Weed Growth and Efficacy of PRE-Applied Herbicides in Alternative Rooting Substrates Used in Container-Grown Nursery Crops

Author(s): Glenn Wehtje, James E. Altland, Charles H. Gilliam, Stephen C. Marble, Albert J. Van Hoogmoed, and Glenn B. Fain

Source: Weed Technology, 23(3):455-459. 2009.
Published By: Weed Science Society of America
DOI: 10.1614/WT-09-011.1
URL: http://www.bioone.org/doi/full/10.1614/WT-09-011.1

Weed Growth and Efficacy of PRE-Applied Herbicides in Alternative Rooting Substrates Used in Container-Grown Nursery Crops

Glenn Wehtje, James E. Altland, Charles H. Gilliam, Stephen C. Marble, Albert J. Van Hoogmoed, and Glenn B. Fain*

Container-grown nursery crops in the southeastern United States are typically grown in a rooting substrate comprised primarily of the ground bark of pine trees. However, pine bark is becoming less available and more costly because of changes in production and marketing practices within southeastern pine forestry. This shortage has resulted in the economic incentive to seek pine bark alternatives. Two possible alternatives are clean chip residual and whole tree. These alternatives are like pine bark, because both are products of southern pine forestry. Unlike pine bark, which is a single part of the tree, these alternatives contain all parts of the tree, including wood and foliage in various portions. Registration of preemergence-active herbicides has been based solely upon data obtained from pine bark–based nursery production. Research was conducted to determine if the control of (1) large crabgrass with prodiamine, (2) eclipta with flumioxazin, and (3) spotted spurge with isoxaben would be comparable in these alternatives to what has been established in pine bark. Seed germination of all three weed species in no-herbicide controls was approximately 10% and equivalent between pine bark and the alternatives. Foliage fresh weight production of large crabgrass and spotted spurge was less in the alternatives compared to pine bark; eclipta was not affected. For all three weed species–herbicide combinations, weed control was nearly identical between pine bark and the alternative substrates, provided the herbicide had been applied at its registered rate. For all three herbicides, rates that are effective in pine bark substrates will be equally effective in the pine bark alternatives.

Nomenclature: Flumioxazin; isoxaben; prodiamine; eclipta *Eclipta alba* (L.); large crabgrass *Digitaria sanguinalis* (L.) Scop.; spotted spurge *Chamaesyce maculata* (L.) Small.

Key words: Clean chip residual, ornamental plant production, pine bark, soilless growth media, southern pine forestry.

Container-grown nursery crops are a major agricultural industry in the United States. These crops are not grown in soil, but in substrates comprised primarily of organic material. Ground pine bark (predominately, but not exclusively, *Pinus taeda* L.) has been the most commonly used organic material in the southeast. Pine bark–based substrates became the industry standard because they (1) were readily available and economical, (2) offered an excellent balance between water retention and drainage, (3) were relatively sanitary with respect to plant diseases, and (4) were sufficiently light in weight so as to minimize product shipping costs (Davidson et al. 2000).

Pine bark has recently become costlier and less readily available because of changes in harvesting and marketing practices within southeastern pine forestry (Lu et al. 2006). Reduced availability has forced producers of container-grown ornamentals to examine other organic materials as either a partial or complete replacement for pine bark. Clean chip residual (CCR) and whole tree (WT) are two possible alternatives. Like pine bark, both CCR and WT are products derived from southeastern pine forestry. In-field harvesting and processing of pine trees is becoming more common. In such operations trees are cut and processed in situ into wood chips, termed "clean chips," which are utilized by pulp mills. CCR is a byproduct of this harvesting process. CCR can account for up to 25% of the total biomass available, and is typically composed of 50% wood, 40% bark, and 10% needles. WT is a variation of this process in that trees are also removed in toto and chipped, but no portion is preferentially selected. WT is typically composed of 80% wood, 10% bark, and 10% needles (Boyer et al. 2008). Further descriptions of these materials, including physical and chemical properties, are available elsewhere (Boyer et al. 2008; Fain et al. 2008; Gruda and Schnitzler 2003b). The ability of these substrates to be utilized for nursery crop production has been evaluated by several researchers (Boyer et al. 2006, 2008; Fain et al. 2008; Gruda and Schnitzler 2003a; Wright and Browder 2005; Wright et al. 2006, 2008). In general these authors conclude that these materials have merit as possible alternatives to pine bark, provided that appropriate changes in nutrient management are observed.

Weed control remains a constant issue in the production of container-grown ornamentals. Substrates are relatively free of weed seed when first prepared; however, containers quickly become contaminated with weed seed through wind and/or water dispersal. Several preemergence-active herbicides are registered for use in container-grown nursery crops. Registration of these products, as well as the recommendations for their use, has been based primarily upon data obtained from pine bark–based production. It would seem logical that if alternative substrates can support the growth of the nursery crops, weed infestation would also be likely. However, it remains unclear whether the recommended rates for preemergence-active herbicides used in container-grown ornamentals, which were likely derived from research conducted in pine bark–based production, will be equally effective in alternative

DOI: 10.1614/WT-09-011.1

* First author: Professor, Agronomy and Soils, Auburn University, Auburn, AL 36849; second author: Research Horticulturist, U.S. Department of Agriculture—Agricultural Research Service, Wooster, OH 44691; third author: Professor, Horticulture, Auburn University, Auburn, AL 36849; fourth and fifth authors: Graduate Research Assistants in Horticulture, Auburn University, Auburn, AL 36849; sixth author: Assistant Professor, Horticulture, Auburn University, Auburn, AL 36849. Corresponding author's E-mail: wehtjgr@auburn.edu

Table 1. Germination and growth of three weed species when seeded into substrates comprised of pine bark and four pine bark alternatives.

Substrate		Weed species					
		Large crabgrass		Eclipta		Spotted spurge	
Organic material[a]	Size	Germination	Fresh weight	Germination	Fresh weight	Germination	Fresh weight
		%	g/pot	%	g/pot	%	g/pot
PB	–	11.7	12.7	9.3	2.9	9.7	7.4
CCR	Small	14.3	8.5	15.0	2.2	11.0	1.6*
CCR	Large	12.7	8.7	14.0	2.2	10.3	2.3*
WT	Small	15.0	5.8*[b]	15.3	2.0	9.0	4.8*
WT	Large	11.7	5.6*	14.7	2.3	12.3	5.2*
$LSD_{0.05}$		5.5	5.0	6.3	1.4	3.1	1.7

[a] Abbreviations: PB = pine bark, CCR = clean chip residue, and WT = whole tree.

[b] The asterisks indicate that the mean is significantly different from pine bark based upon Fisher's Protected $LSD_{0.05}$ comparison. All data collected 1 mo after seeding.

substrates. Our first research objective was to compare weed seed germination and subsequent growth of selected weed species between a pine bark–based and the aforementioned alternative substrates. Our second objective was to compare herbicide performance between these alternative substrates and the traditional pine bark–based substrate.

Materials and Methods

Studies were conducted between April and September of 2008. All experiments were conducted at the Paterson Greenhouse Complex, located on the main campus of Auburn University, Auburn, AL. Large crabgrass, eclipta, and spotted spurge were selected for evaluation because of their prevalence in container nursery production. Seed of large crabgrass were obtained from a commercial source.[1] Seed of eclipta and spotted spurge had been collected locally the previous year and stored at 4 C. The preemergence herbicides prodiamine, isoxaben, and flumioxazin were selected for evaluation. Herbicide treatments were applied within an enclosed-cabinet sprayer calibrated to deliver 280 L/ha at 193 kPa.

Five substrates were prepared: one using pine bark, two with CCR, and two with WT. The pine bark substrate was prepared by mixing pine bark (which had been passed through a 0.95 cm screen) and sand in a 6 : 1 ratio (v/v). This substrate was then amended with a controlled-release granular fertilizer,[2] dolomitic limestone, and a micronutrient fertilizer[3] at 10.9, 5.1, and 1.2 kg/m^3, respectively. Bulk CCR, which had been obtained from a local supplier, was passed through either a 0.95-cm screen to yield CCR-small, or through a 1.27-cm inch screen to yield CCR-large. These two sizes of CCR were then used to prepare substrates as previously described, but with the CCR used in lieu of pine bark. Comparable procedures were used to prepare two WT-based substrates.

Prodiamine was applied at six rates: 1.34, 1.12, 0.78, 0.56, 0.45, 0.34, and 0.22 kg/ha. Each rate was applied to six, 10-cm square plastic pots that had been filled with each of the five substrates. Immediately after herbicide treatment, pots were overseeded with 25 large crabgrass seed. Prodiamine is registered for large crabgrass control at rates between 0.74 and 1.68 kg/ha. Isoxaben was applied at the same rates as was prodiamine and subsequently overseeded with 25 spotted spurge seed. Isoxaben is registered for spotted spurge control at 1.12 kg/ha. Flumioxazin was applied 0.50, 0.44, 0.29, 0.21, 0.17, 0.13, and 0.08 kg/ha, and treated pots were overseeded with 25 eclipta seed. Flumioxazin is registered for eclipta control at 0.43 kg/ha. Experimental controls included the three weed species overseeded on to the five substrates but with no herbicide treatment. Pots were maintained outside under full sun exposure, where they received 0.6 cm of overhead irrigation daily. A randomized complete block design was used. Weed species–herbicide were the blocking criteria. Experiments were repeated in time. All data were collected 1 mo after treatment.

Effect of alternative substrates on weed seed germination and seedling growth was determined from the controls, i.e., treatments where seed had been overseeded onto the five substrates but herbicide had not been applied. Germination was determined by expressing the number of seedlings present as a percentage of the 25 seed that had been planted. Seedling growth was determined by clipping and determining weed foliage fresh weight. Data were subjected to ANOVA with the use of the general linear model procedure in SAS®.[4] Percent germination data were arcsin square-root transformed prior to analysis, although actual data are presented for clarity. Data were pooled over the two repetitions, because no treatment-by-experimental-repetition interactions were detected in the initial ANOVA. Fisher's protected $LSD_{0.05}$ test was used to compare germination and weed growth between the pine bark–based and the alternative substrates.

Herbicide efficacy was determined by clipping and determining the fresh weight of the weed foliage in all herbicide-receiving treatments, and expressed as percent reduction relative to the appropriate nontreated control. Data were pooled over the two experimental repetitions because no treatment-by-repetition interactions were detected in the initial ANOVA. Model fitting was performed with SAS to determine the most appropriate linear or nonlinear model, as well as which terms should be included in the model (Freund and Littel 2000; Seefeldt et al. 1995). Comparisons of models were performed with the lack-of-fit test. SigmaPlot®[5] was used to summarize and present control data.

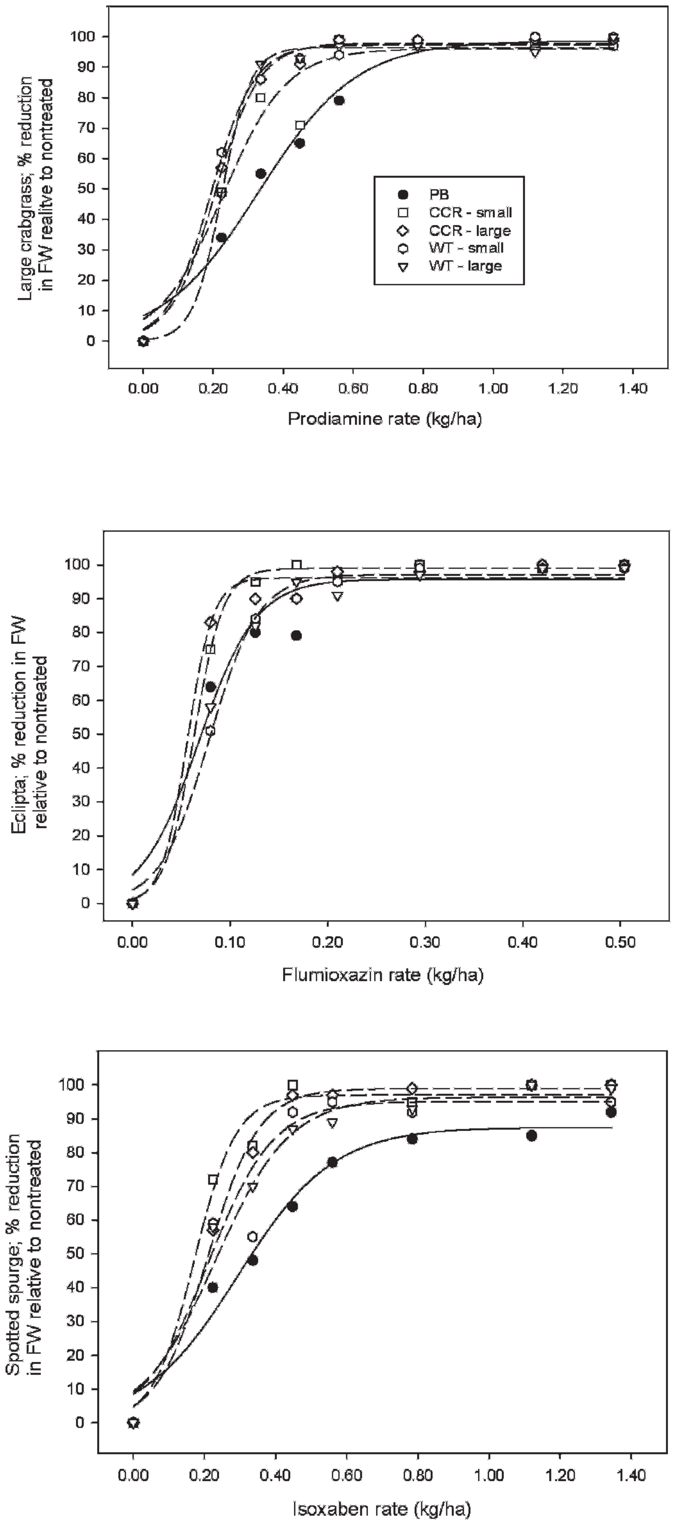

Figure 1. Percent reduction in foliar fresh weight (FW) of three weed species as a function of herbicide rate and substrate. Substrates include pine bark (PB) and four alternatives: i.e., clean cut residue (CCR) with small and large particles, and whole tree (WT) small and large. Refer to Table 2 for parameter estimates derived from nonlinear regression.

Results and Discussion

Seed germination of large crabgrass, eclipta, and spotted spurge in pine bark substrate was 11.7, 9.3, and 9.7%, respectively (Table 1). Statistically equivalent germination was obtained in all four alternative substrates. Large crabgrass foliar weight was less in both sizes of the WT substrate. Spotted spurge weight was less in all four alternative substrates (i.e., CCR-large and -small, and WT-large and -small). Only eclipta was able to growth equally well in the alternatives as it did in pine bark. CCR was inhibitory to the growth of spotted spurge. WT was inhibitory to both large crabgrass and spotted spurge.

Lack-of-fit test was used to determine the most effective model in describing weed control response to herbicide rate. Furthermore, it was also used to determine if substrate types and particle size were important (significant) terms in describing variation of weed response to herbicide rate. For each of the three weed species–herbicide combinations, it was determined that both substrate type and particle size were important factors; thus separate functions for each of the five substrate combinations are presented (Figure 1 and Table 2).

Large crabgrass control with prodiamine could be accurately expressed with a three-parameter log-logistic function; R^2 values ≥ 0.81 (Figure 1 and Table 2). The response of large crabgrass to prodiamine rate was different for each of the five substrates evaluated ($P < 0.001$, as determined by comparing the log-logistic functions with the lack-of-fit test). Large crabgrass control was approximately 99% with prodiamine at rates $\geq$ 0.78 kg/ha in pine bark, and in all four alternatives (Figure 1). Control progressively decreased as the rate decreased below 0.78 kg/ha. Decreasing control with decreasing rates was more pronounced in pine bark than in the alternatives. This difference is evident in the LD_{50} values (Table 2), which indicates the rate required for 50% control of the target (i.e., large crabgrass) population. The LD_{50} for prodiamine in pine bark was 0.29 kg/ha vs 0.17 to 0.20 kg/ha in the alternatives. Thus less prodiamine was needed to obtain comparable control in the alternatives than in pine bark. The $> b =$ term in the model indicates the slope or steepness of ascent from the minimum to the maximum part of the curve, a more negative b indicating a steeper slope. Both CCR-large and WT-large had higher (i.e., more negative) b values than other substrates. This difference indicates the transition between no efficacy and efficacy occurs within a narrower rate range compared to the other substrates.

Eclipta control with flumioxazin was also accurately expressed with a three-parameter log-logistic function; R^2 values ≥ 0.81 (Figure 1 and Table 2). Control also differed in each of the five substrates ($P = 0.001$). However, eclipta control in all five substrates was approximately 99% with flumioxazin rates $\geq$ 0.21 kg/ha (Figure 1). LD_{50} values were similar (i.e., 0.06 to 0.07 kg/ha) for all substrates except CCR-large (0.02 kg/ha). Both CCR-small and WT-small had noticeably higher b values, again indicating that the transition between no efficacy and efficacy occurred within a comparatively narrow rate range.

As with the previous two species, spotted spurge control with isoxaben was accurately expressed with a three-parameter log-logistic function; R^2 values ≥ 0.75 (Figure 1 and

Table 2. Three-parameter log-logistic equations describing reduction in foliar fresh weight of three weed species to selected herbicides when in pine bark and four alternative substrates. Three-parameter model: $y = D/[1 + (\text{rate}/LD_{50})^b]$.

Herbicide/weed species	Substrate[a]		Model parameters[b]			
	Organic material	Size	*D*	*b*	LD_{50}	R^2
Prodiamine/large crabgrass	PB	–	105.0 (7.4)	− 2.13 (0.49)	0.29 (0.03)	0.85
	CCR	Small	100.3 (5.6)	− 2.46 (0.82)	0.20 (0.02)	0.81
	CCR	Large	100.0 (2.5)	− 3.46 (0.82)	0.18 (0.01)	0.92
	WT	Small	99.6 (2.6)	− 2.96 (0.75)	0.17 (0.17)	0.93
	WT	Large	96.9 (1.6)	− 6.42 (1.48)	0.20 (0.00)	0.94
Flumioxazin/eclipta	PB	–	106.4 (11.1)	− 1.48 (0.80)	0.06 (0.01)	0.81
	CCR	Small	99.3 (2.2)	− 4.43 (2.66)	0.06 (0.01)	0.91
	CCR	Large	105.2 (12.2)	− 1.02 (1.04)	0.02 (0.02)	0.90
	WT	Small	99.8 (2.9)	− 3.19 (0.72)	0.07 (0.00)	0.91
	WT	Large	99.5 (3.5)	− 2.70 (0.86)	0.06 (0.01)	0.87
Isoxaben/spotted spurge	PB	–	96.0 (10.6)	− 1.91 (0.70)	0.27 (0.04)	0.75
	CCR	Small	99.0 (3.9)	− 2.34 (1.10)	0.13 (0.03)	0.89
	CCR	Large	100.9 (3.8)	− 3.26 (1.05)	0.19 (0.02)	0.85
	WT	Small	101.9 (6.2)	− 1.96 (0.62)	0.19 (0.02)	0.86
	WT	Large	103.8 (6.5)	− 1.71 (0.54)	0.18 (0.02)	0.90

[a] Abbreviations: PB = pine bark, CCR = clean chip residue, and WT = whole tree.

[b] Values in parentheses = standard error for associated parameter.

Table 2). Control differed in each of the five substrates (P = 0.001). Similar to large crabgrass control with prodiamine, spotted spurge control with marginal isoxaben rates was greater in the alternative substrates compared to pine bark. Spotted spurge control in pine bark progressed from approximately 35 to 90% as the isoxaben rate progressed from 0.22 to 1.34 kg/ha (Figure 1). Control in the alternatives followed a similar trend; however, control in the alternatives remained numerically higher than control in pine bark. The LD_{50} value was highest for pine bark, i.e., 0.27 kg/ha vs $\leq$ 0.19 kg/ha for the alternatives.

For all three herbicide–weed species combinations, weed control was nearly identical between the pine bark–based substrate and the alternative substrates provided the specific herbicide had been applied at its registered rate(s). Consequently, these data support the conclusion that herbicide rates deemed adequate for pine bark–based substrates will likely also be adequate for use in the alternative substrates we evaluated. In the nontreated controls, weed growth tended to be either less (large crabgrass and spotted spurge), or equivalent (spotted spurge) in the alternatives compared to pine bark. No weed species grew more in the alternatives compared to pine bark. For large crabgrass control with prodiamine and spotted spurge control with isoxaben, efficacy of marginal herbicide rates was frequently greater in the alternatives compared to pine bark. It is tempting to credit this greater efficacy at marginal rates simply to less weed growth. However, the control data in herbicide rate response curves were based on comparisons to nontreated control within each individual substrate. Therefore, the response is already normalized against any direct negative influence the substrate may have had on weed growth.

Previous research has demonstrated that if managed correctly, the alternative substrates evaluated herein can be used in lieu of pine bark in containerized nursery crop production (Boyer et al. 2006, 2008; Fain et al. 2008; Gruda and Schnitzler 2003a; Wright and Browder 2005; Wright et al. 2006, 2008). Our data further show the potential utility of these alternatives by demonstrating that typical herbicide treatments used for weed control in pine bark substrates will likely provide similar and/or superior results in the alternatives. However, it must also be noted that the differential ability of weed species to grow in these alternatives compared to pine bark could also indicate that wide-scale adoption of these alternatives may result in shifts in the weed species deemed to be the most problematic.

Sources of Materials

[1] Azlin Seed Service, P.O. Box 914, Leland, MS 38756.

[2] Granular fertilizer, Polyon® 17N-6P-12K, available from Harrell's Fertilizer, Inc., 203 West 4th Street, Sylacauga, AL 35105.

[3] Micronutrient fertilizer, Micromax®, O. M. Scott Corp., 14111 Scotts Lawn Road, Marysville, OH 43401.

[4] SAS® software, Release 8.3, SAS Institute, Inc., Box 8000, SAS Circle, Cary, NC 27513.

[5] SigmaPlot® 2000 for Windows®, Version 6.00, Systat Software Inc., 501 Canal Boulevard, Suite E, Point Richmond, CA 94804-2058.

Literature Cited

Boyer, C. R., G. B. Fain, C. H. Gilliam, T. V. Gallagher, H. A. Torbert, and J. L. Sibley. 2006. Evaluation of freshly chipped pine tree substrates of container-grown *Lantana camara*. Hortscience 41:1027. [Abstract]

Boyer, C. R., G. B. Fain, C. H. Gilliam, T. V. Gallagher, H. A. Torbert, and J. L. Sibley. 2008. Clean chip residual as a substrate for perennial nursery crop production. J. Environ. Hortic. 26:239–246.

Davidson, H., R. Mecklenberg, and C. Peterson. 2000. Nursery Management Administration and Culture, 4th ed. Upper Saddle River, NJ: Prentice Hall.

Fain, G. B., C. H. Gilliam, J. L. Sibley, and C. R. Boyer. 2008. *WholeTree* substrates derived from three species of pine in production of annual vinca. Horttechnol. 18:13–17.

Freund, R. J. and R. C. Littell. 2000. SAS Systems for Regression. 3rd ed. Cary, NC: SAS Institute.

Gruda, N. and W. H. Schnitzler. 2003a. Suitability of wood fiber substrates and their effect on growth of lettuce seedlings. Acta Hortic. 548:415–423.
Gruda, N. and W. H. Schnitzler. 2003b. Suitability of wood fiber substrates for production of vegetable transplants II. The effect of wood fiber substrates and their volume weights on the growth of tomato transplants. Sci. Hortic. (Amst.) 100:333–340.
Lu, W., J. L. Sibley, C. H. Gilliam, J. S. Bannon, and Y. Zhang. 2006. Estimation of U.S. bark generation and implications for horticultural industries. J. Environ. Hortic. 24:29–34.
Seefeldt, S. S., J. E. Jensen, and E. P. Fuerst. 1995. Log-logistic analysis of herbicide dose- response relationships. Weed Technol. 9:218–227.
Wright, R. D. and J. F. Browder. 2005. Chipped pine logs; a potential substrate for greenhouse and nursery crops. Hortscience 40:1513–1515.
Wright, R. D., J. F. Browder, and B. E. Jackson. 2006. Ground pine chips as a substrate for container-grown woody nursery crops. J. Environ. Hortic. 24:181–184.
Wright, R. D., B. E. Jackson, J. F. Browder, and J. G. Latimer. 2008. Growth of chrysanthemum in a pine tree substrate requires additional fertilizer. Hort Technol. 18:111–115.

Received January 27, 2009, and approved May 14, 2009.