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Section Editor

Pre and Post-distilled Cedar as Alternative Substrate Components in the Production of Greenhouse-grown Annuals

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Index Words: Peat moss, perlite, soilless substrate, *Petunia ×hybrida*, *Catharanthus roseus*, *Juniperus virginiana*

Significance to the Industry: Peat moss is the main component in soilless greenhouse substrates today and is thus in high demand commercially. The demand for peat moss has caused both economic and environmental concerns. In previous studies post-distilled cedar was found to be a promising alternative substrate component in the production of greenhouse-grown annuals (7). The experiment indicated that a standard peatlite mix (80:20 peat:perlite) could be amended with up to 40% cedar and be equal to, if not better than, the standard mix when growing annuals. The objective of this study was to compare the post-distilled cedar to cedar that has not undergone the distillation process. *Petunia ×hybrida* and *Catharanthus roseus* were grown in peatlite substrates that were amended with varying rates of pre and post-distilled cedar. The results of this study indicated that the quality of plants grown in post-distilled cedar were equal to, if not greater than, those grown in cedar.

Nature of Work: The two most common components in greenhouse media are peat moss and perlite. Due to an increasing demand for peat moss, the issue of peat bog preservation has been receiving attention. Another concern associated with peat moss production is the cost of shipping from Canada and Europe and the economic strain it puts on growers. As of September 23, 2011 a press release was issued by the Canadian Sphagnum Peat Moss Association (CSPMA) stating that the harvesting season for peat in Canada had effectively come to an end. Due to unfavorable weather conditions only 15% to 30% of the targeted peat bogs in Eastern Canada were harvested. The hardest hit areas were Quebec and New Brunswick, which account for 60-70% of all Canada's peat production. Therefore, it can be concluded that the industry is facing one of its poorest peat harvest seasons to date. Perlite is also experiencing increased demand. Perlite is not only expensive to produce, but there are also high amounts of energy required for both the production and shipping processes. Perlite is considered a health nuisance, causing lung and eye irritation in cases involving over-exposure (2).

Due to these concerns, growers have been concerned with finding replacement substrate options for both peat moss and perlite. In recent years research regarding

alternative substrates has steadily increased with an emphasis on local and regional sources of materials which are considered to be more sustainable. Numerous types of alternative substrates have been tested in greenhouse crops. Recent examples include research efforts on Clean Chip Residual, WholeTree, and Pine tree substrate (1, 3, 9).

An interest in using *Juniperus virginiana* (L.) (Eastern red cedar) as an alternative substrate component for peat moss has recently risen. Research has shown that plants grown in substrates amended with *Juniperus virginiana* tended to have equivalent growth quality to those grown in a traditional peatlite mix. Murphy et al. (5) indicated greenhouse producers could amend standard greenhouse substrates with up to 50% cedar with little to no difference in plant growth. Starr et al. (6) indicated that *Juniperus virginiana* chips could be used as a substrate for container-grown *Rudbeckia fulgida* var. *fulgida* (L.), with chips milled to pass a 0.5 cm screen size performing the best when compared to a pine bark substrate. In addition to the replacement of peat moss, the physical nature of cedar tends to add substrate porosity normally achieved with the addition of perlite. Therefore, we believe a reduction or elimination in the need for perlite might also be realized with the use of cedar as a substrate component.

One potential source of cedar is CedarSafe, a company located in Huntsville, AL. It is unlike cedar found in other substrate research projects, due to the fact that this cedar is a by-product of cedar oil production at the CedarSafe facilities. The process begins with debarked cedar logs (*Juniperus virginiana*), which are shaved and then sent through a hammer mill. It is then conveyed to a set of boilers, where the material undergoes a steam distillation process, which extracts a percentage of the cedar oil. CedarSafe currently has no market for the post-distilled cedar biomass. In previous studies it was found that this post-distilled cedar biomass could be a successful alternative substrate component in growing greenhouse annuals (7). Therefore, this study will compare post-distilled cedar to cedar that has not undergone the distillation process.

The study was implemented on June 15, 2011 at the Paterson Greenhouse Complex at Auburn University. Pre (C) and post-distilled cedar (DC) were used in volumetric combination with an industry standard peatlite (PL) base mix (80% Peat: 20% Perlite). There were six treatments compared in this study: Trt. 1-60:40 C:PL, Trt. 2-40:60 C:PL, Trt. 3-20:80 C:PL, Trt. 4-60:40 DC:PL, Trt.5-40:60 DC:PL, and Trt. 6-20:80 DC:PL. Substrate treatments had the following amendments added per cubic yard at mixing: 5 lbs. lime (added only to PL base); 2 lbs. starter nutrient charge (7-3-10, Greencare Fertilizers Inc. Kankakee, IL), 1 lb. Micromax (The Scott's Company LLC. Marysville, OH), and 6 lbs. slow release fertilizer (13-6-16, Harrell's LLC. Lakeland, FL). Aqua-Gro L was added at 4 oz. per cubic yard. 1.8 L containers (Dillen Products Middlefield, OH) were filled with the substrates and either 2 plugs (200 cell flat) of *Petunia ×hybrida* or 3 plugs (200 cell flat) of *Catharanthus roseus* were planted into each container. Containers were placed in a twin wall polycarbonate greenhouse on elevated benches and hand watered as needed. Containers were arranged in a randomized complete block with 12 blocks per treatment. Species were arranged as separate experiments.

Data collected included pH and EC ratings at initial planting and then at weekly intervals throughout the experiment using the pour-through method (8). At termination each plant's blooms were counted. Roots were visually inspected and rated on a scale of 0 to 5, with 0 having no visible roots and 5 having roots visible over the entire substrate surface. At termination shoots were removed at substrate surface, oven dried, and weighed to determine shoot dry weight. Initial substrate airspace, container capacity, total porosity, and bulk density were determined using the NCSU Porometer method, as well as particle size distribution (4). Data was analyzed using Tukey's Studentized Range Test ($P \leq 0.05$) (SAS Institute version 9.1, Cary, NC).

Results and Discussions: Results from porometer readings indicated that all substrate treatments had a similar total porosity (Table 1). Substrates containing higher amounts of cedar had higher air space and thus lower container capacity. These rates are due to the larger particle size that cedar has compared to peat moss.

Results for pH of both petunias and vinca at 0, 14, 28, and 35 DAP (days after planting) indicated that as the percentage of cedar decreased in a substrate the pH for that substrate also decreased (Table 2, 3). It was observed that EC values for vinca at 0 and 14 DAP decreased with an increasing rate of cedar (Table 3). The same results were seen in petunias at 0 DAP (Table 2). EC values at 28 and 35 DAP for both petunias and vinca were similar among all substrate treatments.

Data taken at termination indicated that plants grown in treatments containing a smaller percentage of cedar had better growth data than those grown in higher percentages of cedar for both pre and post-distilled substrates (Table 4). In previous studies similar results were seen and were contributed mainly to the larger particle size of the cedar biomass and its leaching effects (7). Bloom counts for petunias were similar amongst pre and post-distilled cedar treatments when compared to substrates with the same percent. Bloom counts for vinca at 20% and 40% were comparable between pre and post-distilled cedar. However, in vinca, a bloom count increase of about 46% was observed in 60% post-distilled cedar when compared to 60% pre-distilled cedar. Root ratings for both petunias and vinca were comparable at 20% in both pre and post-distilled substrates. However, plants grown in substrates containing 40% and 60% post-distilled cedar had higher root ratings than that of those grown in pre-distilled cedar. Shoot dry weights for petunias were similar between 20% and 60% cedar amended substrates. A weight increase of about 30% was seen in 40% post-distilled cedar when compared to 40% pre-distilled cedar. In vinca grown substrates, a similarity was seen between 20% and 40% cedar amended substrates. However, a weight increase of about 28% was seen when comparing 60% post-distilled cedar to 60% pre-distilled cedar.

It can be concluded that distilled cedar substrates performed equal to, if not better than, cedar substrates. This could be due, in part, to the distillation process that our cedar biomass undergoes. The act of removing a percentage of the cedar's oil may positively affect plant growth, as was seen with previous studies (7). This cedar could potentially

be a viable alternative for the horticulture industry and replace portions of peatmoss and perlite in the production of greenhouse-grown annuals.

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Table 1. Physical properties of cedar amended substrates.[z]

Substrates	Air space[y]	Container capacity[x]	Total porosity[w]	Bulk density[v] (g/cm^3)
	---------- (% vol) ----------			
20% C[u]	8.20 cd[t]	84.23 a	89.43 a	0.11 b
20% DC	5.77 bcd	83.10 ab	88.80 ab	0.10 b
40% C	2.87 d	82.30 ab	85.17 b	0.13 ab
40% DC	7.30 abc	79.50 bc	86.77 ab	0.12 ab
60% C	10.63 a	75.20 d	85.87 ab	0.14 a
60% DC	9.20 ab	78.43 cd	87.60 ab	0.13 ab

[z]Analysis performed using the NCSU porometer method.

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

[x]Container capacity is (wet weight - oven dry weight) ÷ volume of the sample.

[w]Total porosity is container capacity ÷ air space.

[v]Bulk density after forced-air drying at 105 °C (221 °F) for 48 h (g/cm3 = 62.4274 lb/ft3).

[u]C= pre-distilled cedar DC= post-distilled cedar; used in volumetric combination with a PL mix (80% Peat: 20% Perlite).

[t]Means separation within columns using Tukeys Studentized Range Test ($P \leq 0.05$, n = 3).

Table 2. Effects of substrate on pH and electrical conductivity of greenhouse grown *Petunia ×hybrida.*

	0 DAP[z]		14 DAP		28 DAP		35 DAP	
Substrates	pH	EC[y]	pH	EC	pH	EC	pH	EC
20% C[x]	4.49 de[w]	3.66 ab	5.26 bc	3.71 a	5.12 c	2.00 a	5.28 ab	1.34 a
20% DC	4.47 e	3.54 bc	5.08 c	4.58 a	4.65 d	2.16 a	4.81 b	1.20 a
40% C	4.61 d	2.88 d	5.46 ab	3.54 a	5.38 c	1.69 a	5.29 ab	1.27 a
40% DC	4.77 c	4.21 a	5.39 abc	4.22 a	5.41 bc	1.43 a	5.37 ab	1.12 a
60% C	5.01 b	2.63 d	5.69 a	3.95 a	6.21 a	1.19 a	5.95 a	0.82 a
60% DC	5.17 a	2.92 cd	5.56 ab	4.31 a	5.84 ab	1.42 a	5.90 a	0.88 a

[z]Days After Planting.

[y]Electrical Conductivity (dS/cm) of substrate solution using the pour through method.

[x]C= pre-distilled cedar DC= post-distilled cedar; used in volumetric combination with a PL mix (80% Peat: 20% Perlite).

[w]Means separation within columns using Tukeys Studentized Range Test (P ≤ 0.05, n = 4).

Table 3. Effects of substrate on pH and electrical conductivity of greenhouse grown *Catharanthus roseus.*

	0 DAP[z]		14 DAP		28 DAP		35 DAP	
Substrates	pH	EC[y]	pH	EC	pH	EC	pH	EC
20% C[x]	4.49 de[w]	3.66 ab	5.40 b	3.08 bc	4.91 d	1.41 a	4.66 d	1.67 a
20% DC	4.47 e	3.54 bc	5.11 c	4.65 a	4.79 d	1.61 a	4.80 d	1.08 a
40% C	4.61 d	2.88 d	5.36 bc	2.51 c	5.35 c	1.57 a	4.78 d	1.22 a
40% DC	4.77 c	4.21 a	5.40 b	4.05 ab	5.50 c	1.31 a	5.27 c	1.19 a
60% C	5.01 b	2.63 d	5.93 a	3.00 c	6.47 a	1.32 a	6.35 a	0.67 a
60% DC	5.17 a	2.92 cd	5.60 b	3.30 bc	6.10 b	1.24 a	5.74 b	1.01 a

[z]Days After Planting.

[y]Electrical Conductivity (dS/cm) of substrate solution using the pour through method.

[x]C= pre-distilled cedar DC= post-distilled cedar; used in volumetric combination with a PL mix (80% Peat: 20% Perlite).

[w]Means separation within columns using Tukeys Studentized Range Test (P ≤ 0.05, n = 4).

Table 4. Use of cedar as an alternative substrate component.[z]

Substrates	Bloom counts[y]	Root rating[x]	Shoot dry weight[w]
	Petunia ×hybrida		
20% C[v]	22.33 a[u]	2.75 bc	9.36 a
20% DC	23.08 a	3.63 ab	9.11 a
40% C	19.42 ab	2.50 c	7.00 b
40% DC	23.67 a	3.75 a	9.21 a
60% C	16.08 b	2.38 c	6.01 b
60% DC	20.25 ab	3.00 abc	6.55 b
	Catharanthus roseus		
20% C	24.17 ab	2.75 bc	10.73 a
20% DC	27.00 a	3.50 ab	10.53 ab
40% C	18.42 cd	2.00 c	9.39 bc
40% DC	21.25 bc	4.25 a	10.30 ab
60% C	11.33 e	1.88 c	6.88 d
60% DC	16.50 d	3.75 ab	8.80 c

[z]Experiment installed at the Paterson Greenhouse Complex on June 15, 2011.

[y]Bloom count = number of blooms or buds showing color at 35 days ($P \leq 0.05$, $n = 12$).

[x]Root ratings 0-5 scale (0 = no visible roots and 5 = roots visable on the entire container substrate interface) ($P \leq 0.05$, $n = 8$).

[w]Shoot dry weight measured in grams ($P \leq 0.05$, $n = 8$).

[v]C= pre-distilled cedar DC= post-distilled cedar; used in volumetric combination with a PL mix (80% Peat: 20% Perlite).

[u]Means separation within columns using Tukeys Studentized Range Test ($P \leq 0.05$, $n = 12$).

Effects of Fertilizer Rate on Production of *Petunia ×hybrida* in Corncob Amended Substrates

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Significance to the Industry: Perlite (PL) is a component in most soilless greenhouse substrates. Perlite takes significant energy to produce and transport and is known to be an eye and lung irritant (3). Corncob, a possible new alternative to perlite, may require nitrogen management during greenhouse crop production. This study evaluated the effect of nitrogen fertilizer rates on corncob-amended substrates in the production of *Petunia ×hybrida.*

Peatmoss was combined with soaked corncob, unsoaked corncob, or perlite, and mixed with 2, 4, 6, or 8 lbs/yd^3 of slow-release fertilizer (13-6-16 Harrell's Lakeland, FL). Results indicated an increase in the growth of petunias with the increase of fertilizer rate. This study continues to show that corncob might be a viable alternative to perlite. Although additional studies need to be conducted to determine the best nutrient management practices. Additional advantages of corncob are its potential to be regionally available and more carbon neutral compared to perlite.

Nature of Work: In the production of greenhouse crops, soilless substrates are often used as the growing media and the major components of those substrates often include peat moss and perlite (1, 2). These components are often mixed at different rates to reach the desired physical properties of the selected crops. Perlite remains popular because of its ability to add air space to peat-based substrates without increasing bulk density. Perlite, an inorganic rock, is mined and heated to 1,600 ^{o}C to remove all water and expand the rock (7). This process can produce a fine particle dust that has been shown to cause eye and lung irritation (3).

Alternatives to perlite have been looked at to provide the same function and to provide a more worker-friendly environment. Alternatives include: ricehulls, Hydrocks, and expanded polystyrene (4, 5,10). Another potential alternative to the use of perlite is processed corncob, a readily available domestic product (11). One concern with the use of corncobs is the possibility of N-Immobilization (9). Due to the possible nitrogen concerns, the objective of this study was to look at the effect of fertilizer rate on corncob-amended substrates in the growth of *Petunia ×hybrida.*

Materials and Methods: Experiments were installed on June 6, 2011 at the Paterson Greenhouse Complex at Auburn University. Two types of corncob were used for this

study: corncobs that were unsoaked (US), and corncobs that were soaked (S) (Corncob was placed in plastic containers and soaked for 24 hours and air-dried on a greenhouse bench). Based on previous studies, we chose to pre-wet the corncob to rinse possible residual nutrients and allow the corncob to imbibe water (our corncob source had been heat-dried during processing). Each type of corncob was blended with peat moss at a ratio of 80:20 peat:corncob(US) and 80:20 peat:corncob(S) (v:v); compared to an 80:20 peat:perlite standard. Each substrates was amended with 3 lb/yd^3 of Dolomitic Limestone, 1.5 lbs/yd^3 of micromax (The Scotts Company, Marysville, OH), Controlled release fertilizer (13- 6 -16 control release fertilizer Harrell's, Lakeland, FL) was added to each substrate at 2, 4, 6, 8 lbs/yd^3. Containers (shuttle pot SP 525 East Jordan Plastics, INC, East Jordan, MI) were filled with substrates and planted with 2 plugs (200 cell flat) of *Petunia* ×*hybrida* 'Rambling Sugar Plum'. Containers were placed on a raised bench in a twin wall polycarbonate greenhouse and watered as needed.

Data collected included initial substrate pH and EC, and weekly there after days using the pour-through method (12). Final growth measurements collected at 35 days after planting (DAP) included: growth index (GI) [(height + width + Perpendicular width ÷ 3 (cm)], bloom count (BC) (number of blooms showing color), and shoot-dry weights (SDW) (oven dried at 70^{o}F for 72 h). Substrate total porosity (TP), container capacity (CC), air space (AS), and bulk density (BD) were determined using the NCSU porometer method (6). Containers were randomized complete block design (RCB) with 12 single pot replicates. Data were subjected to analysis of variance using the general linear models procedure and a multiple comparison of means was conducted using Tukey's Honest Significant Difference Test (version 9.1: SAS Institute, Cary, NC).

Results and Discussion: Physical properties analysis (Table 1) indicated TP and CC in corncob-amended substrates compared to the peat-lite mix, with corncob-amended substrates being higher in TP and CC. Air space was higher for unsoaked corncob compared to peat-lite mixes, while soaked corncob was found to have no difference when compared to peat-lite. One reason for soaked corncob to have a slight lower AS than unsoaked could be the expanding of the corncob after it was soaked in water. Results from pH at 0 and 7 DAP revealed a pH lower than the recommended range for petunias of 5.5 – 6.2 with no difference found between substrates (Table 2). Readings at 14 DAP showed pH for unsoaked corncob to be higher than those of soaked and perlite among all fertilizer rates. Electrical conductivity results showed a decrease in readings over time with 7, 14, 21, and 35 DAP showing no significant difference among the different substrates.

Results from SDW (Table 3) of Petunias increased with increasing fertilizer rate for all substrates with GI following a similar trend. Bloom counts were highest at the 8 lbs of fertilizer rate of peat:perlite. Soaked and unsoaked corncobs were found to have similar counts at the 2 and 4 lb rates. Differences were found in 6 and 8 lbs with soaked cob being 40% greater in 6 lbs and 50% greater in 8 lbs. Root ratings for soaked corncob at rates 6 and 8 lbs and unsoaked corncob at 8 lbs were found to be similar to the PL mix at fertilizer rates of 2, 4, and 6 lbs. Soaked and unsoaked corncob also showed a linear increase in RR with an increasing fertilizer rate.

Results of this study indicated that the increase in fertilizer rate had a positive effect in the growth of petunias in the corncob-amended substrates. Petunias grown in the peat-lite mix had greater growth than petunias grown in unsoaked and soaked corncob. Petunias grown in substrates with soaked cob at 8lbs fertilizer rate was found to have similar results to the peat-lite mix at 6lbs with respect to GI and BC, suggesting that pre-soaking the corncob before mixing could also have an effect on the growth of petunias.

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Table 1. Physical Properties of Corncob Amended Substrates.[z]

Substrates	Air[y] Space	Container[x] capacity	Total[w] porosity	Bulk[v] density
	---------- (% vol) ----------			(g/cm^3)
Peat:Corncob(us)[u]	13.5a[r]	76.6a	90.1a	0.13a
Peat:Corncob(s)[t]	12.4ab	77.6a	90.0a	0.11b
Peat-lite[s]	11.2b	75.1b	86.3b	0.09c

[z]Analysis performed using the NCSU porometer.

[y]Air space is volume of water drained from the sample ÷ volume of sample x 100.

[x]Container Capacity is (wet weight - oven dry weight) ÷ volume of the sample x 100.

[w]Total porsity is container capacity + air space.

[v]Bulk density after forced air drying at 105^0 C (221.0^oF) for 48 h.

[u]Peat:Corncob(us)= 80:20 peat:corncob (v:v) us = unsoaked.

[t]Peat:Corncob(s)= 80:20 peat:corncob (v:v) s = soaked.

[s]Peat-lite = 80:20 peat:perlite (v:v).

[r]Tukeys Studentized Range Test ($P \leq 0.05$, n = 3).
Means with same leter in column=no significant difference

Table 2: Fertlizer Rate effect on pH and electrical conductivty of petuanis in corncob amended substrates.

		0 DAP[z]		7 DAP		14 DAP		21 DAP		28 DAP		35 DAP	
Substrate	**Rate (lbs)**	**pH**	**Ec[x]**	**pH**	**EC**	**pH**	**EC**	**pH**	**EC**	**pH**	**EC**	**pH**	**EC**
Peat:Corncob(us)[L]	2	4.14	3.52	4.68	4.12	5.58	2.29	5.41	2.21	5.44	1.96	5.15	2.05
Peat:Corncob(us)	4	3.85	3.01	5.06	4.66	5.41	2.64	5.12	2.94	5.18	1.99	5.28	1.88
Peat:Corncob(us)	6	3.84	2.48	5.34	3.99	5.18	2.65	5.53	2.42	5.40	2.56	5.31	2.51
Peat:Corncob(us)	8	3.93	4.39	5.06	5.09	5.16	2.76	5.08	2.77	5.30	1.62	5.12	2.14
Peat:Corncob(s)[t]	2	3.89	3.09	4.49	3.77	4.37	2.61	4.64	2.49	4.54	1.59	4.81	1.02
Peat:Corncob(s)	4	3.81	2.83	3.28	3.97	4.53	2.72	4.51	2.57	4.69	1.11	4.82	0.79
Peat:Corncob(s)	6	3.97	4.51	4.24	5.72	4.30	3.02	4.36	2.43	4.77	0.86	4.75	0.80
Peat:Corncob(s)	8	3.89	3.54	4.25	7.90	4.03	4.48	4.29	1.86	4.45	1.14	4.31	1.76
Peat-lite[s]	2	3.82	3.72	4.23	4.39	3.88	2.50	3.89	2.41	4.43	0.46	4.52	1.67
Peat-lite	4	3.90	4.31	4.06	6.01	3.98	2.67	3.86	2.48	4.14	0.67	4.24	0.69
Peat-lite	6	3.83	3.93	4.21	6.11	4.10	3.28	3.80	2.87	3.88	1.13	4.11	1.10
Peat-lite	8	3.78	4.38	4.12	4.12	4.11	5.38	2.80	2.30	3.85	1.42	4.33	0.82
	HSD	***0.18[u]***	***1.36***	***1.69***	***2.81***	***0.53***	***2.47***	***1.47***	***2.50***	***0.61***	***1.05***	***0.44***	***2.00***
						Fertlizer Rate Response							
un-washed		L**[t]Q***	L*Q***	NS	NS	L**	L**	NS	NS	NS	Q**	NS	NS
washed		NS	NS	NS	L***	L**Q*	NS	NS	NS	NS	NS	L**Q*	NS
Peat-Lite		NS	NS	NS	Q**	NS	L**	L*	NS	L**	L**	Q**	NS

[z]Days after planting.

[y]lbs/yd3 of 13-6-16 slow release fertlizer.

[x]Electrical conductivity (dS/cm) of substrate solution using the pourthrough method.

[w]Peat:Corncob(us)= 80:20 peat:corncob (v:v) us = unsoaked.

[v]Peat:Corncob(s)= 80:20 peat:corncob (v:v) s = soaked.

[u]Peat-lite = 80:20 peat:perlite (v:v) .

[U]Tukeys Honest Significant Difference Test (P ≤ 0.05, n=4) .

[t]Non Significant (NS), Linear (L) or Quadratic (Q) response at P ≤ 0.05 (*), 0.01 (**) or 0.001 (***).

Table 3: Fertilizer rate effect on the growth of Petunias in corncob amended susbstrates.

Substrate	Fertilizer Rate	Growth Parameters			
	(lbs[z])	GI[y]	BC[x]	RR[w]	SDW[v]
Peat:Corncob(us)[u]	2	7.7	2.3	1.9	1.0
Peat:Corncob(us)	4	13.0	8.1	2.6	3.8
Peat:Corncob(us)	6	25.4	21.5	3.1	3.0
Peat:Corncob(us)	8	28.8	35.3	3.4	5.4
Peat:Corncob(s)[t]	2	13.6	5.6	2.4	1.4
Peat:Corncob(s)	4	21.3	16.9	3.1	2.8
Peat:Corncob(s)	6	32.4	49.7	3.4	6.4
Peat:Corncob(s)	8	36.4	66.1	3.6	9.6
Peat-lite[s]	2	29.9	43.7	4.0	7.0
Peat-lite	4	37.8	53.4	4.0	10.4
Peat-lite	6	41.1	76.7	4.3	14.5
Peat-lite	8	44.3	90.4	4.6	16.9
	HSD[r]	***5.8***	***12.3***	***1.0***	***3.8***
	Fertilizer Rate Response				
Peat:Corncob(us)		L***[q]	L***	L***	L**
Peat:Corncob(s)[t]		L***	L***	L***	L***
Peat-lite		L***	L***	L**	L***

[z]lbs/yd^3 of 13-6-16 slow release fertlizer

[y]Growth index = [(height + width1 + width2)/3].($P \leq 0.05$, n = 12).

[x]Bloom count = number of blooms showing color at 35 DAP.($P \leq 0.05$, n = 12).

[w]Root ratings 0-5 scale($P \leq 0.05$, n = 8).

[v]Shoot dry weight measured in grams.($P \leq 0.05$, n = 8).

[u]Peat:Corncob(us)= 80:20 peat:corncob (v:v) us = unsoaked.

[t]Peat:Corncob(s)= 80:20 peat:corncob (v:v) s = soaked.

[s]Peat-lite = 80:20 peat:perlite (v:v).

[r]Tukeys Honest Significant Difference Test ($P \leq 0.05$, n = 8).

[q]Linear (L) response at $P \leq 0.05$ (*), 0.01 (**) or 0.001 (***).

Heat Tolerance of Heucheras Using Laboratory-Based Methods

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Index Words: cell membrane thermostability, triphenyl tetrazolium chloride test

Significance to Industry: High temperature is often a major problem for cool-climate ornamentals during summer months, especially in the south, resulting in less plant vigor and reduced landscape aesthetic value. Current cultivar screenings for heat tolerance rely on whole-plant techniques including multi-location multi-growing season field trials, which could involve tremendous amount of cost if the companies have a large number of plant materials to evaluate. Laboratory-based methods, including cell membrane thermostability (CMT) test and triphenyl tetrazolium chloride (TTC) test, offer a rapid and cost-effective alternative/assistance to field evaluation. Field evaluation might be irreplaceable for its comprehensive evaluation results. However, field trials based on results from laboratory-based screening procedures could focus on a smaller number of plants, potentially shorten the period of time needed, and lower cost of field evaluation of heat tolerance of ornamental plants for the industry.

Nature of Work: Twenty *Heuchera* cultivars (Table 1) were selected for evaluation of heat tolerance using CMT and TTC tests. Six plants of each cultivar was grown in commercial potting mix under greenhouse conditions and fertilized as needed before measurements are taken as described below. Plants were placed in a 38 ºC/28 ºC greenhouse for 24 hours before CMT and TTC tests were conducted following procedures adjusted from Fokar et al. (1)

CMT test: Each plant assay consists of two sets of five leaf discs from a fully expanded leaves. Leaf discs were washed and two paired sets of leaf discs were placed into two separate test tubes with 20 mL of deionized water. One set of test tubes was incubated for 20 min at 55 ºC water bath. The other set was left at room temperature. Test tubes were then immediately incubated at 10 ºC for 12 h. After incubation, the initial conductance was measured using an electrical conductivity meter. Test tubes were then sealed with aluminum foil and autoclaved at 120 ºC and 0.15 MPa for 20 min. The autoclaved tubes were cooled to 25 ºC and contents were mixed thoroughly before final conductance was recorded.

Relative injury (RI) to cell membranes resulting from the temperature treatments is calculated using the equation: $RI\ (\%)=\{1-[1-(T_i/T_f)]/\ [1-(C_i/C_f)]\}*100$. T and C refer to the

conductance of the treatment (55 ºC) and control (25 ºC), respectively, and the subscripts, *i* and *f*, indicate initial and final conductance, respectively.

TTC test: A 2.5-cm segment about 0.5 cm from the leaf tip was excised from the same leaf where discs were obtained for CMT test, which was then quartered along the length. Every two quarter segments were placed in a capped 10-mL test tube containing 100 µl distilled water. Treatment tubes were heated in a water bath for 1 h at 50 ºC while control tubes remained at 10 ºC. Two ml of 0.8% TTC (w/v) dissolved in a 0.05 M phosphate buffer (pH 7.4) were added to all tubes, and then the tubes were placed in vacuum chamber for infiltration of TTC into leaf tissues. Tubes were placed in total darkness for 12 h at 25 ºC. After that, the TTC solution was drained and leaf segments rinsed in distilled H_2O. Formazan dye was extracted by addition of 2.5 mL of 95% ethanol. Tubes were capped and allowed to remain in darkness for 24 h at 25 ºC. The amount of formazan dye produced by TTC reduction was determined spectrophotometrically at 530 nm. Cell viability as a measurement of thermotolerance was determined as the percent of absorbency for treated segments relative to the control.

Statistical analysis: The experiment was a completely randomized block design with three replications in each of five blocks. RI and cell viability were subjected to arcsine transformation before the analysis of variance using SAS PROC GLM procedures. Means are separated using Duncan's test at 95% confident level. The original RI and cell viability data were presented in the table.

Results and Discussion: There was a wide range of relative injury from CMT test and cell viability from TTC test (Table 1). The relative injury of the twenty cultivars ranged from 6% in 'Sunspot' to 56% in 'Gypsy Dance', where higher relative injury indicated less heat tolerance and lower relative injury indicated better heat tolerance. According to CMT test, 'Sunspot', 'Stoplight', 'Ginger', 'Can Can', 'Lime Rickey', 'Obsidian' and 'Paris' were more heat tolerant compared to 'Gypsy Dance', 'Cherries Jubilee', 'Ebony and Ivory', 'Café Ole' and 'Peach Flamebe'. The cell viability of the twenty cultivars ranged from 3% in 'Sunspot' to 59% in 'Sparkling Burgundy', where higher value indicated better heat tolerance. According to TTC test, 'Sparkling Burgundy', 'Ginger', 'Can Can', 'Café Ole', 'Hollywood', 'Obsidian', 'Paris' and 'Stoplight' were more heat tolerant than 'Gypsy Dance', 'Ebony and Ivory', 'Strawberry Candy', 'Blood Red' and 'Cherries Jubilee'.

Generally speaking, *Heuchera* cultivars listed at the lower part of the table indicated better heat tolerance than the cultivars at the upper part of the table. Although discrepancy occurred in the exact order of 20 cultivars from two tests, the table offered a good reference for future field evaluation, which could focus on the plants listed at the lower part of the table for heat tolerance.

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Table 1. Relative injury (%) from cell membrance thermostability test and cell viability from triphenyl tetrazolium chloride test of 20 *Heuchera* cultivars.

Cell membrane thermostability test		Triphenyl tetrazolium chloride test	
Cultivar	*Relative injury (%)*	Cultivar	Cell viability (%)
Gypsy Dance	56 a[z]	Gypsy Dance	3 j
Cherries Jubilee	43 ab	Ebony and Ivory	10 i
Ebony and Ivory	30 bc	Strawberry Candy	16 hi
Café Ole	28 bcd	Blood Red	16 hi
Peach Flamebe	27 b-e	Cherries Jubilee	25 gh
Black Beauty	25 c-f	Black Beauty	28 fg
Marmalade	23 c-g	Lime Rickey	28 fg
Strawberry Candy	21 c-h	Peach Flamebe	28 fg
Hollywood	17 c-i	Marmalade	30 efg
Fantasia	14 d-i	Fantasia	34 e-g
Green Spice	14 e-i	Sunspot	36 def
Sparkling Burgundy	13 e-i	Green Spice	36 def
Blood Red	14 e-i	Stoplight	41 cde
Paris	13 f-i	Paris	42 cd
Obsidian	11 f-i	Obsidian	43 cd
Lime Rickey	11 f-i	Hollywood	44 bcd
Can Can	9 ghi	Café Ole	45 bcd
Ginger	9 hi	Can Can	49 abc
Stoplight	8 hi	Ginger	55 ab
Sunspot	6 i	Sparkling Burgundy	59 a

Effects of Cover Crops on Soil Fertility and Sunflower Production in High Tunnels

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Index Words: Cover crop, high tunnel, cut flower

Significance to Industry: High tunnels are unheated greenhouse-like structures that provide a relatively low-cost modified environment for crop production. Growers use the tunnels to extend growing seasons, reduce environmental variability, increase yields, improve crop quality, and increase income (1). Cover crops are critical management tools in many sustainable soil-based systems. Cover crops have the potential to cut fertilizer costs, reduce the need for herbicides and pesticides, prevent soil erosion, conserve soil moisture, improve yields, and protect water quality (2, 4, 5). While there has been extensive research on the use of cover crops in open field production systems, few studies have been conducted on how the use of cover crops in high tunnels will impact soil properties and crop production. This study evaluated the effects of different cover crops on soil fertility and sunflower cut flower production in high tunnels. Cover crops were grown over the winter and incorporated into the soil in the following spring and subsequently sunflower plants were grown in the high tunnels. Composted broiler litter at a rate of 5 tons/acre was incorporated into the soil before transplanting sunflower plants into high tunnels. Preliminary data from the first year study indicated that in general, sunflower plants grown in the no cover crop plot were taller than plants grown in the cover crop plots, especially earlier in the season. However, the total number of stems was similar among all treatments, with plants grown in mustard plot produced slightly less stems. The soil analysis data showed that prior to tilling the cover crops, soil nitrate concentrations in the top 20 cm were more than 50% higher in the no cover crop plot than in the cover crop plots. Further studies will be conducted to look at the long-term effects of cover crops on soil properties and crop production in high tunnels.

Nature of Work: In recent years, high tunnels are rapidly emerging as a desirable system for many specialty crop producers due to the relatively modest inputs required and the potential high profitability. The use of cover crops in high tunnel systems may lead to improved soil properties and crop productivity. Here, we report on a study that tests the effects of cover crops on soil characteristics and subsequent production of sunflowers for fresh cut flower production.

The study was conducted in two high tunnels located at the Truck Crops Branch Experiment Station in Crystal Springs, MS. The high tunnels were placed in full sun and

oriented north to south. Each tunnel is 96 ft. long by 30 ft. wide. The soil was Loring silt loam. The study was a randomized complete block design. Each high tunnel serves as a block. Winter cover crops were sown on Nov. 10, 2010 with four treatments: Annual ryegrass (*Lolium multiflorum* Lam.) (75 lbs/acre), Annual ryegrass (50 lbs/acre) + hairy vetch (*Vicia villosa*) (31 lbs/acre), Caliente 199 mustard blend (*Brassica juncea* + *Sinapis alba*) (10 lbs/acre), and no cover crop (control). Each treatment consisted of one fourth of one high tunnel divided from the middle of the high tunnel. After growing about three months in high tunnels, cover crops were cut and tilled into the soil on Feb. 16, 2011. Composted broiler litter (Currie Farms, Raleigh, MS) at a rate of 5 tons/acre was incorporated into the soil on March 1, 2011. Sunflower 'Infrared Mix F1' was selected for sunflower cut flower. Sunflower seedlings were transplanted to raise beds in high tunnels on March 3, 2011. Each cover crop treatment included 80 sunflower plants which were planted one ft. apart with two parallel rows on one bed. The beds were 2 ft across the top. Two drip tapes were placed one ft. apart in the center of the bed, and buried one inch below the top of the bed. Irrigation was supplied as needed through the drip tape. The beds were covered with black plastic mulch.

On March 22 and April 26, 2011, leaf greenness (chlorophyll content) was quantified using a SPAD-502 Chlorophyll Meter (Minolta Camera Co., Ramsey, NJ). For each plant, three recently fully expanded leaves were randomly chosen for SPAD measurement and the average of the three readings was recorded. On the same dates, plant heights were also measured. Sunflower stems were harvested as soon as the blooms were completely opened, starting from April 27 through May 19, 2011. The number of stems longer than 12 inches was recorded.

Results and Discussion: Since we have only two high tunnels (replications) in this study, we only present the mean value of the data. Sunflower 'Infrared Mix F1' grew very tall in spring in high tunnels, reaching over 200 cm when we started to harvest the stems on 55 days after transplanting (DAP) (Table 1). In general, sunflower plants grown in the no cover crop plot were taller than plants grown in the cover crop plots. This was possibly due to cover crops utilizing some of the nutrients in the soil, leaving less nutrients for subsequent cash crops (3). The soil analysis data showed that prior to tilling the cover crops, soil nitrate concentrations in the top 20 cm were 50% higher in the no cover crop plots than in the cover crop plots. There was no difference among all plots in extractable P, K, Ca, Mg, Na, and soil organic matter prior to tilling the cover crops. The plant leaf SPAD readings were similar among all treatments. The total number of stems was also similar among treatments, with plants grown in biofumigant mustard plots produced slightly less stems. Further studies will be conducted to look at the long-term effects of cover crops on soil fertility and plant growth and production in high tunnels.

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Table 1. Effects of cover crops on plant height (cm), leaf SPAD value, and total number of stems per plant (> 12 in.) of sunflower 'Infrared Mix F1' in high tunnels.

Cover Crop Treatments	Plant height (cm)		SPAD value		Stems/plant
	20 DAP	55 DAP	20 DAP	55 DAP	
Annual ryegrass	31.1	233.5	44.1	46.8	8.9
Annual ryegrass + hairy vetch	30.8	256.5	44.0	45.5	10.1
Mustard blend	29.5	229.0	43.7	46.1	8.0
No cover crop (control)	34.9	259.8	44.9	46.8	9.5