Herbicide Efficacy in Alternative Substrates for Container-grown Nursery Crops[1]

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Abstract

Three experiments were conducted to evaluate the influence of alternative substrates on herbicide efficacy in container grown nursery crops. In Experiment 1, alternative substrates evaluated were either pine wood chips hammer-milled, to pass between 0.48 cm (0.19 in) screen (PWCH1) or 0.64 cm (0.25 in) screen (PWCH2), whole pine trees chipped or hammer-milled (WTCH), to pass between a 0.48 cm (0.19 in) screen, or the previously mentioned combined with pinebark. A commercial pine bark substrate (PB) with a 6:1 (by vol) ratio of pine bark to sand was maintained as a control treatment. Rout® at 3 lbs aia (oxyfluorfen + oryzalin at 2.24 + 1.12 $kg \cdot ha^{-1}$) and Ronstar at 4.0 lb aia (oxadiazon at 4.48 $kg \cdot ha^{-1}$) were applied at recommended label rates. Herbicides were applied and irrigated, and each container was overseeded with 25 spotted spurge (*Euphorbia maculata*) seed per container. In general, the greatest spurge numbers occurred in PB substrates. Rout provided superior spurge control compared to Ronstar. In Experiment 2, substrates evaluated were PWCH2, WTCH and PBS with 7.0 $kg \cdot m^{-3}$ (12 $lbs \cdot yd^{-3}$) of Polyon 17-6-12 or with an additional 8 $lbs \cdot yd^{-3}$ of Polyon 17-6-12, or PWCH2 and WTCH combined with composted poultry litter (CPL). PWCH2 tended to have the fewest spurge numbers throughout the experiment, while WTCH and PBS tended to have similar spurge numbers and spurge fresh weight. Addition of CPL and additional fertilizer tended to increase spurge numbers and spurge fresh weight in all substrates. Rout and Ronstar provided similar spurge control in this study. In Experiment 3, substrates evaluated were PB (100%), WTCH (100%), CCR (100%), and PB:S (6:1 vol), WTCH:S (6:1 vol), and CCR:S (6:1 vol). Rout and Ronstar were each applied at 0.25×, 0.50×, 0.75×, and 1.0× label rate. There was a significant substrate affect on all dates except 14 DAT. Spurge numbers and spurge fresh weight were greatest in PB or PB:S substrates. Spurge numbers and spurge fresh weight in general decreased with increasing herbicide rates. At 45 DAT and 60 DAT, Rout had superior spurge control compared to Ronstar. With WT and CCR substrates, Rout provided excellent control (less than 1.0 gram fresh weight) at the 0.50× and 1.0× rates. In general, weed control in alternative substrates was superior to that obtained in commercially used pinebark.

Index words: weed control, nursery production.

Herbicides used in this study: Rout® (oryzalin + oxyfluorfen) 3,5-dinitro-N[4],N[4]-dipropylsulfanilamide + 2-chloro-1-(3-ethoxyl-4nitrophenoxy)-4-(trifluoromethyl) benzene; Ronstar 2G (oxadiazon), {3-[2,4-dichloro-5-(1-methylethoxy)phenyl]-5-1(1,1-dimethylethyl)-1,3,4-oxadiazol-2-(3H)-one}.

Significance to the Nursery Industry

Recent research has focused on alternative substrates derived from forest products. While these substrates have been successfully used to produce a wide range of crops, no research has been conducted to evaluate the efficacy of herbicides used with these substrates. The objective of this study was to evaluate the efficacy of commonly used herbicides on prostrate spurge control with alternative substrates, currently being evaluated for container-grown nursery crop production to determine if current weed control practices will need to be adjusted. These data show that control of spotted spurge with commonly used preemergence applied herbicides may actually be improved with some of the alternative substrates currently being evaluated.

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Introduction

In the past few years the supply of pinebark for use in container nursery crop production has declined (12). Several factors have contributed to this decline including: use of pine bark for fuel or increased in-field harvesting which leaves the pine bark in the forest, and increased foreign importation of logs without bark (12). With limited supply and increasing prices, there is greater interest in the use of alternative substrates in container nursery crop production.

Many alternative substrates have been evaluated for container grown crops including: biosolids (6, 8, 9, 10), wood waste (13), coco fibers (14), and pine tree biomass (2, 5, 11, 16, 20). In 2004, Gruda and Schnitzler (7) had success in growing vegetable transplants in spruce wood chips. Boyer et al. (2) reported that perennials grown in clean chip residual (forestry by-product of in-field harvesting) were similar to plants grown in pinebark. Fain et al. (5) evaluated a substrate made from all above ground portions of loblolly pine, whole tree (WT). Plants grown in WT were similar in size to those grown in traditional pinebark substrates. Wright and Browder (20) demonstrated that *Ilex crenata* 'Chesapeake' could be grown effectively in ground loblolly pine logs.

While these substrates have been evaluated for container-grown crops, limited research has been done with alternative substrates to determine if herbicide efficacy is affected. Preemergence herbicides are the most common method of weed control in container nurseries (4). Herbicides are applied to and adsorbed by the substrate and it must be desorbed into solution for uptake by the weed (3). Many of the alternative substrates contain higher wood content than traditional pine bark based substrate. Impact of high wood content substrates on herbicide adsorption is unknown; however, other cultural practices have been impacted by these substrates. For example, Wright and Browder (20) demonstrated electrical conductivity (EC) was lower in crops grown in pine wood chips and additional fertilizer was required in order to have similar growth to crops grown in pine bark.

Euphorbia maculata (spotted spurge) was selected as weed species to use in comparing herbicide efficacy with several alternative substrates. Spurge is a common summer annual weed that germinates quickly (18) causing a major weed problem throughout the United States. The objective of this study was to compare herbicide efficacy on control of spotted spurge grown in alternative substrates compared to a traditional pine bark substrate.

Materials and Methods

Experiment 1. Nine substrates were evaluated for herbicide efficacy in container grown nursery crops: pine wood chips (~ 95% wood) hammer-milled to pass a 0.40 cm (0.16 in) screen (PWCH1), pine wood chips hammer-milled to pass a 0.64 cm (0.25 in) screen (PWCH2), whole pine tree chipped (WTC) [96% passed through a 5.0 cm (2.0 in) screen], WTC-hammer-milled to pass a 0.48 cm (0.19 in) screen (WTCH), PWCH1:pinebark (PB) (1:1 by vol), PWCH2:PB (1:1 by vol), WTC:PB (1:1 by vol), WTCH:PB (1:1 by vol), and PB:sand (6:1 by vol) (PBS). Substrates were amended with 7.1 $kg{\cdot}m^{-3}$ (12 $lbs{\cdot}yd^{-3}$) of 17-6-12 (17N-2.6P-10K), Polyon controlled-release fertilizer (CRF), 3.0 $kg{\cdot}m^{-3}$ (5 $lb{\cdot}yd^{-3}$) of lime, and 0.9 $kg{\cdot}m^{-3}$ (1.5 $lbs{\cdot}yd^{-3}$) Micromax. Pour through extractions were conducted at 21, 56, and 85 days after potting (DAP) for pH and electrical conductivity (EC) (21). Substrate container capacity, airspace, total porosity, and bulk density were determined with procedures described by Bilderback et al. (1). In general physical and chemical characteristics were within acceptable ranges (22) (Table 1). On June 15, 2006, 10.2 cm (4 in) containers were filled with substrate, watered in and the following day two herbicides, Rout (oxyfluorfen + oryzalin at 2.24 + 1.12 $kg{\cdot}ha^{-1}$) (3 lbs aia) and Ronstar (oxadiazon at 4.48 $kg{\cdot}ha^{-1}$) (4 lbs aia) were applied. Non-treated controls were maintained throughout the study. One day after herbicide application, each container was overseeded with 25 spotted spurge seed and placed in full sun with overhead impact irrigation. Data collected included spotted spurge number at 30 and 60 days after treatment (DAT), and spurge fresh weights at 60 DAT. Treatments consisted of a 9 × 3 factorial; 9 substrates and 3 herbicide treatments (Rout, Ronstar, and non-treated control). Experiment was conducted as a completely random design with 10 single plant replicates. Data were analyzed using a generalized linear model with least significant difference means separation.

Experiment 2. Materials and methods were similar to experiment one with the following exceptions. Composted poultry litter (CPL) was added as a substrate amendment and with one set of substrates the fertilizer rate was increased to 11.8 $kg{\cdot}m^{-3}$ (20 $lbs{\cdot}yd^{-3}$). Test was initiated August 29,

Table 1. pH, electrical conductivity, and physical properties of alternative substrates, Expt. 1 and 2.

Substrates	Ratio/rate	pH[z] 21 DAP[u]	pH[z] 85 DAP	EC 21 DAP	Container capacity[y]	Air space[x] (% vol)	Total porosity[w]	Bulk density[v] ($g{\cdot}cm^{-3}$)
Experiment 1								
PWCH1[t]	100%	6.0fg[s]	6.0ab	0.3a	48.2b	32.1de	80.3bc	0.1efg
PWCH2[r]	100%	6.2ef	5.9abc	0.3ab	29.6f	39.0c	86.8a	0.1efg
WTC[q]	100%	6.7b	6.1a	0.2c	29.6f	51.5a	81.1bc	0.2def
WTCH[p]	100%	6.4d	5.8bcd	0.3ab	36.2de	50.8a	86.9a	0.1g
PWCH1:PB	1:1	6.4cd	5.3e	0.2b	48.4b	33.0d	81.4bc	0.2de
PWCH2:PB	1:1	5.9g	4.8f	0.3ab	41.2c	37.6c	78.8cd	0.1def
WTC:PB	1:1	6.4cd	5.6cd	0.2bc	28.6f	46.1b	74.6d	0.2bc
WTCH:PB	1:1	6.3de	5.2e	0.2bc	36.3de	45.7b	82.0bc	0.1fg
PBS[o]	1:1	6.6bc	5.6d	0.3a	38.5cd	28.8e	67.2e	0.3a
Experiment 2								
PWCH2:CPL[n]	6:1	7.2a	6.0ab	0.3a	54.0a	30.1de	84.2ab	0.2bc
WTC:CPL	6:1	7.2a	6.1a	0.3ab	33.5e	45.1b	78.6cd	0.2cd

[z]pH range was acceptable as reported by Yeager et al., 1997. Best Management Practicses Guide for Producing Container-grown Plants.

[y]Container capacity = (wet weight – oven dry weight) ÷ volume of the sample.

[x]Air space = volume of water drained from the sample ÷ volume of the sample.

[w]Total porosity = container capacity + air space.

[v]Bulk density after forced-air drying at 105C for 48 h (1 $g{\cdot}cm^{-3}$ = 62.43 $lb{\cdot}ft^{-3}$).

[u]DAP = days after potting.

[t]PWCH1 = pine wood chips (100% wood) hammer-milled to pass a 0.48 cm screen.

[s]Means (within a column) with different letters are significantly different, within substrates or herbicides according to Least Significant Difference test (α = 0.05).

[r]PWCH2 = pine wood chips hammer-milled to pass a 0.64 cm screen.

[q]WTC = whole pine tree chipped.

[p]WTCH = WTC-hammer-milled to pass a 0.48 cm screen.

[o]PBS = pinebark:sand.

[n]CPL = composted poultry litter.

Table 2. Preemergence herbicide efficacy evaluated with alternative substrates, Experiment 1.

Alternative substrates	Ratio/rate	Spurge number[z]		Fresh weight (gm)
		30 DAT[y]	60 DAT	60 DAT
PWCH1[x]	100 %	1.8abc[w]	3.0ab	8.7ab
PWCH2[v]	100 %	1.6bc	2.1bc	2.4f
WTC[u]	100 %	0.8c	1.5c	3.7ef
WTCH[t]	100 %	1.9ab	3.4a	9.0ab
PWCH1:PB[s]	1:1	2.0ab	3.2a	7.9abc
PWCH2:PB	1:1	2.0ab	3.0ab	4.3def
WTC:PB	1:1	1.2bc	2.9ab	5.7cde
WTCH:PB	1:1	1.9ab	3.4a	6.8bcd
PBS[r]	6:1	2.7a	2.7ab	10.7a
Herbicide				
Rout	3 lb/aia	0.2c	1.0c	1.4c
Ronstar	4 lb/aia	0.9b	1.7b	6.7b
Non-treated	—	4.2a	5.8a	11.9a
Main Effects				
Substrate		0.013	0.002	0.001
Herbicide		0.001	0.001	0.001
Interaction		0.001	0.401	0.001

[z]Spurge number per container overseeded at 25 seed per container.

[y]DAT = days after treatment.

[x]PWCH1 = pine wood chips (~ 95% wood) hammer-milled to pass a 0.48 cm screen.

[w]Means (within a column) with different letters are significantly different, within substrates or herbicides according to Least Significant Difference test ($\alpha = 0.05$).

[v]PWCH2 = pine wood chips hammer-milled to pass a 0.64 cm screen.

[u]WTC = whole pine tree chipped.

[t]WTCH = WTC-hammer-milled to pass a 0.48 cm screen.

[s]Substrates with pinebark added 1:1 (v:v).

[r]PBS = pinebark:sand 6:1 (v:v).

2007. Substrates evaluated included: PWCH2, WTCH, PBS, PWCH2 + 12.5% composted poultry litter (CPL) [PWCH2:CPL (6:1 by vol)], WTCH:CPL (6:1 by vol), PWCH2 incorporated with 7.1 $kg \cdot m^{-3}$ Polyon control release fertilizer (CRF) (PWCH2:CRF), WTCH:CRF, and PBS:CRF. Spurge numbers were taken at 30 and 60 DAT and fresh weights were taken at 60 DAT. The experimental design was similar to experiment 1; treatments consisted of an 8 (substrates) × 3 (herbicide) factorial with 10 replications. Data were analyzed using a generalized linear model with Least Significant Difference and Duncan's Multiple Range Test, $\alpha = 0.05$ (19).

Experiment 3. Materials and methods were similar to experiments one and two with the following exceptions. September 14, 2007, six alternative substrates were potted; PB, PBS, Whole tree (WT), WT:sand (v:v) (6:1 by vol) (WTS), Clean Chip Residual (CCR), and CCR:sand (v:v) (6:1 by vol) (CCRS). On September 17, 2007, either Rout or Ronstar treatments were applied (0.25×, 0.5×, 0.75×, or 1.0× label rate) and the following day 25 spotted spurge seed were overseeded per container on treated and control containers. Containers were placed in a double layer polyethylene greenhouse with a minimum temperature of 70F. Spurge numbers were taken at 15, 30, 45, and 60 DAT and weed fresh weights were taken at 60 DAT. Rout and Ronstar treatments consisted of a 2 × 6 × 5 factorial with 6 single pot replications. All experiments were conducted at the Auburn University Paterson Greenhouse Complex, Auburn, AL. Data were analyzed using a generalized linear model with $\alpha = 0.05$.

Results and Discussion

Experiment 1. At 30 DAT, spurge number was similar for WTC, PWCH1, PWCH2 and WTC:PB with WTC. The highest spurge numbers tended to occur in substrates with PB. (Table 2). These trends continued at 60 DAT with WTC having lower spurge number than any of the other substrates with the exception of PWCH2. Lower spurge number in these substrates could be a result of the large particle sizes, which are not as conducive for weed germination (21). Richardson et al. (17) reported reduced spurge number in large containers (# 7) when pine bark mini-nuggets were applied to a depth of either 1.5 or 3 inches. Spurge fresh weights (SFW) were 78 and 65% lower in PWCH2 and WTC respectively than PBS.

Overall, Rout provided superior spurge control throughout the study (Table 2). For example, spurge numbers were less per container with Rout at 30 (77%) and 60 (41%) DAT and SFW were 79% less than containers treated with Ronstar. These results concur with previous rankings of herbicide efficacy comparing Rout and Ronstar for spurge control (15).

Significant herbicide × substrate interactions occurred at 30 and 60 DAT. Substrates treated with Rout had similar spurge control at 30 and 60 DAT compared to the PBS substrate (Table 3). All substrates treated with Rout had similar SFW compared to the commercial substrate (PBS) with the exception of WTCH. Ronstar applied to PWCH2, WTC, and WTC:PB had less spurge number compared to the commercial substrate (PBS) at 30 DAT. Similarly spurge fresh weights were reduced by > 99 (PWCH2), 58 (WTC), 82 (PWCH2:PB), and 65% (WTC:PB) compared to the

Table 3. Herbicide-substrate interaction on spurge control in alternative substrates with commonly used preemergence applied herbicides, Experiment 1.

Alternative substrates	Rout			Ronstar			Non-treated		
	Spurge number[z]		FW[y]	Spurge number		FW	Spurge number		FW
	30 DAT[x]	60 DAT	60 DAT	30 DAT	60 DAT	60 DAT	30 DAT	60 DAT	60 DAT
PWCH1[w]	0.0a[v]	0.6bcd	0.3b	0.9abc	2.5ab	7.1abc	4.4 bc	5.8ab	18.8a
PWCH2[u]	0.0a	0.2cd	0.1b	0.0c	0.4c	0.1d	4.8ab	5.6abc	6.8e
WTC[t]	1.1a	0.1d	0.1b	0.3c	0.8bc	5.5bcd	1.1d	3.9c	5.8e
WTCH[s]	1.0a	2.1a	6.0a	1.8ab	2.7a	8.5abc	2.9c	5.4bc	12.6cd
PWCH1:PB[r]	0.0a	1.0abcd	1.2b	0.8abc	1.5abc	7.7abc	5.2ab	7.3a	14.9bc
PWCH2:PB	0.0a	1.6ab	1.5b	0.6abc	1.6abc	2.4cd	5.3ab	5.9ab	9.0de
WTC:PB	0.0a	0.5bcd	1.1b	0.4bc	1.9abc	4.5bcd	3.1c	6.3ab	11.6cd
WTCH:PB	0.0a	1.4abc	1.1b	1.1abc	2.4ab	10.4ab	4.9ab	6.7ab	9.2de
PBS[q]	0.0a	1.1abcd	1.5b	1.9a	1.6abc	13.0a	6.2a	5.4bc	17.5ab

[z]Spurge number per container overseeded at 25 seed per container.
[y]Fresh weight (grams).
[x]DAT = days after treatment.
[w]PWCH1 = pine wood chips (~ 95% wood) hammer-milled to pass a 0.48 cm screen.
[v]Means (within column) with different letters are significantly different, within substrates or herbicides according to Least Significant Difference test ($\alpha = 0.05$).
[u]PWCH2 = pine wood chips hammer-milled to pass a 0.64 cm screen.
[t]WTC = whole pine tree chipped.
[s]WTCH = WTC-hammer-milled to pass a 0.48 cm screen.
[r]Substrates with pinebark added 1:1 (v:v).
[q]PBS = pinebark:sand 6:1 (v:v).

commercial substrate (PBS). Comparing non-treated substrates; PWCH2, PWCH1:PB, PWCH2:PB, and WTCH:PB had similar spurge numbers compared to the commercial substrate (PBS) at 30 DAT. At 60 DAT spurge number per container were similar in all non-treated substrates compared to the commercial substrate (PBS), except those grown in PWCH1:PB, which had the highest spurge number. Spurge fresh weights were significantly less in PWCH2, WTC, WTCH, PWCH2:PB, WTC:PB, and WTCH:PB compared to the commercial substrate (PBS).

Table 4. Influence of alternative substrates on herbicide efficacy, Experiment 2.

Alternative substrates	Ratio/rate	Spurge number[z]		Fresh weight (gm)
		30 DAT[y]	60 DAT	60 DAT
PWCH2[x]	100%	0.4e[w]	0.6e	0.3d
WTCH[v]	100%	3.4ab	3.3bc	0.9cd
PBS[u]	6:1	2.2cd	2.8bc	3.8abc
PWCH2:CPL[t]	6:1	1.8d	2.0cd	5.8ab
WTCH:CPL	6:1	4.0a	5.5a	6.6a
PWCH2:CRF[s]	100% + 20 lb CRF	1.1de	1.4de	0.9cd
WTCH:CRF	100% + 20 lb CRF	2.3bcd	3.4bc	3.1bcd
PBS:CRF	6:1	3.2abc	3.8b	5.8ab
Herbicides				
Rout	3 lb·aia^{-1}	0.8b	1.0b	1.2b
Ronstar	4 lb·aia^{-1}	0.9b	1.3b	1.5b
Non-treated		5.2a	6.2a	7.7a
Main Effects				
Substrate		0.0001	0.0001	0.0001
Herbicide		0.0001	0.0001	0.0001
Interaction		0.0018	0.0001	0.0001

[z]Spurge number per container overseeded at 25 per container.
[y]DAT = days after treatment.
[x]PWCH2 = pine wood chips hammer-milled to pass a 0.64 cm screen.
[w]Means (within a column) with different letters are significantly different, according to Least Significant Difference Test ($\alpha = 0.05$).
[v]WTCH = whole pine tree chipped, hammermilled 3/8 in screen.
[u]PBS = pinebark:sand 6:1 (v:v).
[t]CPL = composted poultry litter.
[s]Substrates with the addition of 20 lb Polyon control release fertilizer.

Table. 5. Herbicide-substrate interaction on weed control in alternative substrates with commonly used preemergence applied herbicides, Experiment 2.

Alternative substrates	Rout			Ronstar			Non-treated		
	Spurge number[z]		FW[y]	Spurge number		FW	Spurge number		FW
	30 DAT[x]	60 DAT	60 DAT	30 DAT	60 DAT	60 DAT	30 DAT	60 DAT	60 DAT
PWCH2[w]	0.0b[v]	0.0c	0.0b	0.0b	0.0c	0.0b	1.1c	1.9c	0.8c
WTC[u]	1.6ab	2.4ab	0.8b	1.5ab	2.3ab	0.8ab	7.0a	5.1bc	1.3c
PBS[t]	0.0b	0.0c	0.0b	0.6ab	0.7bc	2.8ab	5.9a	7.5ab	9.4abc
PWCH2:CPL[s]	0.5ab	0.5c	0.7b	0.1b	0.3c	0.2b	4.8ab	5.4bc	16.6a
WTC:CPL	2.1a	3.1a	4.6a	2.6a	3.6a	3.5a	7.4a	9.9a	11.7ab
PWCH2:CRF[r]	0.0b	0.0c	0.0b	1.1ab	1.6bc	1.0ab	2.1bc	2.5c	1.7c
WTC:CRF	1.1ab	1.4bc	1.3b	0.1b	1.1bc	1.4ab	5.5a	7.8ab	7.0c
PBS:CRF	0.8ab	1.0bc	2.1b	1.1ab	0.6bc	2.5ab	7.6a	9.8a	13.0ab

[z]Spurge number per container overseeded at 25 seed per container.

[y]Fresh weight (grams).

[x]DAT = days after treatment.

[w]PWCH2 = pine wood chips hammer-milled to pass a 0.64 cm screen.

[v]Means (within a column) with different letters are significantly different, according to Least Significant Difference test ($\alpha = 0.05$).

[u]WTC = whole pine tree chipped.

[t]PBS = pinebark:sand 6:1 (v:v).

[s]Substrates with composted poultry liter 6:1 (v:v).

[r]Substrates with the addition of 20 lb·yd^{-3} polyon control release fertilizer.

Experiment 2. Throughout the experiment PWCH2 substrates tended to have the fewest spurge numbers and least SFW (Table 4). Addition of CPL to PWCH2 increased spurge numbers and SFW compared to PWCH2 alone. WTCH spurge numbers were slightly higher at 30 DAT than PBS however, at 60 DAT were similar to PBS. SFW were greatest when grown in CPL substrates or PBS. Rout and Ronstar provided similar spurge control throughout this experiment.

Significant herbicide × substrate interactions occurred with each data set. At 30 DAT all substrates treated with Rout were all similar compared to the commercial substrate (PBS) (Table 5). WTCH:CPL treated with Rout had greater spurge number per container compared to the commercial substrate (PBS) at 30 and 60 DAT. All other substrates had similar spurge numbers compared to PBS. Spurge fresh weights were similar in all Rout treated substrates compared to the commercial substrate (PBS) with the exception of WTCH:CPL.

Similar to Rout, Ronstar provided similar control in all substrates compared to the commercial substrate (PBS), 30 DAT (Table 5). At 60 DAT, Ronstar treated substrates provided similar control to the commercial substrate (PBS) with the exception of WTCH:CPL, which had about 80% more spotted spurge than PBS. All Ronstar treated substrates had similar SFW at 60 DAT compared to the commercial substrate (PBS), although those with PBS or CPL tended to be higher. Ronstar treated substrates with PWCH2 tended to have the least SFW. Comparing non-treated substrates; PWCH2 and PWCH2:CRF had fewer spurge per container at 30 DAT, compared to PBS. At 60 DAT, PWCH2, WTCH, PWCH2:CPL, and PWCH2:CRF had less spurge compared to PBS. Fresh weights were less in PWCH2 and WTC when CRF was added compared to PBS. Nitrogen (N) immobilization in high wood content substrates has been identified as one issue impacting growth of nursery crops. Similarly, spurge growth may be affected. When comparing PWCH2

Table 6. Physical properties of alternative substrates, Experiment 3.

Substrates	Ratio	Container capacity[z]	Air space[y]	Total porosity[x]	Bulk density[w]
		(% vol)			(g·cm^{-3})
PB	100%	44.6	34.7	79.3	0.18
PB:S	6:1	47.3	24.5	71.8	0.36
WT	100%	59.4	23.2	82.7	0.14
WT:S	6:1	65.8	16.8	82.6	0.36
CCR	100%	55.6	24.6	80.3	0.16
CCR:S	6:1	55.4	24.8	80.2	0.37
LSD[v]		4.8	5.2	2.1	0.01

[z]Container capacity = (wet weight – oven dry weight) ÷ volume of the sample.

[y]Air space = volume of water drained from the sample ÷ volume of the sample.

[x]Total porosity = container capacity + air space.

[w]Bulk density after forced-air drying at 105C for 48 h (1 g·cm^{-3} = 62.43 lb·ft^{-3}).

[v]Least Significant Difference test ($\alpha = 0.05$).

Table 7. Main effects of substrate data pooled over all rates and the non-treated, Experiment 3.

Alternative substrate	Ratio/rate[x]	Spurge number[z]				FW[y]
		14 DAT[w]	30 DAT	45 DAT	60 DAT	60 DAT
PB[v]	100%	2.5a[u]	2.8ab	3.1ab	3.5ab	21.6a
PB:S[t]	6:1	2.6a	3.4a	3.5a	4.1a	23.2a
WT[s]	100%	2.6a	2.2bc	2.6bc	2.8bc	0.8c
WT:S[r]	6:1	1.7b	1.8c	1.8d	2.2c	0.5c
CCR[q]	100%	2.3ab	2.5bc	2.3cd	3.0bc	7.4b
CCR:S[p]	6:1	2.2ab	2.2bc	2.5bcd	2.8bc	3.0bc
Rate[o]						
1	0.00×	4.5a	5.5a	5.4a	5.8a	22.7a
2	0.25×	2.9b	3.2b	3.2b	3.3b	8.6b
3	0.50×	1.9c	1.7c	2.5c	2.7bc	8.8b
4	0.75×	1.5c	1.4c	1.4d	2.4c	6.3b
5	1.00×	0.8d	0.6d	0.7d	1.2d	0.8c
Herbicide — 1.0× rate						
Rout	3 lb·aia^{-1}	2.3a	2.4a	2.3b	2.4b	6.2b
Ronstar	4 lb·aia^{-1}	2.3a	2.5a	3.0a	3.7a	12.8a
Main effects						
Substrate		0.1281	0.0005	0.0001	0.0003	0.0001
Rate		0.0001	0.0001	0.0001	0.0001	0.0001
Substrate × Rate		0.1297	0.3292	0.2437	0.2458	0.0001
Herbicide		0.8913	0.8051	0.0014	0.0001	0.0001
Substrate × Herbicide		0.4262	0.3905	0.9848	0.0271	0.0010
Rate × Herbicide		0.6166	0.6846	0.2326	0.8689	0.3698
Substrate × Rate × Herbicide		0.4820	0.1505	0.1631	0.0568	0.0001

[z]Spurge number per container overseeded at 25 seed per container.
[y]FW = fresh weight (grams)
[x]Ratio/rate = ratio is either 100 % substrate or mixed with sand 6:1 (v:v); rate is herbicide applied per treatment based on label rate (Rout = 3 lb·aia^{-1}, Ronstar = 4 lb·aia^{-1}).
[w]DAT = days after treatment.
[v]PB = pinbark (100%).
[u]Means (within a column) are significantly different according to Least Significant Difference test ($\alpha = 0.05$), Experiment 3.
[t]PB:S = pine bark:sand 6:1 (v:v).
[s]WT = whole pine tree chipped.
[r]WT:S whole pine tree chipped:sand 6:1 (v:v).
[q]CCR = clean chip residual.
[p]CCR:S = clean chip residual:sand 6:1 (v:v).
[o]Pooled comparison of herbicide × rate data.

substrates, addition of CPL increased spurge fresh weights by 95% while adding CRF increased spurge fresh weight by 53%. WTCH substrates tended to respond similarly.

Experiment 3. Analysis of physical properties showed that substrates containing WT and CCR had greater container capacity than PB substrates (Table 6). Air space was similar among all substrates except 100% PB which was highest. According to a pooled comparison over all rates and the non-treated, no rate-by-herbicide interactions were detected (Table 7); however, there was a substrate effect at 30, 45, and 60 DAT. At 30 DAT, PBS had the most weeds per container (3.4) compared to all other substrates with the exception of PB (2.8). At 45 and 60 DAT, PBS had more spotted spurge per container than WT, WT:S, CCR, and CCR:S. Fresh weight was considerably less in all substrates (0.8 gm·container^{-1} [WT], 0.5 [WT:S], 7.4 [CCR], 3.0 [CCR:S]) compared to PB (21.6) and PBS (23.2). Additionally, as expected there was a rate effect throughout the study. As rate of herbicide increased spotted spurge number decreased. At 60 DAT there was a substrate × rate effect in SFW. Rout and Ronstar had similar control at 14 and 30 DAT, however at 45 and 60 DAT Rout had better spurge control. There was also a substrate × herbicide effect at 60 DAT (weed number and SFW) and a substrate × rate × herbicide effect at 60 DAT (SFW).

Comparing substrates within rates showed spotted spurge numbers tended to be less in substrates with higher wood content (WT, WT:S, CCR, CCR:S) (Table 8). In the non-treated substrates, spurge numbers were generally similar throughout the study, with the exception of WT:S at 14, 30 and 60 DAT. Spurge fresh weights in non-treated substrates were greatest in PB or PBS substrates.

Rout applied at 0.25× rate to all substrates at 14, 30, and 45 DAT had similar spurge numbers (Table 8). However at 60 DAT PBS had more spurge number per container (4.5) compared to CCR (1.0) and CCR:S (1.7). SFW was 93 and 97% less in WT and WT:S compared to PBS at 60 DAT. In CCR and CCR:S SFW was 99 and 93% less than PB:S. Rout applied at 0.5× had similar spurge numbers at 14 and 30 DAT in all substrates. At 45 DAT WT (0.8) and WT:S (0.8) had 79% less spurge number per container and CCR (0.2) had 95% less compared to PBS (3.8). Additionally at 60

Table 8. Evaluating rates of Rout and Ronstar in alternative substrates, Experiment 3.

		Rout					Ronstar				
		Spurge number[z]				FW[y]	Spurge number				FW
Rate[x]	Substrate	14 DAT[w]	30 DAT	45 DAT	60 DAT	60 DAT	14 DAT	30 DAT	45 DAT	60 DAT	60 DAT
0×	PB[v]	4.0	4.8	6.2	5.8	36.2	4.7	5.8	4.5	6.3	66.0
	PB:S[u]	6.0	6.2	5.8	5.8	61.3	2.7	6.3	5.2	6.5	38.8
	WT[t]	6.5	6.3	6.5	6.8	0.7	5.8	5.7	6.5	7.0	2.3
	WT:S[s]	2.5	2.3	2.8	2.7	0.8	3.2	5.8	5.5	6.3	2.5
	CCR[r]	4.2	6.5	5.7	5.0	11.0	5.7	6.2	5.0	5.8	34.6
	CCR:S[q]	4.7	5.2	5.3	6.0	12.2	3.7	4.5	5.3	5.3	6.3
	LSD[p]	3.2	3.3	3.0	3.0	12.9	2.8	3.6	2.7	3.2	26.3
0.25×	PB	3.3	3.5	3.7	2.5	10.0	3.7	4.5	3.8	4.7	38.7
	PB:S	1.5	3.8	3.3	4.5	15.1	2.7	3.0	3.5	4.0	16.3
	WT	3.3	3.5	3.2	3.0	1.0	2.3	1.5	2.8	2.0	0.7
	WT:S	3.0	3.7	3.2	2.8	0.5	2.0	1.3	1.8	2.5	0.1
	CCR	3.3	2.5	2.2	1.0	0.2	4.0	3.8	4.0	4.7	13.2
	CCR:S	3.2	3.3	2.0	1.7	1.0	2.7	4.3	4.5	5.7	6.3
	LSD	2.6	2.2	2.7	2.5	7.4	2.6	2.5	2.3	2.6	20.4
0.5×	PB	2.0	2.0	2.5	2.5	13.3	1.5	1.7	3.7	3.3	10.2
	PB:S	2.8	2.7	3.8	4.0	10.5	4.2	5.2	5.5	6.3	59.9
	WT	0.8	0.7	0.8	1.3	0.2	3.4	1.6	4.6	3.3	2.2
	WT:S	1.2	1.2	0.8	0.8	0.2	1.2	0.8	1.5	2.7	0.1
	CCR	0.5	0.8	0.2	0.0	0.0	1.7	1.0	2.0	3.3	4.5
	CCR:S	2.0	1.5	2.7	2.8	0.2	1.7	0.8	2.2	2.5	2.9
	LSD	2.5	2.4	2.3	2.1	11.1	2.2	5.8	5.8	2.7	11.8
0.75×	PB	0.7	0.8	0.7	2.0	6.0	2.5	3.5	2.7	3.5	32.1
	PB:S	2.0	2.5	2.7	2.8	6.0	1.8	2.3	2.7	3.2	19.0
	WT	1.0	1.2	0.2	1.2	0.0	1.0	0.0	0.8	1.3	0.8
	WT:S	1.5	1.7	0.5	2.0	0.1	1.2	0.3	1.7	1.5	0.5
	CCR	1.0	1.3	0.5	1.0	0.0	1.5	1.7	1.8	6.8	9.1
	CCR:S	2.8	1.2	0.8	2.3	0.0	0.8	0.3	1.2	1.3	1.0
	LSD	2.1	2.0	1.9	2.2	9.9	3.1	2.7	2.4	5.0	26.3
1.0×	PB	2.0	0.5	1.2	1.2	0.0	1.0	0.7	1.8	3.2	3.1
	PB:S	0.8	1.0	0.5	0.7	0.0	1.0	0.8	2.0	3.2	5.6
	WT	1.2	0.7	0.5	1.0	0.0	0.7	0.3	0.3	0.8	0.0
	WT:S	0.5	0.2	0.0	0.2	0.0	0.5	0.3	0.3	0.5	0.0
	CCR	0.3	0.8	0.3	0.7	0.0	0.8	0.3	0.8	1.8	1.1
	CCR:S	0.2	0.8	0.2	0.3	0.0	0.3	0.2	0.7	0.8	0.1
	LSD	1.2	1.6	0.9	1.1	0.0	1.3	1.0	1.4	1.6	4.4

[z]Spurge number per container overseeded at 25 seed per container.

[y]FW = fresh weight (grams).

[x]Rate = amount of herbicide applied per treatment based on label rate (Rout = 0.25× = 0.75 lb·ai·a^{-1}, 0.5× = 1.5 lb·ai·a^{-1}, 0.75× = 2.25 lb·ai·a^{-1}, 1.0× = 3.0 lb·ai·a^{-1}; Ronstar = 0.25× = 1.0 lb·ai·a^{-1}, 0.5× = 2.0 lb·ai·a^{-1}, 0.75× = 3.0 lb·ai·a^{-1}, 1.0× = 4.0 lb·ai·a^{-1}).

[w]DAT = days after treatment.

[v]PB = pine bark.

[u]PB:S = pine bark:sand 6:1 (v:v).

[t]WT = whole pine tree chipped.

[s]WT:S whole pine tree chipped:sand 6:1 (v:v).

[r]CCR = clean chip residual.

[q]CCR:S = clean chip residual:sand 6:1 (v:v).

[p]Least Significant Difference Test (α = 0.05).

DAT WT (1.3), WT:S (0.8), and CCR (0.0) had less spurge numbers per container compared to PBS (4.0). Spurge FW at 60 DAT were similar when comparing substrates to PBS, which is the industry substrate standard. Rout applied at 0.75× had similar spurge number at 14 and 30 DAT when comparing the substrates to PB:S. However at 45 DAT, PB (0.7), WT (0.2), WT:S (0.5), and CCR (0.5) had fewer spurge number compared to PBS (2.7). Spurge fresh weights were greatest in PB substrate. Rout applied at 0.75× or the recommended label rate generally provided similar control in all substrates regardless of DAT, with no FW difference in any of the substrates.

Ronstar applied at 0.25× rate provided similar control in all substrates throughout the study with the exception of spurge fresh weight in PB (Table 8). When Ronstar was applied at 0.5× rate at 14 and 30 DAT, all substrates had fewer spurge numbers per container compared to PBS with the exception of WT at 14 DAT. Spurge number at 45 DAT were less in WT:S (1.5), CCR (2.0), and CCR:S (2.2) compared to PBS (5.5). Spurge number and FW (60 DAT) was less in all substrates compared to PBS. When Ronstar was applied at 0.75× rate spurge number and FW throughout the study was similar among all substrates compared to PBS. Ronstar applied at recommended label rate at 14 and 30 DAT had similar spurge numbers per container regardless of substrate. At 45 DAT WT (0.3) and WT:S (0.3) had 85% less spurge number compared to PBS (2.0). Similar trends occurred at 60 DAT with WT (0.8), WT:S (0.5), and CCR:S (0.8) having less spurge number compared to PBS (3.2). Spurge fresh weight was less in all substrates with the exception of PB when comparing the substrates to PBS. In general, spurge fresh weights were lowest throughout the study with WT or WTS. When Rout was applied, rates at 0.5× and above provided acceptable spurge control in WT and WTS. While spurge numbers tended to be higher when Ronstar was applied, the trend was similar in that WT and WTS substrates generally had the fewest spurge and lowest SFW. WT has about 80% wood; CCR has about 50% wood; and PBS has minimal wood. The higher wood content in these substrates appear to suppress spurge growth. In most cases, spurge numbers were similar, however, SFWs were much lower in WT or WTS. Spurge growth in PB or PBS had the highest SFWs regardless of herbicide rate or herbicide applied followed by CCR or CCR:S.

Generally, alternative substrates treated with Rout and Ronstar had slightly fewer spurge numbers compared to PBS in all three experiments. Additionally, substrates with added pinebark tended to have more spurge compared to non-amended substrates (Exp. 1). In experiment 2, spurge number and fresh weights tended to be greater with PB or with the addition of CPL. In experiment 3, non-treated containers had similar spurge numbers throughout the study, respectively. However, 60 DAT SFW were significantly greater in PB and PBS compared to the other substrates. Overall in experiment 3, Rout and Ronstar treated substrates, that contained a higher wood content, tended to have less SFW than PB and PBS. These data show that control of spotted spurge may actually be improved with commonly used pre-emergent applied herbicides on some alternative substrates.

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