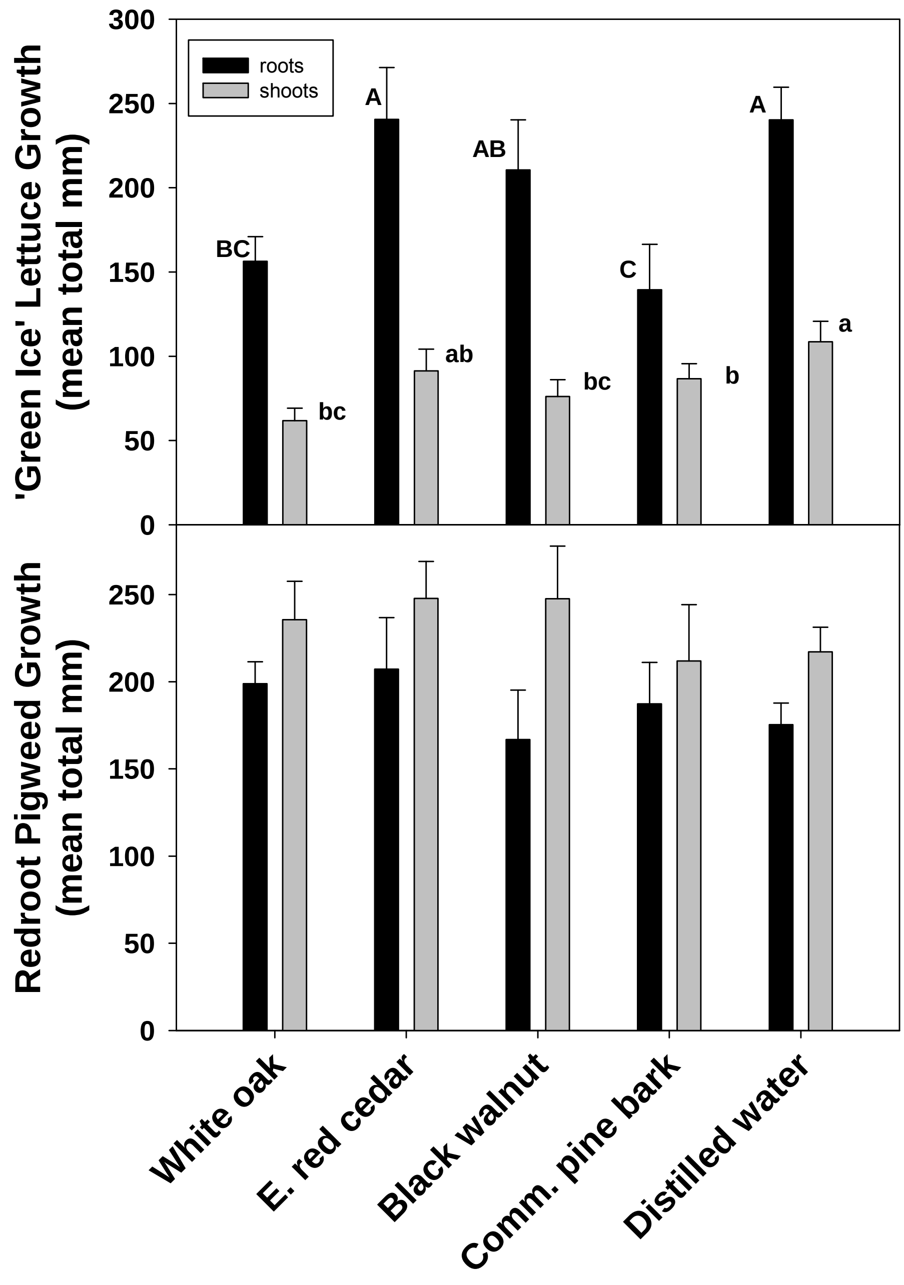

Figure 3. Lettuce and Pigweed seedling growth following 5DAT exposure to 35C biomulch solution extracts. Total root and shoot lengths were only different among treatments at 5DAT. Treatment means observed for root (upper case) and shoot lengths (lower case) in 'Green Ice' lettuce were not significantly different when annotated with the same letters (*P* = 0.05).

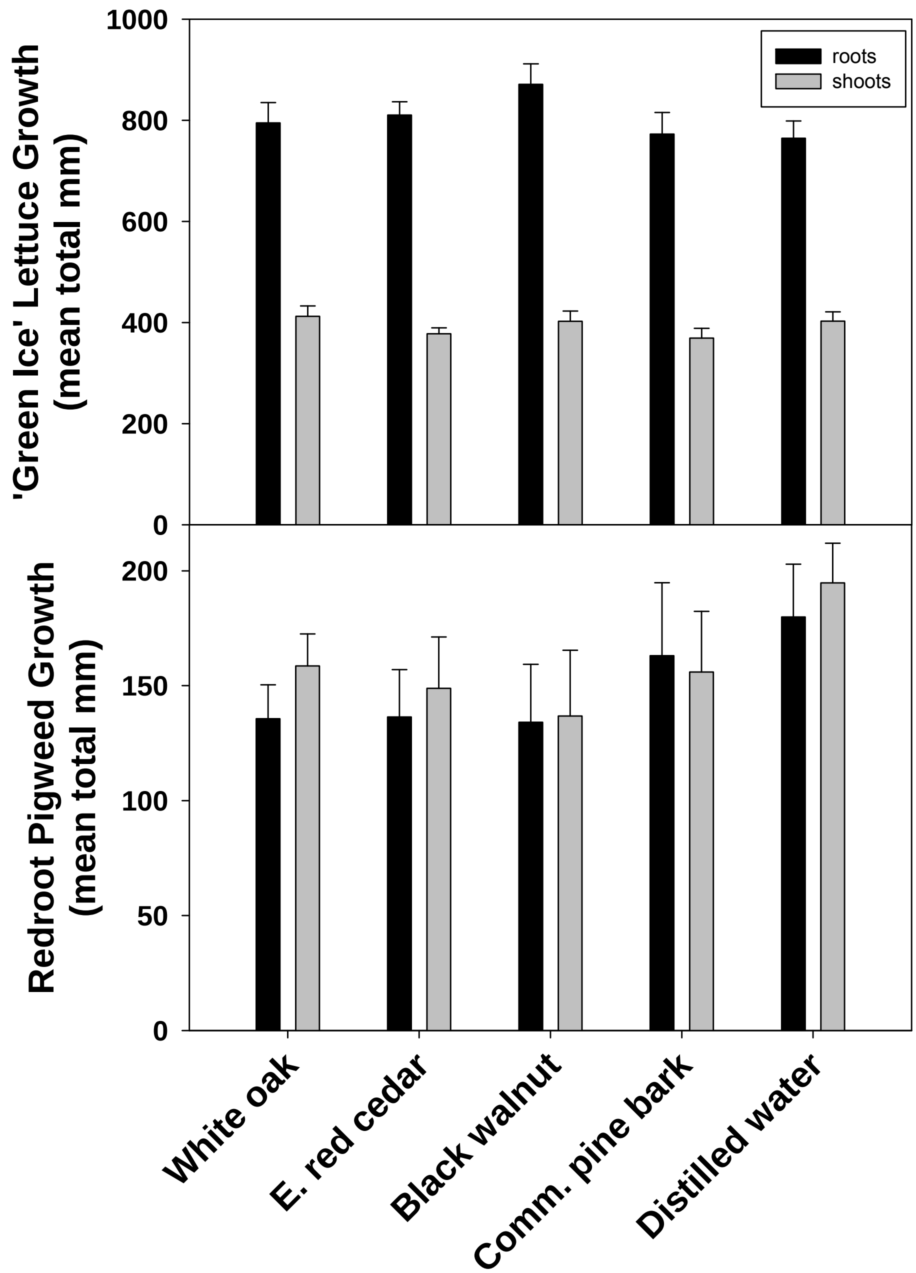

Figure 4. Lettuce and Pigweed seedling growth following 5DAT exposure to 45C biomulch solution extracts. For both plant species, means for total root and shoot lengths did not differ by treatment (*P* = 0.05).

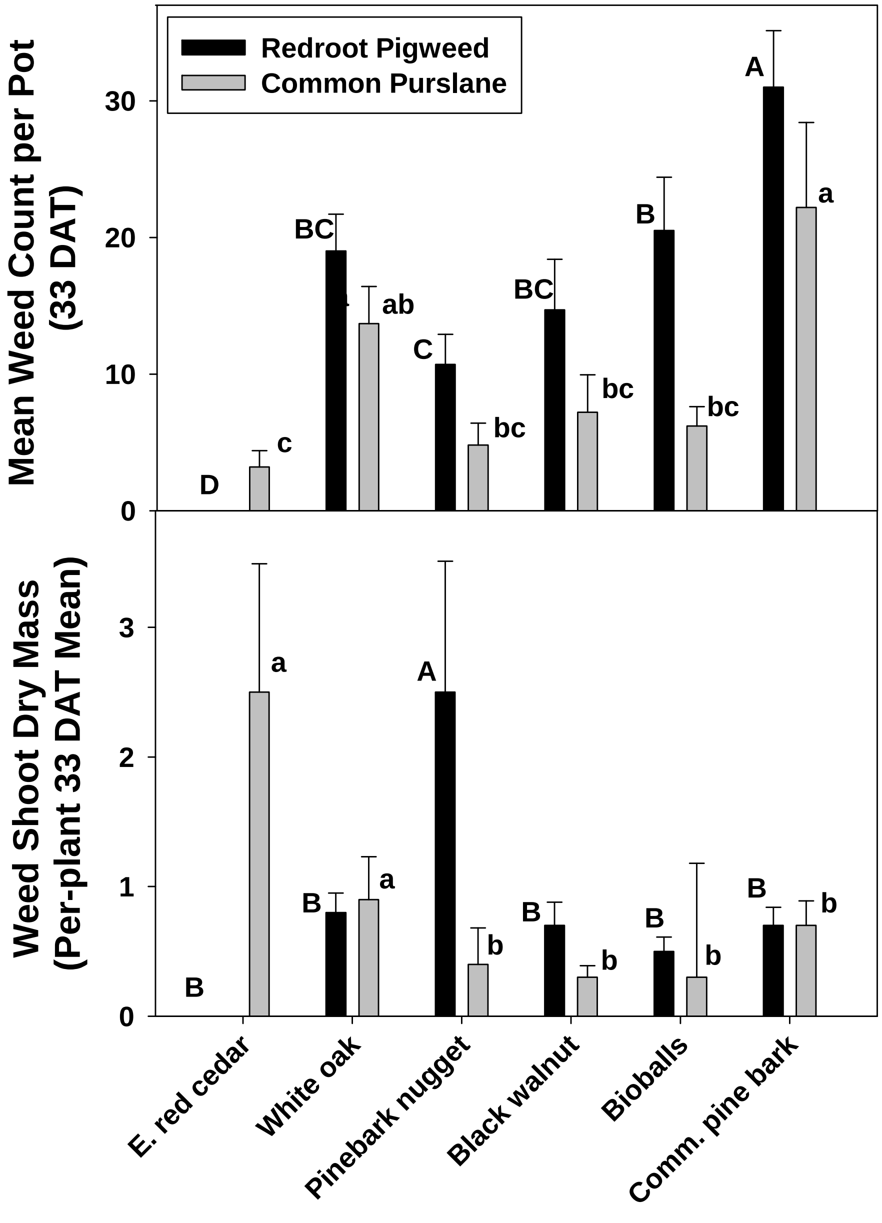

Figure 5. Redroot pigweed and common purslane growth at 33DAT in 3 gal (11.4 L) nursery containers containing a 3-inch topdressing of wood, bark chips, or inert, black plastic Bioball filters. By weed species, treatments within measured parameter are not significantly different (*P* = 0.05) when annotated with the same letters.

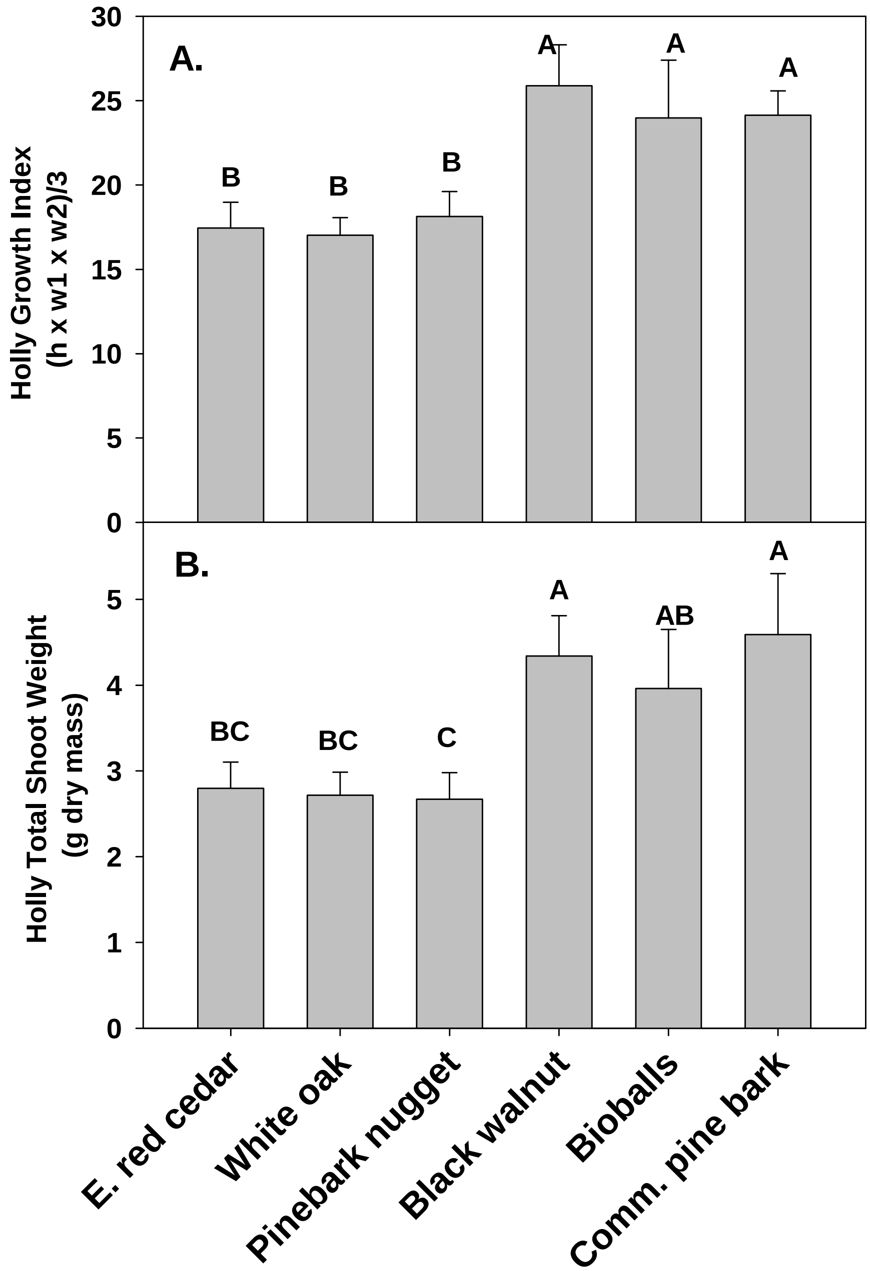

Figure 6. 'Noble Upright' holly performance in 3 gal (11.4 L) nursery containers following 56 d growth with 3-inch topdressing with wood, bark chips, or inert, black plastic Bioball filters. Holly growth indices (A.) and total shoot dry masses (B.) differed across treatment. Within graph, means presented with the same letters were not significantly different (*P* = 0.05).

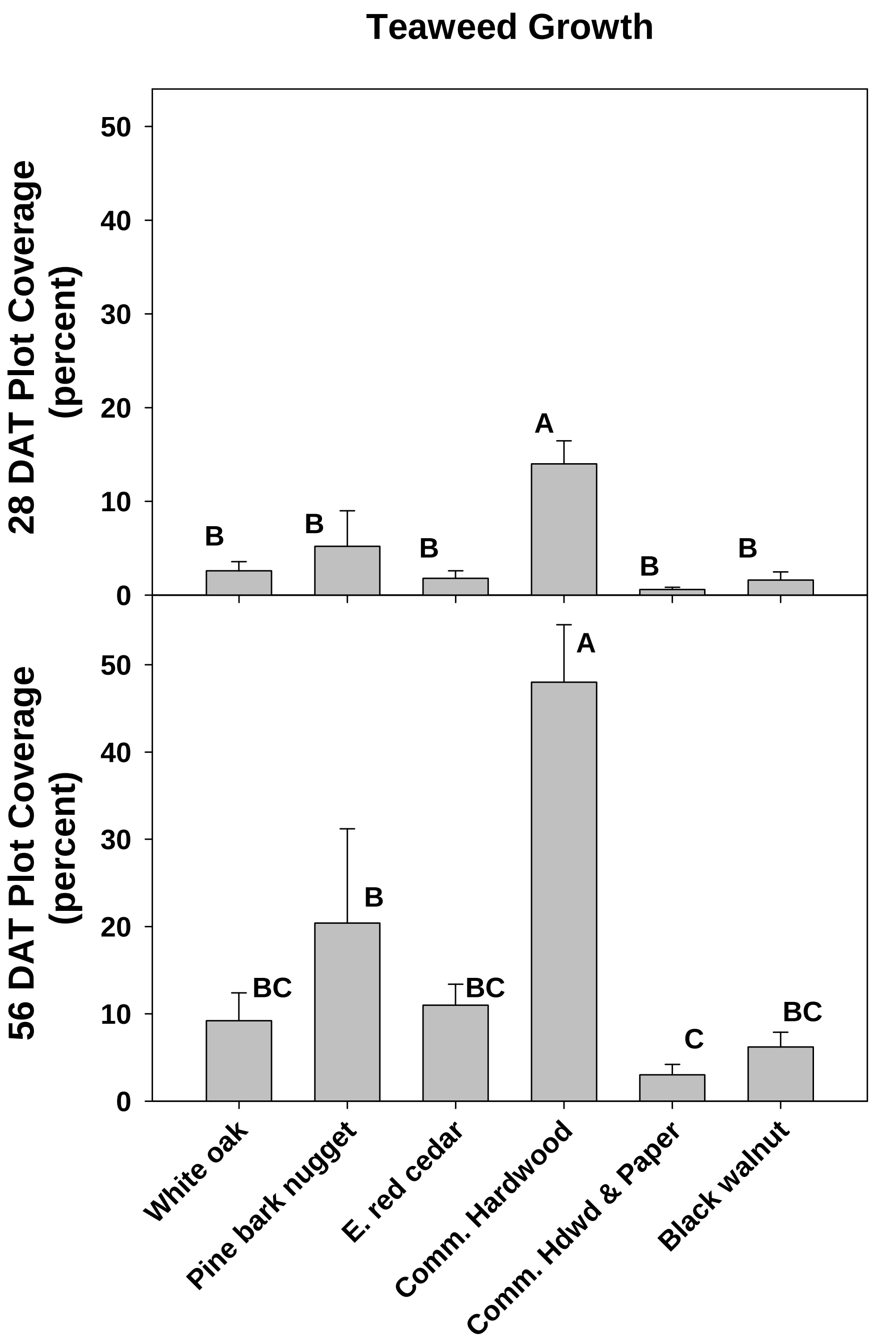

Figure 7. Visual estimates of percentage plot cover across treatments at 28 DAT (top) and 56 DAT (bottom) attributed to teaweed (*Sida spinosa*) seedlings in replicated 1-meter square field plots. Treatment differences were assessed following arcsine squareroot transformation of coverage estimates ($P < 0.05$). Non-transformed means are presented.

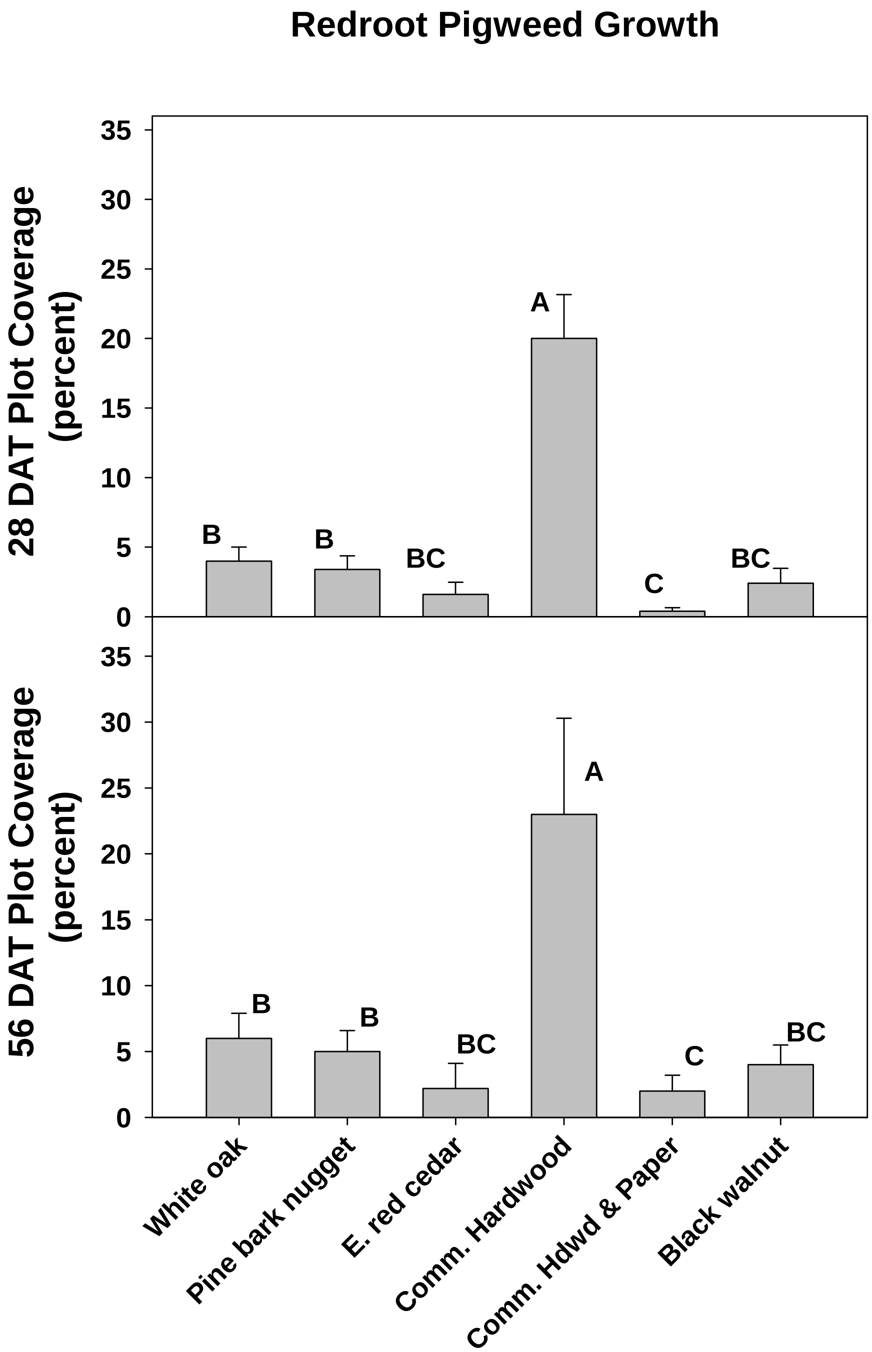

Figure 8. Visual estimates of percentage plot cover across treatments at 28 DAT (top) and 56 DAT (bottom) attributed to redroot pigweed (*Amaranthus retroflexus*) seedlings in replicated 1-meter square field plots. Treatment differences were assessed following arcsine squareroot transformation of coverage estimates ($P < 0.05$). Non-transformed means are presented.

Prostrate Pigweed Control in Containers

Joseph C. Neal and Chris Harlow

Department of Horticultural Science, North Carolina State University, Raleigh NC 27540

joe_neal@ncsu.edu

Index Words: *Amaranthus blitum*, *Amaranthus lividus*, nursery crops, preemergence, livid amaranth, purple amaranth

Significance to Industry: The prevalence of prostrate pigweed is increasing in Southeastern container nurseries suggesting that current weed management practices are not providing adequate control. This preliminary research has demonstrated that prostrate pigweed is controlled for at least 4 weeks by most preemergence herbicides labeled for use in container nursery crops. By 8 weeks after treatment Broadstar, Freehand, Barricade, Showcase (high labeled dose), OH2 and Pendulum 2G provided greater control than Dimension, Tower, Snapshot TG, Showcase (low dose), Pennant Magnum, or Gallery.

Nature of Work: Prostrate pigweed (*Amaranthus blitum* L.; syn: *Amaranthus lividus*), also known as purple amaranth or livid amaranth, was not reported to be present in container nurseries in a 1997 Eastern NC nursery weed scouting program (3). However, in recent years we have encountered this species in container nurseries with increasing frequency. It is a summer annual broadleaf weed in the pigweed family (Amaranthaceae) which reproduces exclusively by seed. Other species of pigweed (*Amaranthus*) are not commonly encountered in container nurseries. Pigweeds are generally well controlled by preemergence herbicides labeled for use in nurseries (2) and the plants' upright growth habit and seedling root structure facilitate easy hand removal. Furthermore, seeds of most common pigweeds have germination requirements that typically prevent germination until the following spring (4). Consequently, pigweeds typically do not have multiple generations per year and, if present, can be removed from container nurseries before seeds mature. In contrast, *Amaranthus lividus* (synonym for *A. blitum*) has been reported to germinate within 30 days of being shed (1). Rapid growth and development as well as limited (or no) seed dormancy, results in the potential for multiple generations of prostrate pigweed each year. These characteristics make prostrate pigweed better adapted to container crop culture than other pigweeds. Its increasing presence in nurseries also suggests that current preemergence herbicide programs are not providing adequate control but no reports are available on prostrate pigweed control in containers. Therefore an experiment was established to compare the effectiveness of several labeled preemergence herbicides for prostrate pigweed control in containers.

On May 8, 2012, one-gallon (nursery trade #1; 3-Liter) pots were filled with a pine bark substrate amended with 6 lb/yd^3 of Harrell's 17-5-11 slow release fertilizer with minor elements. Pots were hand watered after potting to settle the substrate and thereafter received about 0.6 inches of overhead irrigation daily in 3 equal increments early AM, mid-day and late afternoon. On May 11th, preemergence herbicides were applied. Granular treatments were applied in pre-weighed aliquots using a hand-held applicator. Spray treatments were applied with a CO_2 pressurized 2-L bottle sprayer calibrated to deliver 30 gallons per acre. Treatments included most preemergence herbicide active ingredients labeled for weed control in container nursery crops. Treatments were arranged in a randomized complete block design with 6 replications. On May 17th (about 1 week after treatment), prostrate pigweed was surface seeded with about 30 seeds per pot. Weed control was visually evaluated 4, 6 and 8 weeks after treatment (WAT) on a 0 to 10 scale where 0 = no weed control (pots equivalent to the non-treated) and 10 = 100% control (no weeds present). Interim numbers were a visual estimate of reduction in above-ground biomass compared to the non-treated. Because these numbers were evaluated relative to the non-treated, the values for the non-treated (zero) were omitted from the statistical analysis.

Results: All herbicide treatments controlled prostrate pigweed through 4 weeks after treatment (WAT); however, herbicides differed in longevity of control (Table 1). Evaluated 8 WAT there were significant differences in control among the treatments. Broadstar, Freehand, Pendulum 2G, and Barricade each provided greater than 95% control 8 WAT (Table 1). Other treatments that were statistically similar included the highest dose of Showcase, OH2, and Dimension + Gallery. Dimension applied alone provided essentially no control 8 WAT. Pigweed was only slightly stunted by Pennant Magnum or Gallery. Showcase at the lowest labeled rate provided less than 50% control. And, Snapshot applied at 2.5, 3.75 and 5 lb ai/A provided 30, 48 and 57 % control, respectively.

These data show that prostrate pigweed may be suppressed in container nursery crops by several of the labeled preemergence herbicides. But longevity of control varies among herbicides and doses. Additional research should be conducted to confirm these results under different environmental conditions.

Literature Cited

1. Cristaudo, A. F. Gresta, F. Luciani, and A. Restuccia. 2006. Effects of after-harvest period and environmental factors on seed dormancy of *Amaranthus* species. Weed Research 47:327-334.
2. Neal, J. C., W. A. Skroch, J. F. Derr, and A. F Senesac. 1999. Weed Control Suggestions for Christmas trees, woody ornamentals and flowers. NC Cooperative Extension Publication AG-427.
3. Neal, J. C. and A. Williams. 1998. Eastern North Carolina nursery weed scouting program - 1997. Proc. Northeastern Weed Sci. Soc. 52:134.
4. Weaver, S. E. and E. L. McWilliams. 1980. The biology of Canadian weeds. 44. *Amaranthus retroflexus* L., *A. powellii* S. Wats., and *A. hybridus* L. Can. J. Plant Sci. 60: 1215-1234.

Table 1. Prostrate pigweed control in containers with common nursery preemergence herbicides.

Treatment	Form-ulation	Active ingredient(s)	Dose (lb ai/A)	% Control	
				4 WAT*	8 WAT
Non-Treated	na	none	na	0	0
Snapshot TG	2.5 G	trifluralin + isoxaben	2.5 3.75 5.0	86 91 92	30 48 57
Showcase	2.5 G	trifluralin + isoxaben + oxyfluorfen	2.5 5.0	90 100	40 87
OH2 3G	3G	oxyfluorfen + pendimethalin	3.0	98	77
Broadstar	0.25G	flumioxazin	0.375	100	100
Freehand	1.75 G	dimethenamid-p + pendimethalin	3.5	100	100
Dimension	2EW	dithiopyr	0.5	78	7
Pendulum	2G	pendimethalin	4.0	99	100
Barricade	4 L	prodiamine	1.0	95	98
Gallery	75 DF	isoxaben	1.0	88	20
Tower	6 EC	dimethenamid-p	0.98	98	67
Pennant Magnum	7.62 EC	s-metolachlor	2.0	88	30
Dimension + Gallery	4 EW 75 DF	dimethenamid + isoxaben	0.5 + 1.0	98	73
Barricade + Gallery	4 L 75 DF	prodiamine + isoxaben	1 + 1.0	99	97
LSD (0.05)				25	29

*WAT = weeks after treatment
Note: visual evaluations of percent weed control were relative to the non-treated containers; therefore, data for the non-treated (zero) were omitted from the statistical analysis.

Evaluation of Indaziflam G for Pre-emergence Weed Control in Ornamental Landscape Beds

S. Christopher Marble and Charles H. Gilliam
Department of Horticulture, Auburn University, AL 36849

marblsc@tigermail.auburn.edu

Index Words: granular herbicide, annuals, perennials, woodies

Significance to Industry: Landscape contractors are constantly struggling to keep ornamental landscape beds weed-free in order to please their customers. Controlling weeds in beds containing sensitive species, such as annual beds, is often difficult and time consuming because few products exist that are both safe for use around the plants and also provide effective, long-lasting weed control. Indaziflam is a new herbicide now available for use in the landscape industry and is available in both a liquid (SC) and granular (G) formulation. Our objective was to evaluate the tolerance of common annual, perennial, and woody species following an application of Indaziflam G in a landscape setting. Our results indicate that while many of the species evaluated showed no signs of crop injury following an Indaziflam application, some annual species did have significant injury.

Nature of Work: Commercial and residential customers demand weed-free ornamental beds in their landscapes. Currently, there are numerous pre-emergent herbicides labeled for use in turfgrass areas, but significantly less options for controlling weeds in landscape beds, specifically, beds containing sensitive annual species. Herbicide manufacturers are hesitant to label herbicides for use around sensitive species, such as annuals, due to liability concerns. In many cases, landscape contractors must remove weeds in annual beds manually. Labor costs are continually increasing and is becoming more difficult to find due to recent immigration reform in many states (6, 4). Therefore it is important to be able to find effective pre-emergent herbicides that can be safely applied in landscape beds containing annual, perennial, or woody species.

Indaziflam is a new active ingredient in the alkylazone chemical class recently released from Bayer CropScience, and controls weeds by inhibiting cellulose biosynthesis (1). Indaziflam provides effective PRE control of grass and broadleaf weeds (7) and the spray formulation been shown to provide early POST control of common weeds in turf grass (2, 3) and in container production (5). The objective of this research was to evaluate the crop tolerance of selected annual, perennial, and woody ornamental species following a fall application of the granular formulation of Indaziflam.

This trial was conducted at the Old Agronomy Farm located on the campus of Auburn University in Auburn, AL. On September 17, 2012, landscape beds were constructed by tilling a field site with a rear-tine tiller. Before tilling, beds were amended with 13N-

5.6P-10.9K (13-13-13) Polyon™ (Agrium Advanced Technologies, Loveland, CO) control release (8 to 9 month) fertilizer applied at a rate of 1 lb. N per 1,000 ft^2 (4.9 g N/m^2). On September 19, 2012, seven species were transplanted from nursery containers or liners (specified parenthetically) into the prepared landscape beds. Species included Chinese holly [*Ilex cornuta*, (trade gallon, 3.0 L)], dwarf gardenia [*Gardenia radicans*, (trade gallon, 3.0 L)], Little zebra miscanthus grass [*Miscanthus sinensis* ‘Little Zebra’ (full gallon, 3.8 L)], Gold mound lantana [*Lantana camara* ‘Gold Mound’ (trade gallon, 3.0 L)], snapdragon [*Antirrhinum majus* (3 in. (7.6 cm) 9 cell pack], Dianthus [*Dianthus spp*. (3 in. (7.6 cm) 9 cell pack)], and pansy [*Viola spp*. (1 in.(2.5 cm) 36 cell pack)]. Plants were planted in rows, by species, and watered in using overhead irrigation [0.5 in (1.3 cm)] after planting. On October 8, 2012, all plots were hand-weeded (hoed and weeded by hand) to remove all emerged weeds. On October 9, 2012 [overcast, 63˚ F (17˚ C), 72% relative humidity, winds S at 6 mph), Indaziflam G was applied over-the-top of the plants at the selected rates (Table 1) to weed-free plots using a belly grinder. Four hours after herbicide treatment, all plots were watered in [0.5 in (1.3 cm)] using overhead irrigation. Plants were then watered as needed using overhead irrigation for the duration of the trial.

The experiment was designed as a randomized complete block design with 3 replications per treatment. Each of the 7 species were planted in single rows and each row contained 8 single plant replications in each block.

Data collected included plant injury ratings (0 to 10, 0 = no injury and 10 = dead plant) each week for 10 weeks after treatment (WAT). Following 10 WAT, injury ratings were recorded every two weeks for 28 weeks. Weed coverage ratings [percent coverage with weeds, 0 = 0% of the plot covered with weeds (100% control); 100 = 100% of the plot covered with weeds (0% control)] were also taken every four weeks (data not shown). Injury data was analyzed by species and weed coverage data was analyzed for each treatment across the entire planting area. All data was analyzed using Tukey’s Honest Significance Test in the Proc GLM procedure using SAS software. In all cases, differences were considered significant at $p = 0.05$. Only injury ratings at 1, 4, 8, 12, and 16 WAT from dwarf gardenia, lantana, dianthus, and pansy are presented due to similarities amongst the data.

Results and Discussion: No injury was observed on dwarf gardenias throughout the study, regardless of rate applied (Tables 1 and 2). Additionally, all gardenias had healthy new growth in the following spring (May, 2013) and no noticeable differences in plant size were observed among the different treatments. Similarly to gardenias, lantanas showed excellent tolerance to Indaziflam applications and had mean injury ratings of 0.0 in all treatments throughout the study (Table 2). While no flower counts were taken, all lantanas appeared to have similar flower production and all would have been considered highly marketable during the growing season.

Minor injury was observed on dianthus when treated at the 800 lbs/A (896 kg/ha) rate and was first observed at 12 WAT (Table 3). Injury seen on Dianthus was minor stunting, and no other symptoms (necrosis, flower reduction, chlorosis, etc.) were observed throughout the study. While dianthus was slightly stunted when treated at the 800 lbs/A (896 kg/ha) rate, injury symptoms were minimal and at no time did mean injury ratings exceed 0.6. Further, dianthus treated at the 200 and 400 lbs/A (224 and 448 kg/ha) rates showed no signs of injury at any time.

Pansies began to show signs of injury at 1 WAT (Table 4). By 4 WAT, mean injury ratings for pansies were 2.4, 2.9, and 3.2 when treated at the 200, 400, and 800 lbs/A (224, 448, and 896 kg/ha rates, respectively). Pansy injury ratings remained above 1.0 for plants treated at the 200 lbs/A (224 kg/ha) rate for most of the trial, while mean injury ratings generally remained above 2.5 and 3.0 for plants treated at the 400 and 800 lbs/A (448 and 896 kg/ha) rates, respectively. Pansy injury was severe stunting, flower reduction, chlorosis, and complete plant death in many cases, specifically at the highest rate.

Data indicate that a fall application of Indaziflam G can be safely applied over-the-top of dwarf gardenias and Gold Mound lantana. While dianthus did show signs of injury when treated at the highest rate, it is likely that dianthus would tolerate a labeled application rate of Indaziflam G. Pansies were very sensitive to applications of Indaziflam at all rates tested and many died within the first 8 weeks after application. It would not be recommended to apply Indaziflam to landscape beds containing pansies, or to turf areas that were in close proximity to annual beds containing pansies.

In this study, Indaziflam provided excellent (10% weed coverage or less) through 16 WAT at all applied rates (data not shown), indicating that Indaziflam applications will provide effective pre-emergent weed control in landscape beds. Results also indicate that Indaziflam can be applied safely around many different ornamental species. While some species, specifically annuals, will show sensitivity to Indaziflam G applications, others species showed tolerance to extremely high application rates [800 lbs/A (896 kg/ha)]. Before making any herbicide application, especially new products, landscapers and growers should test crop tolerance on a small area before making any large-scale applications and always follow the manufacturer's labeled recommendations.

Literature Cited:

1. Anonymous. 2009. Bayer CropScience presents new herbicidal active ingredient indaziflam. Available at http://www.bayercropscience.com/bcsweb/cropprotection.nsf/id/ F730899 C884F 24ADC1257558003E5E76. Accessed on February 2, 2012.
2. Brosnan, J.T., P.E. McCullough, and G.K. Breeden. 2011. Smooth crabgrass control with indaziflam at various spring timings. WeedTechnology. 25:363-366.
3. Brosnan, J.T., G.K. Breeden, P.E. McCullough, and G.M. Henry. 2012. Pre and post control of annual bluegrass (*Poa anna*) with indaziflam. WeedTechnology. 26:48-53.
4. Johnson, K.R. 2011. Sweet home Alabama? Immigration and civil rights in the "new" south. Available at: http://www.stanfordlawreview.org/online.sweet-home-alabama. Accessed: February 2, 2012.

5. Marble, S.C., C.H. Gilliam, G.R. Wehtje, and M. Samuel-Foo. 2013. Early postemergence control of yellow woodsorrel (*Oxalis stricta* L.) with residual herbicides. WeedTech. (In Press).
6. Martin, P. and L. Calvin. 2010. Immigration Reform: What does it mean for agriculture and rural America? Applied Economics Perspectives and Policy. 32:232-253.
7. Myers, D. F., R. Hanrahan, J. Michel, B. Monke, L. Mudge, L.Norton, C. Olsen, A. Parker, J. Smith, and D. Spak. 2009. Indaziflam/BCS-AA10717-A new herbicide for pre-emergent control of grasses and broadleaf weeds for turf and ornamentals. Proc. South. Weed Sci. Soc. 62:393.

Table 1. Crop tolerance of selected ornamentals following Indaziflam G application.

		Dwarf Gardenia Injury Ratings (0 - 10)[z]				
		1 WAT[y]	4 WAT	8 WAT	12 WAT	16 WAT
Herbicide	**Rate**[x]	10/17/12	11/7/12	12/6/12	1/4/13	1/31/13
1. Nontreated	N/A	0.0 a[w]	0.0 a	0.0 a	0.0 a	0.0 a
2. Indaziflam G	200 lbs/A (224 kg/ha)	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a
3. Indaziflam G	400 lbs/A (448 kg/ha)	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a
4. Indaziflam G	800 lbs/A (896 kg/ha)	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a
Herbicide	**Rate**	**Gold Mound Lantana Injury Ratings (0 - 10)**				
1. Nontreated	N/A	0.0 a[w]	0.0 a	0.0 a	0.0 a	0.0 a
2. Indaziflam G	200 lbs/A (224 kg/ha)	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a
3. Indaziflam G	400 lbs/A (448 kg/ha)	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a
4. Indaziflam G	800 lbs/A (896 kg/ha)	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a
Herbicide	**Rate**	**Dianthus Injury Ratings (0 - 10)**				
1. Nontreated	N/A	0.0 a[w]	0.0 a	0.0 a	0.0 b	0.0 b
2. Indaziflam G	200 lbs/A (224 kg/ha)	0.0 a	0.0 a	0.0 a	0.0 b	0.0 b
3. Indaziflam G	400 lbs/A (448 kg/ha)	0.0 a	0.0 a	0.0 a	0.0 b	0.0 b
4. Indaziflam G	800 lbs/A (896 kg/ha)	0.0 a	0.0 a	0.0 a	0.6 a	0.6 a
Herbicide	**Rate**	**Pansy Injury Ratings (0 - 10)**				
1. Nontreated	N/A	0.0 b[w]	0.0 c	0.0 d	0.0 c	0.0 b
2. Indaziflam G	200 lbs/A (224 kg/ha)	0.9 a	2.4 b	1.1 b	1.3 b	0.9 b
3. Indaziflam G	400 lbs/A (448 kg/ha)	0.7 a	2.9 ab	2.6 a	3.1 a	2.9 a
4. Indaziflam G	800 lbs/A (896 kg/ha)	1.1 a	3.2 a	3.1 a	3.6 a	4.2 a

[z]Injury ratings were taken on a scale of 0 to 10; 0 = no injury, >3.0 = unacceptable level of injury, 10 = dead plant.
[y]WAT = weeks after treatment. All plants were treated on October 9, 2012.
[x]lbs/A = pounds of product applied on a per acre basis; kg/ha = kilograms of product applied on a per hectare basis.
[w]Means separated using Tukey's Studentized Range Test. Differences were considered significant at $p \leq 0.05$.