

Use of Ground Wheat Straw in Container Nursery Substrates to Overwinter Daylily Divisions^{1, 2}

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Abstract

Wheat (*Triticum* sp.) straw is being evaluated as a potential component in soilless container mixes either alone or combined with compost to replace a significant portion of the substrate currently supplied by pine bark and peat moss. The objective of this study was to evaluate wheat straw and horse manure compost, locally available resources, as components of container media for establishing and overwintering daylily (*Hemerocallis fulva* 'Stella D'Oro'). A standard commercial, sphagnum peat-based substrate was amended with either wheat straw, horse manure compost, or a combination of the two. Stella D'Oro daylily divisions were grown in each substrate mix and overwintered in an unheated structure for eight months. Physical properties of the mixes were determined to be within production standards and media shrinkage was minimal. Daylilies in all substrate combinations were of comparable vigor to the non-amended substrate when growth resumed in the spring.

Index words: potting mix, herbaceous perennial, daylily, overwintering, *Hemerocallis fulva* 'Stella D'Oro'.

Significance to the Nursery Industry

Pine bark and sphagnum peat moss are, by volume, the primary components of substrates used in container production of herbaceous perennials. The cost of both of these components has been continually rising over the past few years due to external market forces. The objective of this study was to determine if ground wheat straw (WS) or locally sourced horse manure compost (HC) could be substituted for a portion of the volume of the aforementioned components in container media used to establish and overwinter daylily divisions. This study demonstrated that successful daylily overwintering could be achieved in modified growing media utilizing locally available WS and HC. Although results indicated that production protocols may need to be modified slightly, the success of the approach warrants further evaluation for the production of herbaceous perennials.

Introduction

Nursery-grown herbaceous perennials are traditionally produced outdoors or in unheated structures, in containers filled with a soilless substrate composed primarily of pine bark and sphagnum peat moss, with lesser amounts of other materials, such as compost, depending on grower preference and availability. Development of alternatives to the major components in container nursery production is important to the U.S. nursery industry due to availability and cost fluctuations frequently encountered in the supply chain of primary substrate components. The growing interest in and

development of wood-based ethanol production could make supply of many biomass materials scarcer and costly (6).

Agronomic biomass materials, primarily coming from biofuel feedstock production, may be a possible source of alternatives for the use of pine bark and sphagnum peat moss as the major ingredients in container growing media used for herbaceous perennial production. An earlier study (2) showed that particle size of biomass amendments greatly affected air space and container capacity of container media when combined with peat moss. Finer milled switchgrass (*Panicum virgatum*) (processed through a single 0.48-cm screen), when combined with peat moss, provided physical properties more consistent with standard nursery container substrates than coarser milled material. The pH of the switchgrass amended substrate was also higher, and crops grown in the amended substrate had low to moderate tissue levels of calcium and iron. However, with appropriate substrate amendments, the switchgrass substrate provided suitable growth for short production-cycle crops. When miscanthus (*Miscanthus × giganteus*) straw was prepared in a similar manner and blended over a range of 0 to 80% with pine bark, results showed that blends containing a minimum of 20% pine bark provided a suitable substrate for hibiscus (*H. moscheutos*) production for an 8-week study (4). Results from that study showed that miscanthus straw blends (20 to 60%) provided high quality plants of similar color and size to those grown in an industry-standard pine bark substrate. With both of these biomass amendments some adjustment of fertilization practice may be necessary to reduce or eliminate N-immobilization over the entire crop production cycle. In working with straw-based substrates, the authors have noticed shrinkage of the substrate in some containers and this might be of consequence in overwintering perennial plant material. Thus the objective of this experiment was to assess potential shrinkage of substrates containing WS and HC after an overwintering exposure as well as to evaluate plant quality in the spring.

Materials and Methods

Dry wheat straw (WS) was harvested in the summer of 2010 and stored in a barn until needed. Ground WS was prepared by passing baled straw through a hammermill (NO.

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30 with blower discharge, The C.S. Bell Co., Tiffin, OH) equipped with a 0.48 cm (0.188 in) screen. Dehydrated horse manure compost (HC), from 3-year-old aged horse manure at a local horse farm (Whitehouse, OH), was obtained as a sustainable form of compost for this production site. A standard commercial soilless medium composed of 85:15 sphagnum peat moss:perlite (v/v) (Berger BM-1, Berger Peat Moss, Saint-Modeste, Quebec, Canada) was selected as the base substrate for the study. The treatment arrangement was a 2 × 2 factorial with base substrate amended with either 0 or 40% WS and 0 or 10% HC. All substrates were supplemented, prior to potting, with slow release fertilizer (Woodace Flowering Plant Special 14-14-14) at a rate of 0.71 kg·m⁻³ (1.2 lb·yd⁻³) N.

Substrates were filled into 2.97 liter (#1) black plastic nursery containers. Field grown daylily divisions, composed of two to three fans for uniformity of size, were planted into containers on August 20, 2010. Containers were placed in an uncovered hoophouse in Whitehouse, OH. After watering in, the shoots of the daylily divisions were cut back to approximately 5 cm (2 in) above the media surface. Containers were hand watered, as needed to supplement rainfall, for the first eight weeks to allow establishment. The structure was covered with white polycarbonate plastic on October 17, 2010. The white polycarbonate cover was replaced with clear polycarbonate cover on March 4, 2011. Temperature sensors (HOBO Pro v2 data loggers, Onset Computer Corp., Pocasset, MA) were inserted to a uniform depth of 6.5 cm (2.6 in) below the substrate surface within three representative containers for each treatment as well as inside and outside the greenhouse structure to measure and record substrate and ambient air temperature throughout the trial.

A sample of each substrate was set aside at the time of potting to determine physical properties. Three replicate subsamples of each substrate were packed in aluminum cores [7.6 cm (3 in) tall by 7.6 cm (3 in) i.d.] according to methods described by Fonteno and Bilderback (7). There were three replications for each substrate. Aluminum (Al) cores were attached to North Carolina State University Porometers™ (Horticultural Substrates Laboratory, North Carolina State University, Raleigh, NC) for determination of air space (AS). Cores were weighed, oven dried for four days at 72C (162F), and weighed again to determine container capacity (CC). Total porosity (TP) was calculated as the sum of AS and CC. Bulk density (D_b) was determined using oven dried substrate in Al cores.

Substrate shrinkage was determined by measuring the distance from the container lip down to the substrate surface of eight randomly selected containers in each treatment on October 5, 2010. Four measurements were made around the circumference of each container. The same containers were measured again on April 26, 2011 when the experiment was terminated. Shrinkage was calculated as the difference between these two measurements. Substrate pH and electrical conductivity (EC) were determined with the pour-through procedure at the conclusion of the trial (12). Seven leaves per pot of recently matured foliage were harvested for foliar nutrient analysis (9), rinsed with deionized water, then oven dried at 55C (131F) for 3 days prior to grinding. Samples were ground in a mortar and pestle and prepared for analysis. Foliar nitrogen (N) was determined with a PerkinElmer Series II CHNS/O Analyzer (PerkinElmer Instruments, Shelton, CT). Other macronutrients and micronutrients were

determined with a Thermo Iris Intrepid ICP-OES (Thermo Electron Corp., Waltham, MA). Shoot dry weight (SDW) was measured at the conclusion of the experiment. Root masses were visually quantified on a 0–10 scale (roots at substrate/container interface only) where 0 = no observable root mass and 10 = complete coverage of the substrate/container interface with roots.

There were 15 replications per substrate treatment arranged in a completely randomized design. Data were subjected to analysis of variance, and means were separated with Fisher's protected least significant difference test ($\alpha = 0.05$).

Results and Discussion

Only WS affected air space (Table 1). Amendment with 40% WS more than doubled AS compared to substrates without WS (28 vs. 12%). Other straw amendments have increased AS of pine bark based substrates (1, 2). Substrates with WS had lower CC compared to those without (61 vs. 73%) while substrates with HC had higher CC compared to those without (69 vs. 64%). Despite differences, AS and CC of all substrates were within recommended physical properties (13). Total porosity increased with the addition of both WS and HC. This research did not show that one amendment is superior to the other, or that the resulting properties of any of the four substrates are more conducive to plant growth or overwintering success. For example, Lowder et al. (8) grew hellebores (*Helleborus ×hybridus* and *H. foetidus*) in pine bark amended with different amounts of sand or peat moss, and demonstrated that hellebores are best grown in substrates with high available water (AW) and low AS. Conversely, Breedlove et al. (5) grew 'Hershey Red' azalea (*Rhododendron* sp.) in pine bark alone or pine bark amended with peat moss or perlite, and showed that greatest growth and quality occurred in 100% pine bark, which among all substrates had the highest AS and lowest AW. Our data simply suggest changes in irrigation management practices may be needed when using either WS, HC, or both. Bulk density was affected by an interaction between WS and HC, although differences among treatments were minor and would not likely have a biological consequence.

Foliar N, P, and K were affected by substrate type at fall and spring collection dates (Table 2). Despite nutrient differences between treatments, plants growing in all substrates

Table 1. Physical properties of an 85:15 sphagnum peat:perlite (v/v) substrate amended with wheat straw and/or horse manure compost.

Wheat straw (% v/v)	Horse compost (% v/v)	Air space	Container capacity (%)	Total porosity	Bulk density (g/cm ³)
0	0	13	70	83	0.10
0	10	11	75	86	0.11
40	0	27	58	85	0.08
40	10	28	63	92	0.11
LSD _{0.05} ^z		5	4	4	0.00
Wheat straw		***y	***	*	***
Compost		NS	**	**	***
Interaction		NS	NS	NS	***

^zLeast significant difference determined by Fisher's test where $\alpha = 0.05$.

^yNS, *, **, *** represent non-significant, significant at 0.05, 0.01, and 0.001 probability levels, respectively.

Table 2. Foliar nutrient levels of daylily grown in an 85:15 sphagnum peat:perlite (v/v) substrate amended with wheat straw and/or horse manure compost.

Sampling date	Wheat straw	Horse compost	N	P	K	Ca	Mg	S	Fe	Mn	B	Cu	Zn
October 5, 2010	0	0	5.9	0.82	2.8	0.63	0.30	0.66	82	242	50.4	6.4	61.3
	40	0	5.6	0.66	2.9	0.75	0.31	0.45	113	183	46.0	10.6	38.5
	0	10	5.8	0.70	2.7	0.31	0.16	0.47	90	106	38.7	7.9	47.7
	40	10	5.5	0.70	3.3	0.56	0.27	0.41	86	166	49.7	6.1	49.2
	LSD _{0.05} ^z		0.2	0.05	0.3	0.1	0.06	0.08	20	44	6.8	1.8	7.2
Wheat straw		NS ^y	*	NS	***	***	***	NS	***	NS	*	NS	
Compost		***	***	**	***	**	***	*	NS	NS	NS	***	
Interaction		NS	***	*	NS	*	**	*	***	**	***	***	
April 26, 2011	0	0	5.0	0.59	3.5	0.46	0.30	0.34	52	93	34.3	5.3	50.2
	40	0	5.1	0.59	3.4	0.49	0.27	0.29	60	49	20.1	5.5	44.6
	0	10	4.7	0.67	4.0	0.45	0.27	0.33	57	119	37.0	4.3	49.0
	40	10	4.0	0.57	3.8	0.49	0.27	0.29	56	54	30.6	3.2	44.6
	LSD _{0.05}		0.7	0.07	0.6	NS	NS	0.03	NS	25	7.4	1.9	NS
Wheat straw		*	NS	*	NS	NS	NS	NS	NS	*	*	NS	
Compost		NS	NS	NS	NS	NS	***	NS	***	***	NS	NS	
Interaction		NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	
Recommended			3.79	0.33	2.77	0.69	0.38	0.24	167	126	24.0	4.0	38.0

^zLeast significant difference determined by Fisher's test where $\alpha = 0.05$.

^yNS, *, **, *** represent non-significant, significant at 0.05, 0.01, and 0.001 probability levels, respectively.

were at or above the recommended range for each of the three macronutrients. Foliar Ca and Mg levels in fall-harvested tissue were lower when amended with HC, and slightly higher when amended with WS. After overwintering, Ca and Mg levels were similar across treatments. Foliar S, B, Cu, and Zn were affected by substrate treatment in either fall-harvested tissue or both fall and spring; however, concentrations of these nutrients were above recommended levels (9). Foliar Fe and Mn were generally lower than recommended levels(9), although plants displayed none of the classic deficiency symptoms of interveinal or marginal chlorosis.

Electrical conductivity measured in the fall (October 5, 2010) was similar across treatments. Electrical conductivity measured in the spring was less in containers with WS compared to those without (1.8 vs. 4.0 $\text{ds}\cdot\text{m}^{-1}$). There was an interaction between WS and HC levels for substrate pH in the fall measurement. Relative to the non-amended substrate, WS reduced substrate pH while HC (without WS) increased pH. This is contrary to previous research where straw-based materials tended to increase pH when added to pine bark and peat moss substrates (3). By spring 2011, both WS and HC increased substrate pH relative to the non-amended substrate. The effect of WS and HC on pH of the base substrate was additive, not interactive.

Shrinkage was greater in substrates with WS compared to those without (3.9 vs. 0.5 mm). Despite greater shrinkage, 3.9 mm only accounts for about 2.6% shrinkage of the total container depth. Shrinkage in other straw-based substrates has been variable when containers are in production for longer than 8 weeks. While no data are currently available, the extent of shrinkage in straw-based substrates have been observed in other trials to increase with time of production, but decrease in the presence of vigorous root growth. Shrinkage during overwinter periods is of concern due to relative

slow root growth of any crop regardless of its vigor during the growing season. Lack of shrinkage in substrates without WS was surprising considering that others have shown that settling and decomposition of peat-based substrates may be more common than in bark-based substrates. Nash and Laiche (10) reported that increasing levels of peat relative to bark in substrates caused an increase in the amount of shrinkage. Likewise, Nelson et al. (11) showed that shrinkage in peat-based substrates was incrementally reduced as coir incrementally replaced peat in the substrate.

Visual root development ratings made in the spring of 2011 showed little variation among treatments (data not shown). The grower provided a written assessment of plant performance in the spring which indicated growth to be equal among treatments and crop quality slightly better, but not significantly different, for the two treatments containing the WS compared to those without (ratings not shown). It was speculated that amendments might affect substrate temperatures and thus spring emergence date. There were no meaningful differences in substrate temperature throughout the overwinter and spring period, and no observed difference in timing of spring daylily emergence (data not shown). At the conclusion of the experiment, there were no significant differences in shoot mass (Table 3) although shoots grown in substrates amended with WS and HC had more than twice the mass of non-amended substrates. There was considerable variation across treatments resulting in the non-significant differences which could be attributed to the inherent variability of the field-grown daylily transplants (fans), despite our attempt at selecting for uniformity.

In summary, the potential for use of WS or HC alone or in combination as components in container growing media for the overwintering period of daylily production shows promise. Both materials affect physical properties of

Table 3. Beginning and ending EC and pH of substrate solutions, shrinkage over the course of the experiment, and final shoot mass of daylily grown in an 85:15 sphagnum peat:perlite (v/v) substrate amended with wheat straw or horse manure compost.

Wheat straw	Horse compost	Electrical cond.		pH		Shrinkage (mm)	Shoot mass (g)
		Fall ^a (dS/m)	Spring (dS/m)	Fall	Spring		
0	0	1.9	4.4	6.3	5.0	0.4	0.9
0	10	1.8	3.7	6.7	5.2	0.6	1.2
40	0	1.6	1.9	5.8	5.4	4.2	1.1
40	10	2.3	1.7	6.0	5.6	3.7	2.0
LSD _{0.05} ^y		NS	0.7	0.2	0.2	2.3	NS
Wheat straw		NS ^x	***	***	***	***	NS
Compost		NS	NS	**	**	NS	NS
Interaction		NS	NS	*	NS	NS	NS

^aSampling times were October 5, 2010, and April 26, 2011, for Fall and Spring, respectively.

^yLeast significant difference determined by Fisher's test where $\alpha = 0.05$.

^xNS, *, **, *** represent non-significant, significant at 0.05, 0.01, and 0.001 probability levels, respectively.

standard peat-based substrates to the extent that irrigation management practices should be modified, but not so drastically that crops are adversely affected. Both WS and HC affected EC and pH levels in peat-based substrates, but these effects seem to have had little practical impact on mineral nutrition of daylily. Shrinkage was greater in WS amended substrates, but shrinkage as a percent of container height was considered inconsequential. The lack of importance of shrinkage in WS substrates was reflected in the similarity of market quality assigned by the grower between these and substrates not amended with WS. Further research focused on fertilizer requirements, suppressiveness or conduciveness to root pathogens, and long-term physical stability for the duration of the crop production cycle are warranted in order to formulate production recommendations and to determine cost benefit of using WS and HC amendments.

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