Extracted sweet corn tassels as a renewable alternative to peat in greenhouse substrates

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ABSTRACT

Soiless substrates are primarily used in the production of containerized greenhouse and nursery crops. Sphagnum peat moss is a primary constituent of these substrates and its harvest from endangered ecosystems has become a worldwide concern. Ethanol-extracted, coarse-ground corn (Zea mays L. ‘Silver Queen’) tassels were used as a peat replacement for potting substrates. Replacing peat moss with increasing levels of ground tassel (up to 50%, v/v) elevated pH and electrical conductance, while having variable effects on substrate physical properties (bulk density, percent solids, air porosity, container capacity, and total porosity). Two identical greenhouse experiments separated by time were conducted using tomato (Solanum lycopersicum L. ‘Red Robin’) plants grown in 6.0-L pots. In the first experiment, all substrates were similar for total tomato yield per plant and number of fruit per plant, with only the 50% tassel substrate having significantly lower values. There were no differences for plant height or average fruit weight among substrates. No differences were found for any of these variables in the second experiment. This research indicates that extracted ground tassels may be utilized as a suitable replacement for peat in greenhouse substrates for tomatoes.

1. Introduction

Since the 1960s, container production of horticultural crops has primarily utilized soilless substrates (Nelson, 2003). These substrates include organic materials such as peat moss or tree barks blended with other organic or inorganic components such as vermiculite, perlite and sand (Bilderback et al., 2005). Sphagnum peat moss is considered a premier substrate, due to its desirable physical characteristics (e.g. particle size distribution, total porosity, water holding capacity, and bulk density) and high nutrient exchange capacity (Rodale, 1959; Raviv et al., 1986; Nelson, 2003; Bilderback et al., 2005). Increasing public concern around the world has developed over the use of peat, primarily due to ecological concerns over wetland destruction during its harvest (Barkham, 1993; Robertson, 1993; Zeller, 2007; Blok and Verhagen, 2009; Jayasinghe et al., 2010). The utilization of farm, industrial and consumer waste by-products as components of nursery substrates has been extensively investigated during the past several decades (Chong, 2005). Alternatives to peat such as various composts, coir [coconut (Cocos nucifera L.) husk fiber], kenaf (Hibiscus cannabinum L.) stem core, poultry feathers, rice (Oryza sativa L.) hulls, cotton (Gossypium hirsutum L.) gin trash, switchgrass (Panicum virgatum L.), and ground pine (Pinus taeda L.) logs have been examined (Wang, 1994; Pill et al., 1995a; Pill et al., 1995b; Evans et al., 1996; Webber et al., 1999; Noguera et al., 2003; Evans, 2004; Sánchez-Monedero et al., 2004; Papafotiou et al., 2004; Evans and Gachukia, 2007; Papafotiou et al., 2007; Zaller, 2007; Bustamante et al., 2008; Altland and Krause, 2009; Jackson and Wright, 2009; Šrámek and Dubský, 2009; Jayasinghe et al., 2010). Tomatoes are the leading greenhouse vegetable crop grown in the United States (Jones, 2008). While most commercial greenhouse tomato production involves plants grown under one of three soilless hydroponic production techniques (flood-and-drain, nutrient film, or drip irrigation using rock wool or perlite), small greenhouse operations and homeowners primarily utilize several organic soilless substrates, with 50% peat/50% vermiculite (v/v) formulations being the most commonly used (Rippy et al., 2004; Jones, 2008).

Our research team is currently examining the bulk extraction of valuable phytochemicals from sweet corn tassels. The extraction process utilizes 95% ethanol which in addition to extracting these phytochemicals, also removes other constituents such as lipids and soluble proteins which would contribute to off-odors during decomposition of the tassels. The ethanol extraction process also serves to effectively disinfect the tassels. The objective of
the present study was to investigate the use of ethanol-extracted, coarsely ground corn tassels as a replacement for peat in soilless potting substrates.

2. Materials and methods

2.1. Materials

Corn tassels (Zea mays L. ‘Silver Queen’) were harvested between July 31 and August 7, 2009 in Green Valley, Illinois, and were immediately batch extracted for 24 h with 95% ethanol. Tassels were dried in an oven at 40 °C for 48 h to remove solvent, then ground in a Fritsch Rotor-Speed Mill Model VDE 0520 (Fritsch GmbH, Idar-Oberstein, Germany) fitted with a 4-mm screen. Sunshine® vermiculite (medium particle size) was obtained from Sun Gro Horticulture Distribution Inc., Bellevue, WA. Ferti-lome® sphagnum peat moss was obtained from VPG, Bonham, TX. Six substrates were formulated by mixing vermiculite, peat and ground tassels at varying proportions. Each of the six substrates contained 50% (v/v) vermiculite and 0%, 10%, 20%, 30%, 40% or 50% ground tassel with the remainder being peat. All substrates were supplemented with Osmocote® 14-14-14 and Micromax® chemical fertilizers (The Scotts Company LLC, Maryville, OH, USA) at rates of 23 and 3.5 g fertilizer/kg potting mix, respectively. No additional fertilizers were applied during the course of the experiments. Dolomitic limestone was added to the substrates at the rate of 80 g dolomitic limestone/kg potting mix. This amount of limestone allowed the resulting initial pH of all of the substrates to be in the range of 5.0–5.5, where nutrient availability (particularly B, Mn and Zn) is optimal (Lucas and Davis, 1961; Altland and Buamscha, 2008; Jones, 2008). Tomato (Solanum lycopersicum L. ‘Red Robin’) seeds were purchased from Tomato Growers Supply Company, Fort Myers, FL, USA. This cultivar has a determinate habit (plant growth stops after flowering is initiated allowing for end points for fruiting), dwarf plant size and does not require insect pollination for fruit set.

2.2. Physical characteristics of potting substrates

Potting substrate physical properties were determined by the methods of Spomer (1990) and Webber et al. (1999) for bulk density, percent solids, air porosity, container capacity and total porosity, while pH and electrical conductivity (EC; a measure of the concentration of soluble salts) were evaluated by the methods of Milford (1976) using 1:2 volume water extracts employing a HI 9813 portable EC meter (Hanna Instruments, Woonsocket, RI, USA) and an AB 15 pH meter (Thermo Fisher Scientific, Waltham, MA, USA).

2.3. Plant experiments

Tomato seeds were planted in cell plug trays in a growth chamber set at 25 °C, 16-h light/20 °C, 8-h dark on December 14, 2009 and March 8, 2010 for the two experiments, respectively. On January 5 and March 31, 2010, seedlings were transplanted individually for the two experiments, respectively. On January 8, 2010 for the two experiments, respectively. On January 5 and March 31, 2010, seedlings were transplanted individually

Table 1
Bulk densities of oven dried (65 °C, 48 h) substrate components.

<table>
<thead>
<tr>
<th>Substrate component</th>
<th>Bulk density (g cm⁻³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground tassel</td>
<td>0.097*</td>
</tr>
<tr>
<td>Peat moss</td>
<td>0.135</td>
</tr>
<tr>
<td>Vermiculite</td>
<td>0.149</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>0.004</td>
</tr>
</tbody>
</table>

* Values are means of five replications.

after about 10 weeks post-transplant, and all remaining fruit on the plants at 12 weeks after transplanting, whether completely ripe or not, were harvested. Because there were few fruit with defects, no distinction was made concerning fruit grades.

2.4. Statistical design and analyses

Single-factor Analyses of Variance (ANOVARs) were used to analyze differences among the treatments for the chemical and physical characteristics and for fruit number, total fruit weight, average fruit weight, and change in plant height. For plant experiments, six pots containing one plant each (each plant was a replicate) of each treatment were used in a completely randomized design. Levene’s homogeneity of variance test was performed to determine if any dependent variable transformations were necessary before running ANOVAs. If a significant F-test was obtained from an ANOVA, pairwise treatment mean differences were obtained using differences of least squares means with a Bonferroni adjustment at p < 0.05. The Dunnett’s test at the 0.05% significance level was used to calculate LSDs for chemical and physical properties of substrates. All statistical analyses were performed using SAS Version 9.2.2 (SAS Institute, Inc., Cary, NC, USA).

3. Results and discussion

3.1. Chemical and physical characteristics of the substrates

The bulk densities of the substrate components used in this study are shown in Table 1. Ground tassel had a significantly lower bulk density (0.097 g cm⁻³) than either peat moss or vermiculite. While the bulk densities of compost and bark are normally much higher (generally ranging from a low of −0.15 g cm⁻³ for some tree barks up to 0.70 for some composts), it was higher than several types of coir dust (0.04–0.08 g cm⁻³; Evans et al., 1996), coarsely ground kenaf stems (0.0814 g cm⁻³; Webber et al., 1999), and switchgrass (0.066–0.092 g cm⁻³; Altland and Krause, 2009). Bulk densities, pH and EC values, percent solids, air porosity, container capacity and total porosity of the vermiculite/peat/tassel substrate mixtures are shown in Table 2. All 7 single-factor ANOVAs showed significant treatment differences (bulk density, p = 0.0011; pH, p = 0.0036; EC, p < 0.0001; solids, p < 0.0002; air porosity, p < 0.0001; container capacity, p = 0.0138; and total capacity, p = 0.0002). Bulk densities decreased with levels of corn tassel of 30% or higher, which was to be expected due to the lower bulk density of the tassel as compared to peat. The pH of the 50% tassel substrate was higher than the 0%, 10 and 20% tassel substrates, although all were in the desired range of 4.0–5.5, where nutrient availability is highest. As percent tassel content increased, EC values also increased. Except for the 50% tassel substrate, the EC levels were in the desired range of 5.0–5.5, where nutrient availability is highest. As percent tassel content increased, EC values also increased. Except for the 50% tassel substrate, the EC levels were in the desired range of 5.0–5.5, where nutrient availability is highest. As percent tassel content increased, EC values also increased. Except for the 50% tassel substrate, the EC levels were in the desired range of 5.0–5.5, where nutrient availability is highest.
and 20–30% tassel, respectively. No significant treatment differences between the 6 treatment means for average fruit weight (data not shown). The lack of differences among treatments for the second experiment may be due to increased natural light during the duration of this experiment as compared to the first experiment, as plants received equal amounts of artificial light during both experiments.

The current study shows that ground, extracted tassels can be successfully used as a potting substrate without prior composting, in a similar manner to rice hulls, kenaf stem core or switchgrass. Recent research on peat replacements for greenhouse tomatoes has centered on the use of various composts (Garcia-Gomez et al., 2002; Herrera et al., 2008; Farrell and Jones, 2010). Zaller (2007) found that replacing peat with vermicompost produced similar results on tomato seedling growth and subsequent fruit yields and quality. Lazzcano et al. (2009) reported that substitution of peat by compost or vermicompost (up to 100% compost but only up to 50% vermicompost) increased the aerial biomass of tomato transplants. Compost derived from municipal solid waste was effective as a replacement for peat for tomato seedlings when used as 30% of the mixture, with higher levels causing negative effects, probably due to high pH and EC (Herrera et al., 2008). However, data concerning tomato fruit yield and quality were not reported in either of these two studies.

Although in these experiments we utilized corn tassel ground using a single sized screen which limited the maximum size of the particles produced, other particle sizes could be created to produce tassel-based substrates with different physical properties. Webber et al. (1999) found that finely ground kenaf core had nearly twice the bulk density of coarsely ground kenaf core, with the finely ground core having a higher bulk density than peat moss. However, growth of periwinkle (Vinca minor L.) plants were greater with the coarsely ground core than with the fine core. Altland and Krause (2009) similarly found that fine-milled switchgrass had more desirable physical properties than coarse-milled switchgrass, but that growth (shoot and root dry weights) of potted roses (Rosa L. ‘Chew-Maytime’) in switchgrass-peat mixes was similar throughout all of the mixtures tested. Similarly, Wang (1994) found that the growth of umbrella tree [Schefflera actinophylla (Endl.) Harms], Chinese hibiscus (Hibiscus rosa-sinensis L.) and Japanese cheesewood [Pittosporum tobira (Thunb.) Ait.] in 70–100% kenaf core were equal to or greater than plants grown in two commercial peat-vermiculite potting mixes.

### Table 2

<table>
<thead>
<tr>
<th>Tassel (%)</th>
<th>Bulk density * (g cm⁻³)</th>
<th>pH*</th>
<th>EC (μs cm⁻¹)</th>
<th>Solids (%)*</th>
<th>Air porosity (%)*</th>
<th>Container capacity (%)*</th>
<th>Total porosity (%)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.148 a</td>
<td>5.0 b</td>
<td>1.54 d</td>
<td>37.4 bc</td>
<td>34.0 bc</td>
<td>28.6 ab</td>
<td>62.6 ab</td>
</tr>
<tr>
<td>10</td>
<td>0.135 ab</td>
<td>5.1 b</td>
<td>1.42 d</td>
<td>44.6 a</td>
<td>32.5 c</td>
<td>22.9 b</td>
<td>55.4 c</td>
</tr>
<tr>
<td>20</td>
<td>0.134 ab</td>
<td>5.1 b</td>
<td>1.78 cd</td>
<td>41.1 b</td>
<td>34.7 bc</td>
<td>24.2 ab</td>
<td>58.9 bc</td>
</tr>
<tr>
<td>30</td>
<td>0.122 b</td>
<td>5.2 ab</td>
<td>2.18 bc</td>
<td>35.2 bc</td>
<td>40.7 a</td>
<td>24.0 ab</td>
<td>64.8 bc</td>
</tr>
<tr>
<td>40</td>
<td>0.121 b</td>
<td>5.2 ab</td>
<td>2.25 b</td>
<td>36.3 bc</td>
<td>37.3 ab</td>
<td>26.4 ab</td>
<td>63.7 ab</td>
</tr>
<tr>
<td>50</td>
<td>0.122 b</td>
<td>5.3 a</td>
<td>2.84 a</td>
<td>35.6 bc</td>
<td>31.9 a</td>
<td>23.9 ab</td>
<td>67.4 b</td>
</tr>
</tbody>
</table>

* Means within a column followed by the same letter(s) are not significantly different based on differences of least squares means testing using a Bonferroni adjustment at \( p \leq 0.05 \).

### 3.2. Tomato growth and fruit yield

Results from the two repetitions of the plant experiment were not similar, therefore data were not pooled. Values for change in plant heights, number of fruit per plant, total fruit weight per plant and average fruit weight for the first experiment are shown in Table 3. No data transformations were found to be necessary for growth and fruit yield analyses. ANOVA results showed no differences between the 6 treatment means for average fruit weight or change in plant heights, but significant differences were found for number of fruit per plant (\( p < 0.0005 \)), and total fruit weight (\( p < 0.003 \)). The lowest values occurred in the substrate containing 50% tassel, while higher values for number of fruit per plant and total fruit weight were found in substrates containing 0–30% and 20–30% tassel, respectively. No significant treatment differences were found for any of the four dependent variables (change in plant heights, number of fruit per plant, total fruit weight per plant and average fruit weight) examined in the second experiment (data not shown). The lack of differences among treatments for the second experiment may be due to increased natural light during the duration of this experiment as compared to the first experiment, as plants received equal amounts of artificial light during both experiments.

### Table 3

<table>
<thead>
<tr>
<th>Tassel (%)</th>
<th>Plant height (cm)</th>
<th>Number* fruit/plant</th>
<th>Total fruit wt/plant* (g)</th>
<th>Average fruit wt/plant (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>143.5</td>
<td>51.8 a</td>
<td>397.3 ab</td>
<td>7.7</td>
</tr>
<tr>
<td>10</td>
<td>138.0</td>
<td>52.2 a</td>
<td>405.4 ab</td>
<td>7.8</td>
</tr>
<tr>
<td>20</td>
<td>149.2</td>
<td>52.8 a</td>
<td>436.5 a</td>
<td>8.3</td>
</tr>
<tr>
<td>30</td>
<td>137.8</td>
<td>59.8 a</td>
<td>469.5 a</td>
<td>7.8</td>
</tr>
<tr>
<td>40</td>
<td>138.3</td>
<td>49.1 ab</td>
<td>417.7 ab</td>
<td>8.5</td>
</tr>
<tr>
<td>50</td>
<td>129.0</td>
<td>35.3 b</td>
<td>300.9 b</td>
<td>8.5</td>
</tr>
</tbody>
</table>

* Means within a column followed by the same letter(s) are not significantly different based on differences of least squares means testing using a Bonferroni adjustment at \( p \leq 0.05 \).
replacing peat moss were similar to the 50% peat substrate which is commonly used for tomato production. However, during our plant experiments in the greenhouse we found that the 50% tassel substrate generally retained the most water of all of the substrates. This research shows that ground, extracted corn tassels are an acceptable containerized growth substrate for tomatoes. Our results also suggest that additional research using other plant species should be conducted to determine if tassel is an acceptable substrate component for a wider range of plants.

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References


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