Weed Control

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Section Editor

Cost and Effectiveness of Common Weed Control Techniques in Florida Landscapes

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Significance to the Industry: Florida's landscape industry employed over 100,000 people and generated over $6 billion in sales in 2010, with a majority of these sales coming from the landscape maintenance sector (7). One of the most costly and time consuming aspects of landscape maintenance is weed control, specifically in ornamental planting beds and other non-turf areas. While numerous studies have shown the benefits of using organic mulch and herbicides for weed control in landscapes, less research has focused on the expected annual cost of these practices and their effectiveness throughout the year. The objective of this research is to evaluate common landscape weed control methods in terms of long-term efficacy and estimate annual cost by measuring all labor and material inputs.

Nature of Work: Currently there are few chemical options for weed control around desirable ornamentals, and the diversity of species in any one landscape planting bed make finding safe and effective herbicides very difficult for landscapers. In most cases, homeowners or landscapers will use mulch (organic or inorganic), geotextile fabric, herbicides, or a combination of these methods to control weeds. The advantages and disadvantages of each method in terms of weed control have been well documented. Organic mulches have been shown to reduce weed seed germination (2; 9) and improve plant growth (6), but can degrade quickly and may attract unwanted pests (3; 4; 5). Inorganic mulches (gravel/stone) will not degrade but are associated with much higher upfront costs and do not improve soil quality. Multiple geotextile fabrics have been evaluated and most are only effective for a short time and ineffective on perennial weed species (1; 8). Landscape fabrics are designed to be installed at the time of planting, and proper installation in an existing landscape is very difficult. The use of landscape fabric also requires mulch to be applied over the material, increasing the cost. Further, weeds can root through the fabric making hand-weeding difficult and more time consuming. Pre-emergent herbicides are effective when properly timed and can be applied to new or existing landscapes, but options are limited for homeowners and landscapers are becoming more concerned over potential liability issues concerning plant damage.

While many different strategies have been thoroughly evaluated for landscape weed control efficacy, research is lacking on which method or combination of methods is most economical from a homeowner or landscape contractor perspective on a yearly or multi-year basis, and remains one of the most common questions. For example, pine straw is commonly used as mulch in the southeastern U.S. because it is affordable and widely available, but it decomposes quickly (10; 3) and must be replaced more frequently, decreasing the cost advantage. In order to estimate the annual yearly cost and efficacy of common landscape weed control methods, multiple landscape beds (5 ft. by 5 ft.) were constructed at two locations in Florida (Apopka and Wimauma, FL). On September 9, 2014, a shrub species [Schilling's holly *(Ilex vomitoria* 'Schilling's Dwarf') (holly)] and a groundcover species [Asiatic jasmine (*Trachelospermum asiaticum* 'Minima') (Asiatic jasmine)] were transplanted from #3 (11 L) and trade gallon (3.0 L) containers, respectively, into prepared landscape beds in Wimauma, FL containing a sandy soil (2.2% organic matter, pH 7.2). Each 5 ft. by 5 ft. landscape bed was made by placing 5 ft. sections of 2 in. (thickness) × 6 in. (width) lumber around the outside edge of each bed to prevent bed contents (soil, mulch, etc.) from being washed or blown away. Each bed contained either two hollies or three Asiatic jasmine plants (plots were separated by species) on 1.5 ft. spacing. On September 11, weed control treatments were applied (Table 1) to weed-free plots. Treatments consisted of pinestraw alone (PS), pinebark nuggets alone (PB), herbicide alone (H), pinestraw + herbicide (PS+S), pinebark + herbicide (PB+H), and a bare soil (no herbicide) control treatment. Each mulch was applied at a depth of 2 in. (approximately 4.2 cu. ft. per plot) and herbicide [Snapshot®, (trifluralin + isoxaben), Dow AgroSciences, Indianapolis, IN] was applied at the highest recommended label rate [200 lbs. product/acre (5 lbs active ingredient/acre)] after mulch was applied. After treatments were applied, 0.5 inches of irrigation was applied using portable overhead sprinklers to activate the herbicide and drip irrigation was used thereafter to water plants as needed. All plots were fertilized and maintained according to standard industry practices. The experiment was also conducted in Apopka, FL using similar methods with only the following exceptions: On September 23, plants were transplanted into landscape beds containing a sandy soil (1% organic matter, pH 6.2) and weed control treatments were applied on September 25.

Weed coverage data (visual rating scale from 0 to 100, 0 = no weeds, 100 = complete weed coverage), weed species, and mulch depth measurements were taken biweekly. When weed coverage exceeded 20% in any plot, plots were hand weeded to remove all weeds and time needed to hand-weed each plot was recorded. When average mulch depth dropped below 2 in., mulch was added to increase the depth to 2 in. and the amount of mulch added to each plot and application time was recorded. At both locations, herbicide applications were made to herbicide treated plots once every four months so that the manufacturer's maximum annual usage rate (600 lbs. product/acre) was not exceeded. Plots receiving a herbicide treatment were hand weeded prior to application (regardless of weed coverage rating) and watered in as described above. Costs for labor and materials (hand weeding, mulch application, herbicide, mulch) were calculated using average prices in central Florida. Uniform soil characteristics and maintenance history allowed for a completely randomized design in Wimauma while a completely randomized block design was used in Apopka as the experimental site was newly tilled and prepared prior to study initiation (previously fallow). Each treatment was replicated six times at each location for each bed type (groundcover or shrub). Data was analyzed separately for each site and each bed type (shrub and groundcover) bi-weekly (not shown), monthly (not shown), and overall using the PROC GLM procedure in SAS® (SAS Institute, Cary, NC) and means separated using Tukey's HSD (p = 0.05).

Results and Discussion: In Apopka, PB + H provided the best weed control in shrub beds but performed similarly to PS + H in groundcover beds (Table 1). The PB + H treatment provided better weed control than PB alone in both bed types while PB outperformed H. The PS treatment provided similar control to PS + H and H, both in terms of weed control and hand-weeding time needed in both bed types. Fewer differences were noted in Wimauma which had less overall weed pressure than Apopka. In general, the best weed control was achieved with PB + H and PS + H. Herbicide alone was similar to both PB and PS in both beds. Again, no differences were observed between PS and PS + H; however, PB + H provided better control than PB alone in the shrub beds. When data was analyzed bi-weekly, results showed that PB + H provided the lowest weed coverage and required less hand-weeding in both bed types at both locations on most evaluation dates (data not shown). In general, H alone resulted in higher weed coverage and more hand-weeding time than any other weed control method. Lower control from the herbicide was likely due to high populations of Florida pusley (*Richardia floridana*) and several perennial species which are only partially controlled by most preemergence herbicides. Cost estimates show that use of mulch reduced expected hand-weeding labor costs by 39% (PS) and 73% (PB) compared to when H was used alone (Table 2). However, even with a high population of difficult-to-control-weeds, H reduced hand-weeding costs by approximately 48% when compared with the non-mulched non-treated control and the addition of H decreased hand-weeding costs by 55 and 62% for PS and PB, respectively. When estimating total maintenance costs throughout the year, PB + H costed less than any other method, illustrating that the best results will usually be achieved by combining both chemical and non-chemical control methods. Further research will be conducted to evaluate additional weed control methods (organic, inorganic, etc.) and herbicide-mulch combinations in terms of both cost and effectiveness.

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Table 1. Mean bi-weekly weed coverage and hand-weeding time for common weed control methods at two locations in Florida.

Location:	Apopka				Wimauma			
Bed type (species):	Shrub (Holly)		Groundcover (Asiatic jasmine)		Shrub (Holly)		Groundcover (Asiatic jasmine)	
Treatment[z]	Weed Coverage[y]	Hand-weeding Time (min.)	Weed Coverage	Hand-weeding Time (min.)	Weed Coverage	Hand-weeding Time (min.)	Weed Coverage	Hand-weeding Time (min.)
	per 25 ft² Landscape Bed							
PS	11.4 bc[x]	1.0 bc	11.9 bc	0.9 bc	9.3 bc	0.6 b	9.4 bc	1.0 bc
PB	9.4 c	0.5 c	9.5 c	0.6 c	8.5 bc	0.2 b	8.7 bcd	0.3 c
Herbicide	13.8 b	1.7 b	14.1 b	2.0 b	9.8 b	0.8 b	11.3 b	1.3 b
PS + Herbicide	9.8 bc	0.5 c	8.9 cd	0.4 c	7.5 cd	0.3 b	7.5 cd	0.4 c
PB + Herbicide	4.9 d	0.2 c	5.4 d	0.2 c	5.9 d	0.1 b	5.7 d	0.1 c
Control	19.2 a	3.3 a	18.8 a	3.4 a	12.4 a	1.8 a	14.5 a	2.6 a

[z]PS = pinestraw (multiple species); PB = Pinebark nuggets; Both at 2 in. depth; Herbicide = Snapshot® (trifluralin+isoxaben) at 200

[y]Weed coverage taken on a scale of 0 to 100 (0 = no coverage, 100 = complete coverage). Ratings were taken bi-weekly. Plots were hand-weeded when weed coverage exceeded 20%.

[x]Means separated using Tukey's HSD ($p = 0.05$). Means followed by the same letter within each column are not significantly different.

Table 2. Installation, hand-weeding time, and estimated annual maintenance costs of common weed control methods.								
Treatment[z]	Materials[y]	Hand weeding Time (hr)	Labor Cost[x]	Mulch Added (bags or bales)[w]	Mulch Cost[v]	Herbicide Cost[u]	Total Maintenance Cost[t]	Installation + Maintenance
	---per 1,000 ft² Landscape Bed---							
PS	$96	15.2	$175	8	$49	$0	$224	$320
PB	$258	6.9	$79	6	$23	$0	$102	$360
Herbicide	$8	25.1	$289	0	$0	$16	$305	$313
PS + Herbicide	$104	6.9	$79	8	$49	$16	$144	$248
PB + Herbicide	$264	2.6	$30	6	$23	$16	$69	$333
Control	$0	48.2	$555	0	$0	$0	$555	$555

[z]PS = pinestraw (multiple species); PB = Pinebark nuggets; Both at 2 in. depth; Herbicide = Snapshot® (trifluralin+isoxaben) at 200

[y]Materials cost = cost of mulch and herbicide.

[x]Labor cost includes time needed to handweed each treatment using average hourly rates for Florida.

[w]Mulch added includes the number of bags of pinebark (2 ft^3) or bales of pinestraw (2.84 ft^3 baled) to keep mulch depth at 2 in.

[v]Mulch cost based on average retail price for suppliers in central Florida and includes labor cost for application.

[u]Herbicide cost includes chemical and application cost of two maintenance applications (in addition to initial application) made throughout the year (total of 600 lbs/acre/year) plus .

[t]Total maintenance cost = sum of labor, mulch, and herbicide costs.

Mulch Type and Depth Influences Weed Control on Three Major Weed Species in Nursery Container Production

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Significance to Industry: A number of factors over the past several years have forced container-grown plant producers to alter production practices. Increasing labor cost and new immigration laws have forced growers to rely more on herbicides for weed control. Problems associated with herbicide use in container production include non-target loss, achieving correct calibration, and the expense of repeat applications a year (Case and Mathers, 2006). Nonchemical weed control methods could diminish non-target herbicide loss and reduce potential environmental concerns. Data from this study reveals that one application of various mulch species at a depth of at least 5 cm (2 in.) will provide long-term control of spotted spurge, phyllanthus, and eclipta.

Indtoduction: Weeds have been noted to cause major problems in container crop production by reducing the crop value through competitive effects (Berchielli-Robertson et al., 1990) and reducing marketability due to demands for weed free plants (Walker and Williams, 1989). Numerous researchers have reported that only one weed in a small container (trade gal. or 1-gal.) could affect the growth of a container crop (Berchielli-Robertson et al., 1990; Fretz, 1972; Walker and Williams, 1989) but this is highly variable depending on both the crop and weed species. Fretz (1972) reported that one planted red-rooted pigweed (*Amaranthus retroflexus*) resulted in 47% reductions in growth of a trade-gallon container-grown *Ilex crenata* 'Convexa' and one-trade-gallon container-grown *I. crenata* 'Convexa' and one crabgrass (*Digitaria sanguinalis*) reduced the growth of *I. crenata* 'Convexa' up to 60% when compared to the weed free control. One eclipta plant (*Eclipta prostrata*) was observed to have the ability to reduce the shoot dry weight of *Rhododendron* 'Fashion' (Berchielli-Robertson et al., 1990). With the extent of loss from weeds plainly observed and researched, it comes without questioning why concerned nurseries sometimes spend as much as $4000 per acre to control weeds (Pellet and Heleba, 1995). This seems like an egregious amount of money; however, marketability for container crops can be directly associated with the demand for weed-free plants (Simpson et al., 2002).

The necessity to control weeds in container production has driven two practices in container production, hand pulling and herbicide applications. Hand weeding is an increasingly expensive option to do increasing labor cost (Gilliam et al., 1990) and further complicated by new immigration reforms. To reduce the need for hand pulling, nursery growers typically apply preemergence herbicides 3 to 5 times annually. Problems associated with herbicide applications in container production include non-target herbicide loss (Case and Mathers, 2006). This problem is further convoluted with increased container spacing at the time of application. Porter and Parish (1993) showed 12 and 23% non-target loss on trade-gallon containers when configured in a hexagonal pot-to-pot configuration and square pot-to-pot configuration, respectively. Gilliam et al. (1990) reported similar results in that non-target losses ranging from 51 to 80% when herbicides were applied to trade-gal containers spaced 18 to 30 cm on center. Increasing demand for instant landscapes and large container production has led to many growers to begin producing more crops in 7-gal containers and larger. Weed control practices differ from that used in smaller container production. Increased herbicide non-target loss between the large spacing required for large container production renders herbicide applications inefficient and raises environmental concerns.

Mulches have proven to be an effective non-chemical alternative for weed control in large containers. Several criteria must be met in order for a mulch to be considered effective. Effective mulches must be readily available, inexpensive, and acceptable to consumers. Waste products were a focus for many years in mulch research. Products that would normally be sent to a landfill such as newspaper or tires have been evaluated as mulches (Pellet and Heleba, 1995). Smith et al. (1997) reported that newspaper pellets at 2 in. depth controlled spurge in the landscape for at least 60 days. However, waste paper has been shown to reduce available nitrogen when applied to a container's surface as mulch (Glenn et al., 2000). Ground tires were used in a separate study to provide good initial control, but weeds gradually began to penetrate the barrier after 2 months (Calkins et al., 1996). Fabric disk over various materials have also been researched but have found limited success do to voids around the seams or being blown away by winds (Appleton and Derr, 1990). For the most part, waste product mulches have been deemed ineffective due to limited availability and consumer acceptability.

Tree derived mulches such as chipped cedar, pine-bark mini-nuggets, and Douglas fir have widespread availability, reasonable consistency, and acceptable by consumers (Llewellyn et al., 2003). Pine-bark mini-nuggets, as with other tree-derived mulches, create an environment that is not conducive to weed germination due to low fertility, large particle size, and hydrophobic properties (Richardson et al., 2008). Case and Mathers (2003) reported good long container term weed control mulched with Douglas fir and pine-bark nuggets in combinations with either acetochlor applied at 2.5 lbs ai/A, flumioxazin at 2.0 lbs ai/A, or oryzalin at 2.0 lbs. ai/A. Neither oryzalin nor flumioxazin provided long term control when applied alone, but pine-bark nuggets did provide good long term control. Other readily available tree-derived mulch species such as Chinese privet, sweetgum, and eastern red cedar could be used as mulch in container production in lieu of commercialized pine bark mini-nuggets.

The objective of this study was to evaluate four readily-available mulch species at multiple depths for long term weed control and phytotoxicity in nursery crops grown in large containers. The four species tested were Eastern red cedar (*Juniperus virginiana*), ground whole loblolly pine (*Pinus taeda*), Chinese privet (*Ligustrum sinense*), and sweetgum (*Liquidambar styraciflua*). Mulch treatments were evaluated with and without dimethenamid-p herbicide (Tower®).

Materials and Methods: This study is currently being observed at the Paterson greenhouse complex of Auburn University in Auburn, AL. The experiment was initiated 19 April 2014, Eastern red cedar, loblolly pine, Chinese privet, and sweet gum trees, 10 to 20 cm (4 to 8 in.) in diameter measured at 30.5 cm (12 in.) from the soil, were harvested. Only the trunk portions of these trees were used to provide mulch. Harvested trees were chipped with a chipper on 23 April 2014. Along with these four mulches, pine bark mini-nuggets were included (Pine Bark Mini-Nuggets Landscape, Garick, LLC. Cleveland, Ohio) to provide a commercially comparative mulch treatment. Particle size distribution was determined with a series of screens (Fig. 1). Treatments consisted of a factorial arrangement of five mulches (eastern red cedar, loblolly pine, Chinese privet, sweetgum, and pine-bark minnuggets), three mulch depths (1, 2, and 4 in.), and two herbicidal treatments [No herbicide and dimethenamid-p (Tower)]. Two additional treatments were a nontreated control (no mulch with no herbicide) and a no mulch with herbicide for a total of 32 treatments. Three weed species (long-stalked phyllanthus (*Phyllanthus tenellus*), eclipta (*Eclipta prostrata*), and spotted spurge (*Euphorbia maculata*)) were tested, each receiving all 32 treatments. Each treatment was replicated five times for a total of 60 pots per weeds species (note: there are three mulch depth treatments within each mulched container). The study was arranged in a complete random design within each weed species.

On 26 May 2014, 15-gal containers were filled 12.7 cm (5 in.) from the top with a substrate that was 6 pine bark and 1 sand (v/v) amended per cubic yard with 2.3 kg (5 lbs.) dolomitic lime, 6.4 kg (14 lbs.) of Polyon® 18-6-12 (Pursell Technologies, Sylacauga, Alabama) and 0.7 kg (1.5 lbs.) Micromax® (Scotts Co., Maryville, Ohio). Pots were placed on the nursery pad and irrigated twice daily for 3 days with 2.5 cm (1 in.) of water to allow for settling and accurate adjustment of substrate depth. Tower was then applied at 30 fl. oz./A to the herbicide designated pots as a liquid application (30 gal/A) with a CO2 pressure backpack sprayer. The space at the top of the pots was to allow space for dividers. These dividers consisted of untreated plywood cut, grooved, and glued to divide the pots into thirds. Each third of the pot was seeded with 10 seeds of long-stalked phyllanthus, eclipta, or spotted spurge applied to the surface of the media on 31 May 2014. The three partitions of each pot were designated one of the three mulch depths so that each pot contained 2.5, 5.1, and 10.2 cm (1, 2, and 4 in.) of mulch. Mulch was spread also on 31 May 2014.

Weeds were allowed to grow for exactly 30 days after seeding. At this time, weeds, if any, were counted, clipped at the mulch or substrate surface, and fresh weights were taken. These data were expressed as percent reduction relative to the non-treated control. Thus, a “0” control indicated equivalency to the control (100 = no weed growth). One week after weed harvest, the containers were sprayed with paraquat dichloride (Gramoxone® Inteon by Syngenta) to kill any remaining weeds. One week after this treatment, pots were reseeded accordingly on top of the mulch with 10 seeds of the designated weed species. To test the longevity of weed control, this process was repeated three times during the summer of 2014.

An analysis of variance was performed on all responses using PROC GLIMMIX in SAS version 9.3 (SAS Institute, Cary, NC). Each weed species and experimental rounds were analyzed as separate experiments, and the experimental design was a split plot with mulch type and herbicide application in the main plot and mulch depth in the sub-plot. Where residual plots and a significant COVTEST statement with the HOMOGENEITY option indicated heterogeneous variance among treatments, a RANDOM statement with the GROUP option was used to correct heterogeneity for weed fresh weight. Weed counts were analyzed using the Poisson distribution. Single degree of freedom orthogonal contrasts were used to test linear and quadratic trends over mulch depth. Differences between herbicide treatments were determined using the Shaffer Simulated method. All reported means are least squares means. All significances were at $\alpha = 0.05$.

Results and Discussion: Data for the first round of this study was taken 30 June 2014. Mulch depth, herbicide (yes or no), and the herbicide by mulch depth interaction were shown to have the most influence on both weed counts and weed fresh weights. Means comparisons on fresh weights and weed counts of phyllanthus showed significant differences in herbicide application by mulch depth interaction (Table 1.). Both eclipta and spotted-spurged showed similar results as phyllanthus did in Round 1. Tower treated containers showed excellent control on all three weed species with perfect control spotted spurge and eclipta. Long-stalked phyllanthus was 99% controlled when compared to the no herbicide, no mulch control.

After the data were collected from Round 1 of the experiment, all containers received a burn down treatment of Gramoxone (paraquat) to kill any non-target or remaining weeds. The containers were then reseeded with 10 seeds per partition of each container with seeds scattered on top of the mulch on 18 July 2014. Thirty one days after seeding, the weeds were counted and fresh weights were taken. Round 2 of the experiment showed that the preemergent herbicide, Tower, had seemingly lost all activity and showed no significant reduction in weed count or fresh weight in comparison to the control treatment. Depth of the mulch treatments, across all species, showed significance in both weed count and fresh weight. Treatments with 2.5 cm (1 in.) of mulch reduced the weed fresh weight of spotted spurge by 80.3% when compared to the treatments of no mulch with no herbicide and the treatments of no mulch with herbicide. Treatments with 5.1 cm (2 in.) of mulch reduced the foliage fresh weight of spotted spurge by 99.7% and treatments with 10.2 cm (4 in.) of mulch were observed showing complete control of spotted spurge.

Round 3 of the experiment began on 8 September 2014 with 10 weed seed being sown in each partition of the designated weed species. Weeds were counted and fresh weights were taken on 10 October 2014. The final round of the experiment showed similar results of those recorded in Round 2. Tower did not have any effect on weed count or fresh weight in any of the three weed species. Means comparisons on fresh weight and weed counts of spurge showed significant differences with only mulch depth as the main effect (Table 2.). Other weed species showed similar results during Round 3.

Our results have shown that mulch depth, not species, is the main effect for weed control in nursery containers. Tower treated containers lost efficacy after Round 1 most likely due to dimethenamid-p's short half-life of approximately 21 days (Senseman, 2007). Microbial activity coupled with the herbicide's high adsorption to the high levels of organic matter found in soilless growing media presumably rendered the herbicide ineffective by Round 2 (45 Days after treatment). It can be suggested from these data that 2 inches of mulch with particle size distribution similar to that found in study will provide safe, substantial, and long-term weed control in container crop production.

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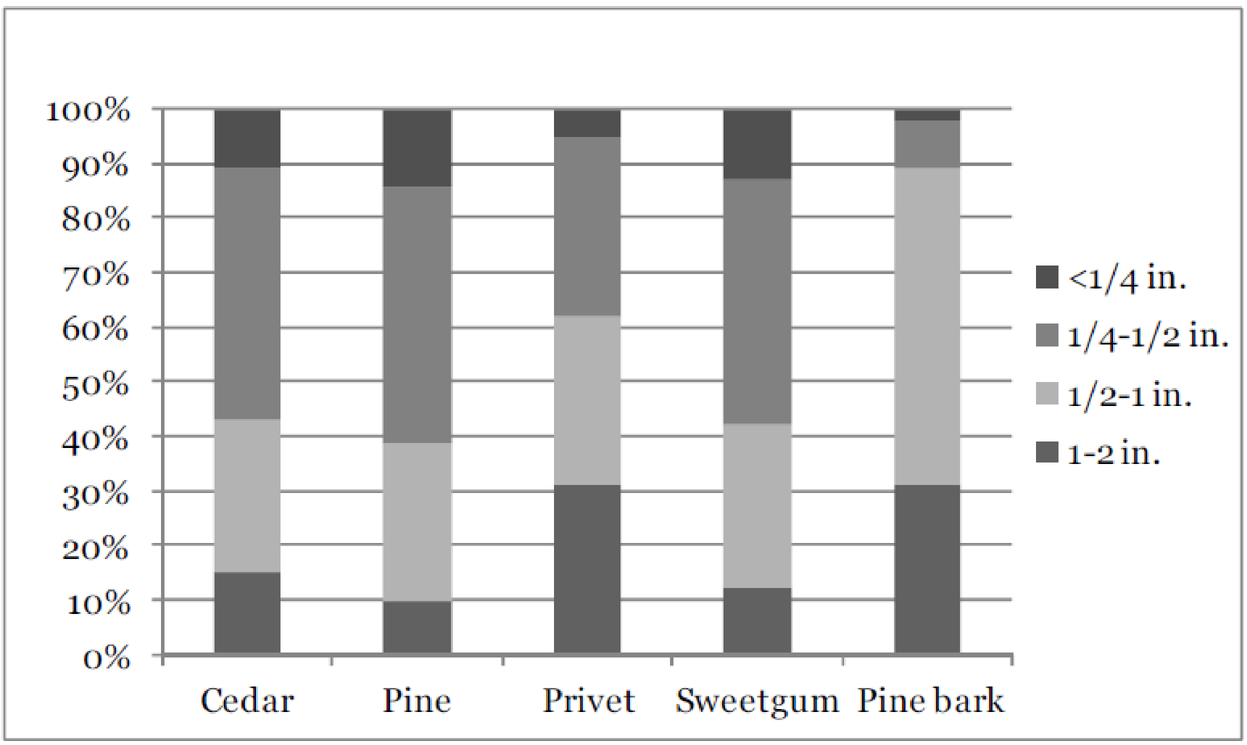

Figure 1. Particle size distribution by mulch species

Table 1. Round 1. Means comparisons on fresh weight and weed counts of Phyllanthus.

Fresh weight	Depth				
	0	1	2	4	Sign.
no	9.28a	1.68ns	0.09ns	0.00ns	Q***
yes	0.04b	0.02	0.00	0.00	NS

Weed count	Depth				
	0	1	2	4	Sign.
no	4a	1ns	0ns	0ns	Q***
yes	2b	1	0	0	Q***

Data was collected for Round 1 on 20 June 2014, 30 days after seeding on 30 May.

The herbicide application by mulch depth interaction was significant at α = 0.05.

Table 2. Round 3. Means comparison on fresh weight and weed counts of spotted spurge.

Fresh weight	Depth				
	0	1	2	4	Sign.
	12.83	4.46	1.00	0.03	Q***

Weed count	Depth				
	0	1	2	4	Sign.
	5	2	1	1	Q***

Data was collected for Round 3 on 10 Oct. 2014, 32 days after seeding on 8 Sep. 2014.

Only the Depth main effect was significant at α = 0.05.

Influence of Substrate Type on Weed Seed Germination

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Significance to Industry: Container nursery substrates are composed primarily of softwood tree bark, with pine (*Pinus taeda*) bark being the predominant type used in the central and eastern United States. Bark is typically amended with various components including, but not limited to, sphagnum peatmoss, sand, compost, and other locally available agricultural or industrial byproducts. Sphagnum peatmoss is one of the most commonly used amendments, and is often incorporated at rates from 10% to 40% of the substrate volume. Sphagnum peatmoss can hold up to 20 times its weight in water, and thus is often used to increase the water holding capacity of pine bark substrates. The objective of this research was to determine how pine bark substrate amended with sphagnum peatmoss affects creeping woodsorrel (*Oxalis corniculata*) germination in containers. This research shows that amending pine bark with increasing rates of sphagnum peat moss from 0% to 40% (by vol.) increases the water holding capacity of the substrate, however, water availability on the substrate surface where weed seedlings 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 vary the water holding characteristics of a substrate in order to provide an optimum growing environment, changes in bulk substrate physical properties will not affect herbicide performance on the substrate surface.

Nature of work: Black nursery containers (#3, approx. 3 gal.) were filled with either 100% pine bark, 80 pine bark : 20 peatmoss, or 60 pine bark : 40 peatmoss (v:v). All substrates were amended with 12 lb/yd^3 controlled release fertilizer to supply all macro and micronutrients (Osmocote 15-9-12 Northern, The Scotts Co., Marysville, OH). After potting, half of the containers were treated with 200 lb/A Pendulum 2G (pendimethalin, BASF) and the other half were left untreated. A group of treated and untreated containers were seeded with 40 creeping woodsorrel seed the day following herbicide application (week 0) and a separate group of containers were seeded every 2 weeks thereafter for 8 weeks. Established creeping woodsorrel were counted 4 weeks after seeds were applied. Containers were placed within an overhead irrigation system and irrigated daily with approximately 0.25 in of water. There were six single-pot replications per treatment and seeding date, arranged in a completely randomized design.
A portion of each substrate type was measured for physical properties using substrate porometers to determine air space (AS), container capacity (CC) and total porosity (TP). Moisture characteristic curves (MCC) were also generated to determine the volumetric water content of each substrate throughout the container profile.

Results and Discussion: Increasing the ratio of sphagnum peatmoss in containers affected the bulk substrate physical properties. Air space decreased and CC increased with increasing peat moss level. Using MCC-generated data, substrates with 20% or 40% peat moss also had higher easily available water. However, MCC were also used to calculate the volumetric water content on the substrate surface. On the surface, all substrates had 40% water content at saturation.

Regardless of substrate type, Pendulum reduced creeping woodsorrel numbers in containers when seeds were applied up to 4 weeks after herbicide application. Among containers in which seed were applied 8 weeks after application, creeping woodsorrel numbers were similar in herbicide and non-treated containers. This suggests the herbicide barrier may have degraded to an ineffective concentration on the substrate surface in as little at 5 to 6 weeks.

Substrate type had an inconsistent and relatively minor effect on creeping woodsorrel numbers. Among containers not treated with Pendulum, 100% bark had greater creeping woodsorrel numbers than the 60 : 40 substrate when seeds were applied 4 or 8 weeks after potting. Among containers treated with Pendulum, weed counts were similar in all substrate types. Little or no effect from substrate type on creeping woodsorrel establishment is probably due to the similar volumetric water content on the substrate surface. While peat moss amendments can have a large effect on bulk substrate physical properties, it had no effect on volumetric water content at the substrate surface.

Table 1. Physical properties of three substrates comprised of varying ratios of pine bark: peat moss.

Pine bark : peat moss	Air space	Container capacity	Easily avail. water	Vol. water at 30 cm
100 : 0	37.2	44.0	11.2	40.0
80 : 20	29.8	53.4	19.4	40.0
60 : 40	21.1	62.0	20.6	40.6
$LSD_{0.05}$	4.6	2.8	ND	ND

ND is not determined.

Table 2. Creeping woodsorrel (Oxalis corniculata) numbers in containers with varying ratios of pine bark : peat, and either treated with Pendulum 2G herbicide or not. Weed seeds were applied either 0, 4, or 8 weeks after herbicide application.

		Weed seed application date[z]		
Herbicide	Substrate	0	4	8
None	100:0	10.8	11.3	10.8
	80:20	11.3	8.2	9.7
	60:40	13.7	7.2	5.5
Pendulum	100:0	1.2	1.3	7.2
	80:20	1.8	4.8	7.7
	60:40	0.8	2.8	5.0
	$LSD_{0.05}$	4.2	4.1	4.4
	Main effects			
	Herbicide	0.0001	0.0001	0.1065
	Substrate	0.6895	0.5254	0.0347
	Interaction	0.4487	0.0576	0.5386

[z] Weed seeds were applied either 0, 4, or 8 weeks after herbicide application.