Influence of Substrate Physical Properties on Container Weed Germination[1]

James E. Altland[2] and Jennifer K. Boldt[3]

Abstract

Container nursery substrates in the central and eastern U.S. are composed primarily of pine bark with lesser percentages of other amendments, including sphagnum peatmoss. Peatmoss is often amended from 0% to 40% (by vol.) to increase the water holding capacity of the substrate. The objective of this research was to determine how a pine bark substrate amended with sphagnum peatmoss affects creeping woodsorrel (*Oxalis corniculata* L.) germination in containers with or without applications of pendimethalin herbicide. Increasing percentage of peatmoss increased the water holding capacity of the substrate; however, water availability on the substrate surface where weed seed germinate and establish was the same in all substrates. Substrates with varying levels of sphagnum peatmoss only slightly affected weed germination. While sphagnum peat moss can be used to increase the water holding characteristics of a substrate, changes in bulk substrate physical properties will not affect herbicide performance or weed germination on the substrate surface.

Index words: Herbicide, irrigation, substrate, porosity, weed control.

Chemicals used in this study: pendimethalin (Pendulum 2G).

Species used in this study: creeping woodsorrel (*Oxalis corniculata* L.) (OXACO).

Significance to the Horticulture Industry

Container substrate components can have a measurable impact on substrate physical properties and water relations, which in turn impacts weed germination and herbicide longevity. Relatively little work has addressed the impact of substrate components on the germination and establishment of weeds in container crops. The objective of this research was to determine how a pine bark substrate amended with varying rates of sphagnum peatmoss affected substrate physical properties and creeping woodsorrel (*Oxalis corniculata* L.) germination in containers with or without applications of a preemergence herbicide. Additions of peatmoss to the pine bark substrate increased water holding capacity of the bulk substrate. However, water was not equally distributed in the vertical profile of a container. Volumetric water content on the container surface was similar regardless of peatmoss amendment. As a result, weed germination and herbicide efficacy was similar across the wide range of peatmoss amendment rates used in this study. Sphagnum peatmoss did not affect weed control with or without the use of a preemergence herbicide.

Introduction

Container nursery substrates are composed primarily of softwood tree bark, with pine (*Pinus taeda* L.) bark being the predominant type used in the central and eastern United States. Pine bark is typically amended with various components including, but not limited to, sphagnum peatmoss, sand, compost, and other locally available agricultural or industrial byproducts. A survey of substrates at a workshop in Hillsborough County FL found that attending nurseries used 16 different components, resulting in 26 different combinations, with the most common components being pine bark, peat, and sand (Yeager and Newton 2001). Physical properties of substrates have been shown to affect crop growth (Tilt and Bilderback 1987), water usage (Beardsell et al. 1979), and disease incidence (Ownley et al. 1990).

Peatmoss is one of the most commonly used substrate amendments for pine bark, and is often incorporated at rates from 10% to 40% (by vol., personal observation). In a review of peatmoss properties, Puustjarvi and Robertson (1975) state that one of the most important properties is its capacity to absorb and internally retain large quantities of water; the amount of water held by peatmoss can be 15 to 20 times its own weight depending on peat type. Research by Gabriel et al. (2008) showed that 15% or 30% sphagnum peatmoss amendment in Douglas fir [*Pseudotsuga menziesii* Mirb.(Franco)] bark increased substrate water holding capacity, available water, and easily available water, compared to 100% Douglas fir bark. Likewise, Fields et al. (2014) showed that as the percent peatmoss incorporated into pine bark increased from 0% to 50%, water holding capacity and easily available water of the mixed substrate increased.

Weed seed can germinate in field soils with water potential as low as -1500 kPa (-217 psi), as summarized by Bullied et al. (2012). Harper and Benton (1966) showed that seed germination in response to water tension on the surface of a water-supplying substrate varies widely by species. For example, garden cress (*Lepidium sativum* L.) germinated similarly and near 100% on substrates with water tension ranging from 0 to -20 kPa (-2.9 psi), while corn cockle (*Agrostemma githago* L.) did not germinate on substrates with tension greater than -10 kPa (-1.5 psi). While there is substantial research on weed seed response

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[2]Research Horticulturist, Application Technology Research Unit, Wooster, OH 44691.

[3]Research Horticulturist, Application Technology Research Unit, Toledo, OH 43606.

Corresponding author's E-mail: james.altland@ars.usda.gov.

to water availability in terms of water tension, most of this work has been done either in field soils or with the use of polyethylene glycol to simulate matric potential with varying osmotic potentials. No research could be found relating the germination of weeds common to nursery container crops in soilless substrates at varying moisture contents or tension.

Soil moisture affects herbicide persistence. Savage (1978) reported that persistence of dinitroaniline herbicides vary widely, and that flooding of soil increased the dissipation rate of pendimethalin. Likewise, Barrett and Lavy (1983) demonstrated that pendimethalin persistence was greater in field conditions in which the herbicide was incorporated into the soil and received low frequency irrigation compared to surface-applied applications with high frequency irrigation. Container nursery crops also receive surface applications of preemergence herbicides, as well as high-frequency irrigation. Work by Fain et al. (2004) corroborated Barrett and Lavy (1983) in that they showed daily irrigation volume split into three or six applications resulted in greater prostrate spurge [*Chamaesyce prostrata* (Aiton) Small)] growth than when the same irrigation volume was applied as a single application.

Container substrate components can have a measurable impact on substrate physical properties and water relations, which in turn impacts weed germination and herbicide longevity. Despite this, relatively little work has addressed the impact of substrate components of the germination and establishment of weeds in container crops. The objective of this research was to determine how pine bark substrate amended with sphagnum peatmoss, and its resultant substrate physical properties, affects creeping woodsorrel germination in containers with or without applications of pendimethalin herbicide.

Materials and Methods

Three substrates were blended in a soil mixer (Twister I Batch Mixer, Bouldin & Lawson LLC, McMinnville, TN). The substrates were composed of pine bark (Buckeye Resources, Dayton, OH) and peatmoss (Sun Gro Horticulture, Seba Beach, Alberta, CN) in three different ratios (10:0, 8:2, or 6:4 by vol.). At the time of blending, each substrate was amended with 7.1 $kg \cdot m^{-3}$ (12 $lb \cdot yd^{-3}$) controlled release fertilizer (15N-3.9P-10K-1Mg-2.3S-0.02B-0.05Cu-0.45Fe- 0.06Mn-0.02Mo-0.05Zn Osmocote Plus, The Scotts Co., Marysville, OH), 1.6 $kg \cdot m^{-3}$ (2.5 $lb \cdot yd^{-3}$) dolomitic limestone (ECOPHRST, National Lime and Stone Co., Findlay, OH), and 0.9 $kg \cdot m^{-3}$ (1.5 $lb \cdot yd^{-3}$) micronutrient fertilizer package (Micromax, The Scotts Co.).

Bulk substrate physical properties. Prior to adding substrates to containers, a small subsample of each substrate was retained for analysis. Mixed substrates were packed in 347 cm^3 (21.2 in^3) aluminum cores [7.6 cm (3 in) tall by 7.6 cm (3 in) internal diameter (i.d.)] according to methods described by Fonteno and Bilderback (1993). There were three replications for each substrate. Aluminum cores were attached to porometers (North Carolina State University Porometers™, Horticultural Substrates Laboratory, North Carolina State University, Raleigh, N.C.) for determination of air space (AS). Cores were weighed, oven dried for 4 d at 110 C (230 F), and weighed again to determine container capacity (CC). Total porosity (TP) was calculated as the sum of AS and CC. Data were subjected to analysis of variance (ANOVA) using SAS v9.3 (SAS Institute, Cary, NC) and means were separated using Fisher's protected least significance difference at $\alpha = 0.05$.

Moisture characteristic curves. Moisture characteristic curves were determined with methods similar to those described by Gabriel et al. (2009). Briefly, columns [152.4 cm (60 in) tall by 7.6 cm (3 in) i.d.] were cut from schedule 40 polyvinyl chloride (PVC) rigid pipe and were hand packed with each substrate. There were three replicate columns per substrate type. After filling, a rubber coupling [8.6 cm (3.4 in) i.d.] was attached to the bottom of each column and fastened with hose clamps (Fernco, Inc. Davison, MI). Columns were bottom saturated with water for $\geq$ 4 h, then remained saturated for $\geq$ 8 h, and allowed to drain to approximately 6 cm (2.4 in) above the base of the column (Z0) for $\geq$ 4 hr. The exact location of Z0 was determined with an attached piezometer made from clear polyvinyl chloride tubing. Columns were placed in a freezer at -21 C (-5.8 F) for $\geq$ 2 d. Frozen cores were cut horizontally into 16 sections. Actual height of each cut section was determined by measuring four points along the circumference with a digital caliper (model CD-6 CS; Mitutoyo, Kanagawa, Japan); volume was calculated for each section separately using its averaged height. The vertical midpoint of each section was used to calculate the midpoint height of each column above Z0, which would represent the tension (cm H2O) in each section. Each cut section was weighed, oven dried at 110 C (230 F) for 3 d, and weighed again to determine water content [$cm^3 \cdot cm^{-3}$ (%/100)]. Moisture characteristic curves (MCC) were plotted as scatter plots of tension (column height, cm) versus volumetric water content. From MCC, easily available water (EAW) was calculated as the percent of available water between 10 and 50 cm (0.14 and 0.71 psi) tension (H_2O) (EAW = θ_{50} - θ_{10}) (de Boodt and Verdonck 1972). Volumetric water content (VWC) at a height of 30 cm (0.43 psi) (θ30) was calculated from the fitted equations. Data for each substrate type were fit to nonlinear log-logistic curves described by Altland et al. (2010) using the 'NLIN' procedure in SAS v9.3. Fitted parameters were compared using the sums of squares reduction (SSR) test, in which *P*-values were generated to test the hypothesis that the fitted equations were similar.

Weed control. On July 25, 2014, each substrate was filled into 60 black nursery containers [7.6 L (2 gal)]. Half of the containers within each substrate were treated with 4.5 kg a.i. $\cdot ha^{-1}$ (4 lb a.i. $\cdot A^{-1}$) pendimethalin (Pendulum 2G, BASF, Triangle Park, NC) and the other half were left untreated. One day after herbicide application, six herbicide-treated and six untreated containers were planted with 40 creeping woodsorrel (week 0). Creeping woodsorrel seed were collected from populations maintained at the Ohio Agricultural Research and Development Center in Wooster, OH. The original source of seed were from a

Table 1. Physical properties of three substrates comprised of varying volumetric ratios of pine bark and peat moss in container trials.

Experiment	Pine bark : peat moss	Air space[z]	Container Capacity[y]	Total Porosity[x]
		(%)		
1	100 : 0	37.2	44.0	81.2
	80 : 20	29.8	53.4	83.2
	60 : 40	21.1	62.0	83.1
	$LSD_{0.05}$[w]	4.6	2.8	NS
2	100 : 0	28.8	53.2	82.0
	80 : 20	17.9	64.1	82.0
	60 : 40	13.4	69.9	83.4
	$LSD_{0.05}$	6.6	4.0	NS

[z]Percent volume of a substrate filled with air after saturation and drainage.

[y]Percent volume of a substrate filled with water after saturation and drainage.

[x]Sum of all pore spaces in a substrate filled with air and water.

[w]Least significant difference according to Fisher's protected means separation test. NS is not significant.

container nursery in Avon, OH. Six additional herbicide-treated and untreated containers were seeded every 2 weeks thereafter for 8 weeks. All containers were maintained on a gravel nursery in full sun. Containers were overhead irrigated with approximately 1 cm (0.4 in) water per day using impact sprinklers (Maxi-bird Impact Sprinkler, Rainbird Corp., Azusa, CA).

Established creeping woodsorrel were counted 4 weeks after seeds were applied. Established seedlings were those with true leaves present. Shoot fresh weights were also determined by harvesting the above-ground portion of the plants. There were six single-pot replications per treatment and seeding date, arranged in a completely randomized design. The treatment design was a 3 by 2 factorial with three substrate types and two herbicide treatments, analyzed independently at five dates of weed seed application post-herbicide application. Data were subjected to ANOVA and means were separated with Fisher's protected least significant difference at $\alpha = 0.05$. All phases of the experiment were repeated on May 29, 2015 using the same methods as the previous year.

Results and Discussion

Bulk substrate physical properties. Increasing the ratio of sphagnum peatmoss in containers affected bulk substrate physical properties. In Expt. 1, AS decreased and CC increased as the ratio of peatmoss increased (Table 1). Total porosity is calculated as the sum of AS and CC, and did not change with peatmoss ratio as the inverse relationship between AS and CC nullified the net effect of peatmoss. A similar trend was observed in Expt. 2, in that AS decreased while CC increased with increasing peatmoss in the substrate. These results corroborate others (Fields et al. 2014, Gabriel et al. 2008) who have showed that the finer particle size and greater water absorbing properties of peatmoss tend to decrease AS and increase CC of bark and wood-based substrates. While not compared statistically, AS was lower and CC higher in Expt. 2 compared to Expt. 1. This is likely due to seasonal

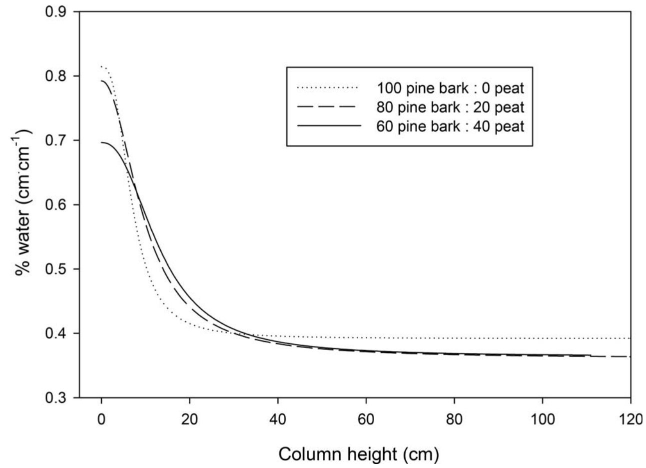

Fig. 1. Moisture characteristic curve for three container nursery substrates relating the height in a column of substrate to the percent volumetric water content. Lines were fit to a four-parameter log-logistic function $\theta_r + (\theta_s - \theta_r)/(1+(h/x_0)^b)$. Parameter estimates for each substrate are provided in Table 2.

or annual differences in the physical properties of the bark used in each year.

Moisture characteristic curves. The fitted logistic curves for each substrate differed from each other ($P < 0.0001$) according to the lack of fit test. The substrate with 100% pine bark had higher θ_r than either substrate with peatmoss in both experiments (Figs. 1 and 2, Table 2). This indicates that pine bark retains greater volumetric water content at high tensions than those with some portion as peatmoss. While peatmoss is capable of absorbing up to 20 times its weight in water, this absorbed water may not be retained at high tensions [> 10 kPa (1.4 psi)] measured by θ_r. Pokorny (1987) found that pine bark particles are comprised of approximately 43% internal porosity which absorbs water available for plant growth. It is possible that water is held

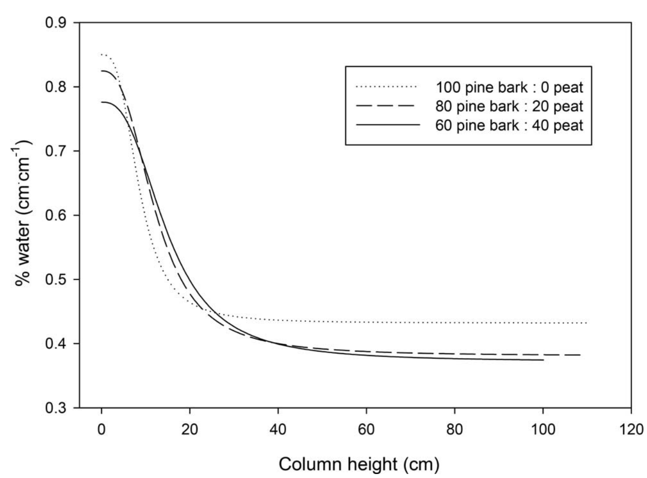

Fig. 2. Moisture characteristic curve for three container nursery substrates in Experiment 2, relating the height in a column of substrate to the percent volumetric water content. Lines were fit to a four-parameter log-logistic function $\theta_r + (\theta_s - \theta_r)/(1+(h/x_0)^b)$. Parameter estimates for each substrate are provided in Table 2.

Table 2. **Estimated parameters and goodness of fit (r^2) for moisture characteristic curves of three nursery substrates composed of varying volumetric ratios of pine bark and peatmoss in container trials (n = 3).**

Experiment	Pine bark: peatmoss	θ_r[z]	θ_s	b	x_0	r2	EAW[y]	θ_{30}[x]
		$cm^3 \cdot cm^{-3}$					$cm^3 \cdot cm^{-3}$	
1	100 : 0	0.39 (0.002)	0.81 (0.008)	2.67 (0.148)	6.88 (0.169)	0.9961	0.11	0.400
	80 : 20	0.36 (0.003)	0.79 (0.009)	2.05 (0.109)	9.69 (0.282)	0.9947	0.19	0.400
	60 : 40	0.36 (0.005)	0.70 (0.015)	2.36 (0.207)	13.27 (0.539)	0.9900	0.21	0.406
2	100 : 0	0.43 (0.003)	0.85 (0.010)	2.93 (0.189)	8.56 (0.222)	0.9906	0.16	0.442
	80 : 20	0.38 (0.003)	0.82 (0.009)	2.64 (0.109)	12.32 (0.219)	0.9959	0.27	0.420
	60 : 40	0.37 (0.003)	0.78 (0.008)	2.64 (0.109)	14.85 (0.249)	0.9960	0.28	0.426

[z]Parameters were estimated for the log-logistic function $\theta_r + (\theta_s - \theta_r)/(1+(h/x_0)^b)$, where θ_r represents residual water content, θ_s represents water content at saturation, b (when n < x_0) is the air entry value, and x_0 is the tension at which the curve changes from convex to concave. The parameter r^2 is the coefficient of determination for the model.

[y]EAW is easily available water, or that which is available between -10 and -50 cm H_2O.

[x]θ_{30} is the percent volumetric water content in the substrate at a height of 30 cm above the container bottom.

more tightly by internal pine bark pore spaces compared to peatmoss. Volumetric water content at saturation (θ_s) also decreased with increasing peatmoss amendment in both experiments. This parameter (θ_s) provides a value somewhat analogous to TP, as it measures the volume of water within the substrate when completely saturated. The finer particle size of the peatmoss would tend to fill the larger pore spaces between pine bark particles, reducing the volume of water capable of being held at complete saturation. The parameter b is sometimes called the air-entry value, and indicates the point along the x-axis at which the sigmoidal curve drops from its maximum. The value of b for 100% pine bark was higher in both experiments compared to those with 20% or 40% peatmoss, but differences were small relative to the standard error of the estimates. The value x_0 represents the point along the x-axis at which the curve transitions from concave to convex, and is the most influential parameter affecting the calculated EAW. As the parameter x_0 increases, the curve becomes less steep in transition from θ_s to θ_r. In both experiments, x_0 increased with increasing peatmoss amendment and thus calculated values for EAW increased concomitantly. This corroborates measured values for CC (Table 1). Despite increases in CC and EAW, both of which measure water availability of the bulk substrate, the calculated volumetric water content at a 30 cm (11.9 in) height was similar for all substrates (Table 2). Other research has shown that water is not distributed evenly throughout the container profile (Owen and Altland, 2008), and that volumetric water content is greatest at the bottom of the container and decreases with increasing height within the container. While one substrate may have higher volumetric water content when measured over the entire container profile, the volumetric water content at any point along the height of the container column may not.

Weed control. Pendimethalin reduced creeping woodsorrel stand across all substrate types when seed were applied up through 4 WAA (Table 3). Derr (2002) likewise reported 100% yellow woodsorrel (*O. stricta* L.) control when seed were applied at or near the time of herbicide application. When seed were applied 6 and 8 WAA, pendimethalin did not reduce creeping woodsorrel numbers within or averaged across substrate types. Similarly, pendimethalin provided control of black cottonwood (*Populus trichocarpa* Torr. & A.Gray ex. Hook.) when seed were applied near the time of herbicide application, but provided no control if seed were applied 6 weeks or more after herbicide application (Altland, 2008). A significant interaction occurred with seed applied 6 WAA (P = 0.0216), in which substrate type affected creeping

Table 3. **Creeping woodsorrel numbers and shoot fresh weight in containers that were either treated with 224 kg ha^{-1} pendimethalin or not, and filled with varying volumetric ratios of pine bark and peat moss. Weed seeds were applied in two week intervals after herbicide application to a different set of containers, and counted 4 weeks later (Expt. 1).**

Herbicide	Substrate	Weed seed application date (WAP)					Weed seed application date (WAP)				
		0	2	4	6	8	0	2	4	6	8
		weed no.					Shoot fresh weight (g)				
None	100:0	10.8	15.7	11.3	5.5	10.8	5.33	2.71	0.91	0.23	0.02
	80:20	11.3	11.2	8.2	3.8	9.7	4.58	2.95	1.48	0.38	0.03
	60:40	13.7	13.2	7.2	1.2	5.5	11.44	3.45	1.25	0.07	0.02
Pendimethalin	100:0	1.2	1.5	1.3	3.2	7.2	0.00	0.00	0.00	0.07	0.05
	80:20	1.8	0.5	4.8	1.7	7.7	0.05	0.00	0.04	0.08	0.00
	60:40	0.8	0.3	2.8	3.8	5.0	0.00	0.00	0.01	0.11	0.03
	$LSD_{0.05}$[z]	4.2	3.9	4.1	2.8	4.4	3.85	1.47	0.78	0.21	NS
Main effects											
Herbicide		0.0001	0.0001	0.0001	0.4421	0.1065	0.0001	0.0001	0.0001	0.0239	0.8055
Substrate		0.6895	0.1395	0.5254	0.1351	0.0347	0.0303	0.7610	0.5264	0.1440	0.4576
Interaction		0.4487	0.4427	0.0576	0.0216	0.5386	0.0286	0.7610	0.6129	0.0578	0.0636

[z]Least significant difference according to Fisher's protected means separation test.

Table 4. Creeping woodsorrel numbers in containers that were either treated with 224 kg ha^{-1} pendimethalin or not, and filled with varying volumetric ratios of pine bark and peat moss. Weed seeds were applied in two week intervals after herbicide application to a different set of containers, and counted 4 weeks later (Expt. 2).

Herbicide	Substrate	Creeping woodsorrel seed application date					Creeping woodsorrel seed application date				
		0	2	4	6	8	0	2	4	6	8
		weed no.					Shoot fresh weight (g)				
None	100:0	20.3	23.0	20.0	18.8	17.5	5.58	4.59	2.00	4.16	1.04
	80:20	20.8	22.0	15.8	16.4	21.2	3.80	1.24	0.92	2.77	1.51
	60:40	22.0	20.7	19.2	13.2	16.2	10.99	1.11	3.56	2.99	1.15
Pendimethalin	100:0	2.7	15.2	13.3	17.8	19.4	0.11	0.50	1.07	4.41	1.27
	80:20	3.3	12.7	13.8	16.8	18.5	0.06	0.20	0.79	2.33	2.24
	60:40	0.8	12.3	10.5	11.0	18.2	0.00	0.15	0.77	3.12	1.79
	$LSD_{0.05}$[z]	8.4	5.6	8.0	5.8	NS	2.20	0.99	0.93	NS	NS
Main effects											
Herbicide		0.0001	0.0001	0.0164	0.5814	0.8146	0.0001	0.0001	0.0001	0.9754	0.0872
Substrate		0.9691	0.4098	0.7507	0.0105	0.4540	0.0002	0.0001	0.0014	0.0817	0.1731
Interaction		0.7767	0.9260	0.4783	0.8136	0.4595	0.0001	0.0001	0.0009	0.8900	0.7877

[z]Least significant difference according to Fisher's protected means separation test.

woodsorrel numbers in containers not treated with the herbicide, but had no effect in containers treated with the herbicide. Pendimethalin reduced creeping woodsorrel shoot fresh weight (SFW) when weed seeds were applied through 6 WAA. Substrate type as a main effect only influenced creeping woodsorrel number when seed were applied 8 WAA ($P = 0.0347$). Contrast analyses showed that averaging across the herbicide main effect, pine bark amended with 40% peatmoss had fewer weed numbers the other two substrates (data not shown). Creeping woodsorrel SFW was only affected by substrate type via an interaction at 0 WAA. With this interaction, SFW was greatest in pine bark amended with 40% peatmoss and not treated with herbicide, while there was no effect with substrate type in containers treated with herbicide.

The experiment was repeated in 2015 with similar results. There were no significant interactions between herbicide and substrate type on creeping woodsorrel number. Pendimethalin reduced weed numbers when seed were applied up through 4 WAA, but not when seed were applied at 6 or 8 WAA (Table 4). Substrate type only affected weed number at 6 WAA, in which pine bark with 40% peatmoss had fewer weeds than the other two substrates. Creeping woodsorrel SFW were affected by the interaction between herbicide and substrate type up through 4 WAA. These interactions were a result of differences in SFW among substrate type not treated with herbicide, while there were no differences among substrate type treated with herbicide.

To summarize across the two weed control experiments, substrate type had little or no effect on creeping woodsorrel establishment and growth. Significant effects from substrate type, alone or interacting with herbicide application, were infrequent, erratic, and relatively minor. Application of pendimethalin reduced creeping woodsorrel establishment and growth when seeds were applied up through 4 WAA, but provided no control when seed were applied later.

There are two practical implications of this research. First, the herbicide pendimethalin provided control of creeping woodsorrel for a much shorter time than was expected (approximately 4 weeks). Creeping woodsorrel seed applied just 6 weeks after herbicide application established and grew similar to those in non-treated containers. Judge et al. (2003) similarly found that trifluralin only controlled large crabgrass [*Digitaria sanguinalis* (L.) Scop.] and perennial ryegrass (*Lolium perenne* L.) for 3 to 37 days depending on the time of year. The commercial formulation of this herbicide (Pendulum 2G) does not provide any instruction for repeat application interval on the product label; however, most nursery growers make three preemergence herbicide applications annually (Gilliam et al. 1990) and extension-based recommendations suggest reapplication at 56 to 90-day intervals (Judge et al. 2003). Our data suggest that the herbicide would need to be reapplied more frequently, assuming consistent weed seed influx over time.

The second practical implication is that substrate type has less impact on weed establishment and herbicide efficacy than what might be expected from differences in bulk physical properties. Water is not distributed equally throughout the container (Owen and Altland 2008). Due to opposing matric and gravitational potentials, there is a gradient of increasing substrate moisture from the top to the bottom of a container and often a zone of saturation near the container bottom. Peatmoss increased CC between 8% and 16% compared to pine bark alone (Table 1) across the two experiments, and increased EAW 9% to 12% compared to pine bark alone (Table 2). Despite these increases in VWC of the bulk container, there was less than a 1% increase of VWC at the substrate surface (θ_{30}) in Expt. 1 and a 2% decrease in Expt. 2 in substrates with 40% peatmoss compared to those with no peatmoss. Data from other research show similar trends. Using equations provided by Gabriel et al. (2008), the calculated VWC of a Douglas fir bark at a height of 10 cm (4 in) from the container bottom increased from 0.47 $cm \cdot cm^{-1}$ (47%) with no peatmoss amendment to 0.54 $cm \cdot cm^{-1}$ (54%) with a 30% (by vol.) peatmoss amendment. However, the VWC at a height of 30 cm (11.8 in) from the bottom of the container only increased from 0.32 $cm \cdot cm^{-1}$ (32%) with no peatmoss to 0.35 $cm \cdot cm^{-1}$ (35%) VWC with 30% peatmoss. Similarly, Fields et al. (2014) reported that shredded pine wood with increasing peatmoss amendment rates from 50% to 100% of the substrate mix had increased container capacity, from 70.8% to 80.1%, respectively, while the calculated VWC of those substrates 100 cm (39.4 in) above the container bottom were similar and averaged 33.2%.

Weed establishment from seed and preemergence herbicide activity occur on or near the substrate surface. Thus VWC of the substrate near the surface should be more relevant to weed germination and herbicide efficacy than measurements of the bulk physical properties (AS and CC). Our data show no differences in VWC at the substrate surface in pine bark substrates with 0% to 40% peatmoss. This is supported in the weed germination data (Tables 3 and 4), in that substrate type had little influence on creeping woodsorrel growth.

The objectives of this research were to determine how substrate physical properties affect creeping woodsorrel germination with or without pendimethalin herbicide. In this experiment, using a typical range of sphagnum peatmoss incorporation rates (typical with respect to the nursery industry) with measurable differences in bulk physical properties, substrate type had little meaningful effect on creeping woodsorrel germination regardless of herbicide. Moisture characteristic curves have only recently been reported for soilless substrates. As more MCC are generated for substrates with varying amendment types and rates, broader conclusions can be drawn on how substrate types affect VWC throughout the container profile and on the substrate surface.

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