Optimizing Growing Media for Enhancement to Vegetative Growth, Yield and Fruit Quality of Greenhouse Tomato Production in Soilless Culture System

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Abstract: Soilless growing is becoming an attractive option because of the unpredictable problems of soil due to fluctuating temperatures, moisture holding capacity, obtainability of nutrients, salinity, root aeration, undesirable microbial activities and nematode, disease and pest to overcome these problems with soilless. Since the growth medium relates to every cultural practice in the soilless production stage, selection or formulation of medium is extremely important. However, the main objective of the study was to determine the effect of coco-peat and perlite media mixtures on vegetative growth, yield and fruit quality of tomato (Solanum lycopersicon Mill var K-21) seedlings in soilless system. Results of statistical analysis showed that growing media had a significant effect (p< 0.01) on vegetative growth, yield and fruit quality of tomato. The 50% coco-peat + 50% perlite media caused a higher chlorophyll content (64.16 SPAD unit) in leaves and this increase was accompanied with increase of plant growth, which produced highest weight and length aerial shoots by 1262 gr and 339.80 cm, respectively. The highest vegetative growth in seedling grown using 50% coco-peat + 50% perlite result in appearance inflorescence in tomato seedling later than other media. Early flowering might be due to adverse vegetative growth and having proper physical properties in other media. So, the best result for air filled porosity and water hold capacity by 23 and 34% was displayed by 50% coco-peat + 50% perlite media. The high yield and fruit number (4.51 kg plant⁻¹ and 40.2) and superior quality of fruits containing 7.31% dry matter content and 4.74 brix TSS results in a media mixture of as evidenced by the positive physical properties and growth of tomato seedlings. From the results of this study it is recommended that 50% coco-peat + 50% perlite can be used on greenhouse tomato seedling production.

Key words: Tomato · Hydroponic · Growing media · Coco-peat · Perlite · Soilless

INTRODUCTION

Hydroponics is the growing of plants without soil, as the knowledge of growing plants utilizing a solution of appropriate nutrients in place of soil, which this can either be through the use of non-soil growing medium or no growing medium at all [1]. Growing plants in soil, as natural media for cultivation of many crops, is unpredictable due to fluctuating temperatures, moisture holding capacity, obtainability of nutrients, changes acidity level, salinity, poor drainage, root aeration, undesirable microbial activities and nematode, disease and pest problems [2]. To overcome to output of soil problems new methods are being introduced such as cultivation of crops under protected environments and growing media followed with appropriate physical-chemical properties, which allowed to the plants thrive on the nutrient-water solution alone [3]. However, eliminating soil from production system can provide number of advantages in the management of both plant nutrition and plant protection compare to conventional soil based production systems [4]. The growing media is totally inert and merely acts as a support for the plants and their root systems, whereas the nutrient solution passes freely.
A good growing medium would provide sufficient anchorage or support to the plant, serves as reservoir for nutrients and water proper to root functions, allow oxygen diffusion to the roots, permit gaseous exchange between the roots and atmosphere outside the root substrate and provide the conditions for practical plant production e.g. easy to supply, suitable cost, easy processing, lightness and homogenous plant production [5, 6]. Among the cultural inputs involved in greenhouse crop production, perhaps the most important is the type of growing media used. Different substrates have various materials and structure which could have direct and/or indirect effects on plant growth and development. While these substrates can be used alone, mixtures of the substrates such as peat and perlite; coir and clay, peat and compost are also used widely. Currently, a wide range of soilless culture techniques have been developed and commercially introduced for intensive production of horticultural crops, particularly vegetables [7]. Results obtained by Alifar et al., (2010) concerning effects of the application of different growing media on yield of cucumber fruit have indicated that highest fruit yield was obtained by Coco-peat whereas the lowest one was obtained by Perlite-Coco-peat [8]. The effect of the substrate on yield and fruit quality of tomato in soilless culture studied by Tzortzakis et al., (2008) showed that plants grown in pumice and perlite substrates obtained lower total yield; and higher yield was obtained from maize substrate [9]. Therefore, substrate selection between the various materials is one of the most important factors affecting plant growth and development in the greenhouse and influencing vegetable quality [10]. Composition of plant growing media may vary depending on the several reasons. Main materials used for the composition of media are sawdust, peat, perlite, and vermiculite. Since the growth medium relates to every cultural practice in the production stage, selection or formulation of medium is extremely important [11]. Successful production of container-grown plants is dependent on the physical and chemical properties of the growing medium selected. Therefore some critical physical and chemical properties need to be evaluated before making a media decision [12]. Physical and chemical properties commonly measured for container media and media components include total pore space, water holding capacity, air space, bulk density, particle size distribution, pH, soluble salts, cation exchange capacity (CEC) and the carbon to nitrogen ratio [13]. Greenhouse production is now an important sector in Iran. Studies on soil-free culture in Iran have advanced during the last decade. There is, however, lack of information regarding the suitability of organic and inorganic materials and their mixes as growing materials for hydroponic crops in soilless culture system [14]. Based on these results, the present study was focused on the evaluation of cultivated perlite, coco-peat and their composition pressed as growing media for quantity and quality of tomato fruits and was determined a suitable growing medium for hydroponic tomato production.

**MATERIALS AND METHODS**

**Plant Material and Seed Germination:** The investigation was carried out in a greenhouse with temperature control (18/24°C, night/day) presented in Faculty of Agriculture, the Technical University of Sanjan, Bojnourd, Iran. The tomato seeds were obtained from Agricultural Research Central of Torogh, North Khorasan (Iran). Healthy seeds of tomato (Lycopersicon esculentum Mill var K-21) were surface sterilized with ethanol 75% for 5 min followed by repeated washings with double distilled water to remove the ethanol residue on the seed surface. The seeds were germinated in sterile seed trays in the greenhouse condition at 27 ± 2°C using peat moss. After germination, the resulting 30 day old seedlings were transplanted to growing media described in Table 1, when they were achieved 5-7 leaf. At transplanting, peat moss around the roots of these seedlings was gently removed using running tap water.

**Formulating Growing Media and Crop Cultivation:** Growing media were prepared using different amount of coco-peat and perlite materials. Six growing media were prepared using certain amounts (by volume) of materials. After obtaining useable coco-peat, six growing media with differential ratio from combination coco-peat with perlite was formulated according to Table 1. Because of the majority greenhouse native farmers of Sanjananof have utilized combination from coco-peat with perlite as most common growth medium component for container production. However, the 60 coco-peat: 40 perlite (60CP: 40PL) ratio was defined as control growing media. The disinfected plastofoam pots were filled with well-uniform formulated growing media containing different ratios of perlite: coco-peat. After the shootings of seedlings were
Table 1: Growing media and mixture rates of differential composition coco-peat with perlite used in the study

<table>
<thead>
<tr>
<th>Growing media</th>
<th>Mixture rate (by volume)</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cocopeat: Perlite</td>
<td>0-100</td>
<td>CP:PL (0:100)</td>
</tr>
<tr>
<td>Cocopeat: Perlite</td>
<td>25-75</td>
<td>CP:PL (25:75)</td>
</tr>
<tr>
<td>Cocopeat: Perlite</td>
<td>50-50</td>
<td>CP:PL (50:50)</td>
</tr>
<tr>
<td>Cocopeat: Perlite</td>
<td>75-25</td>
<td>CP:PL (75:25)</td>
</tr>
<tr>
<td>Cocopeat: Perlite</td>
<td>100-0</td>
<td>CP:PL (100:0)</td>
</tr>
<tr>
<td>Cocopeat: Perlite</td>
<td>60:40</td>
<td>CP:PL (60:40)</td>
</tr>
</tbody>
</table>

appeared, 5-7 leaf-seedlings (stem diameter, <5 mm) were planted to each 250 m² pot. The 30 number plots were arranged randomly in two row with 60 × 50 cm. Each row consisted of 15 pots. The six treatments (6 growing media formulations) were organized in a randomized complete block design (RCBD) with five replications.

Tomato was grown, using strings for maintenance, on wires 2.80 m directly above the ground. The seedlings were irrigated daily through a drip tap with a nutrient solution from 1 to 4 liters per day, depending on the stage of plant growth. Fertigation was applied 6 times daily for 5 minutes using drippers of 2 L hr⁻¹ capacity. The management of the crop, including the nutrient and irrigation regime, was the same for each medium. During the culture of hydroponic tomato production, insect pests were controlled by use of dimethoate and fungal diseases by use of bravo.

Physical Properties of the Growing Media: The air filled porosity (AFP) and water hold capacity (WHC), as two physical properties of growing media, were measured. The AFP and water holding capacity (WHC) for each substrate was determined by the submersion method of Kreij De et al., (2001) and Shinohara et al., (1999), respectively at the beginning of the experiment [15, 16].

Quantity, Quality Fruits and Vegetative Growth Assay: The first harvesting of fruit seedling was implemented in April, 2015 at complete red rippling stage. Overall, this sampling was repeated three times during 3 weeks from April to May. The collected-fruits be up to each sampling were separately counted and then weighted. Finally, with calculating sum of three sampling, the yield fruit of single seedling (YSS) of tomato as kg plant⁻¹ was obtained.

Fruits for each growing media were juiced separately and the juice was directly used for total soluble solid (TSS) using a digital refractometer (ATC1E-ATAGO, Japan) expressed as Brix.

To measure chlorophyll content of leaf seedlings, fresh leaf was randomly chosen and consequently, it was determined by handle chlorophyll meter (SPAD).

For Measurement of dry matter fruit (DMF), from each growing media were randomly chosen five fresh-fruit at complete-red rippling stage and then washed with distilled water. The three mixed-samples (100 g) was provided from five chosen-fruit for each growing media and weight of mixed-samples recorded as fresh fruit weight (FFW). Eventually, they were dried at 75°C for 75 h in a vacuum oven until dry fruit weight (DFW) was obtained. And the DFW was determined by using an electronic balance (model: Series 321 LT) with an accuracy of ±0.01 g. Using the initial weight of mixed-sample recorded prior to exposing vacuum oven, the DMF were expressed by equation, i.e. (FFW-DFW).

The interval between medium until primary in florescence from each growing media, after 20 day transferring seedlings into plots, were measured on a centimeter scale by means of wires and ruler within accuracy of 1 mm so as to obtain interval primary inflorescence (IPI). The length of aerial shoot seedlings (LAS) were also determined to like this at end vegetative stage and consequently their weight (WAS) were ascertained by using an electronic balance.

Statistical Analysis: The experimental data were analyzed on the basis of completely randomized design (CRD) with five replications. Data were subjected to analysis of variance (ANOVA) using SAS Portable ver.9.4 software (Statistical Analysis System, SAS Institute Inc., 1985). Means were compared by least significant difference (LSD) test to analyze the difference between treatments and intervals at 99% confidence level of each variable.

RESULTS AND DISCUSSION

Tomato harvesting started on April, 2015 and continued until on May, 2015. The AFP, WHC, LAS, WAS, IPI, TSS, DMF%, YSS, fruit number (FN) and chlorophyll index (Chl) of tomato (Lycopersicon esculentum Mill var K-21) grown in different media demonstrated statistically significant (P ≤ 0.01) differences depending on growing media (Table 2).

Physical Properties of the Growing Media: Organic and inorganic substrates used in a soil-free culture can differ remarkably in their physical properties. These physical properties affect the air content and retained volume of available water in the substrate. These differences need to be taken into consideration when growing greenhouse crops with changing demands for water and oxygen in the...
Table 2: Analysis of variance for vegetative growth, yield and fruit quality of greenhouse tomato was exposed to growing media treatments in hydroponic culture system

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>df</th>
<th>WHC</th>
<th>AFP</th>
<th>IPI</th>
<th>LAS</th>
<th>WAS</th>
<th>YSS</th>
<th>FN</th>
<th>TSS</th>
<th>DMF</th>
<th>Chl</th>
</tr>
</thead>
<tbody>
<tr>
<td>Growing media treatemnts</td>
<td>5</td>
<td>45.5**</td>
<td>51.33**</td>
<td>481.62**</td>
<td>18009.24**</td>
<td>308085.33**</td>
<td>4.27**</td>
<td>277.60</td>
<td>2.58**</td>
<td>2.06*</td>
<td>1032.78**</td>
</tr>
<tr>
<td>Error</td>
<td>25</td>
<td>6.5</td>
<td>1.58</td>
<td>20.63</td>
<td>786.54</td>
<td>1614.03</td>
<td>0.25</td>
<td>14.83</td>
<td>0.33</td>
<td>0.41</td>
<td>57.51</td>
</tr>
<tr>
<td>Coefficient of variation</td>
<td>7.39</td>
<td>5.43</td>
<td>12.54</td>
<td>11.92</td>
<td>4.49</td>
<td>17.14</td>
<td>13.75</td>
<td>12.90</td>
<td>8.98</td>
<td>17.93</td>
<td></td>
</tr>
</tbody>
</table>

Note: The ** represent significant at 1% level

Table 3: The effects of six different growing media on vegetative growth of tomato seedling and physical properties of growing media utilized in greenhouse tomato culture

<table>
<thead>
<tr>
<th>Growing media</th>
<th>WHC (% vol)</th>
<th>AFP (%)</th>
<th>Total porosity (%)</th>
<th>LAS (cm)</th>
<th>WAS (gr)</th>
<th>IPI (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CP:PL</td>
<td>39 a</td>
<td>19.00 d</td>
<td>58 ab</td>
<td>176.80 c</td>
<td>590 f</td>
<td>26.35 d</td>
</tr>
<tr>
<td>CP:PL</td>
<td>37 ab</td>
<td>25.50 d</td>
<td>57.50 b</td>
<td>198.11 c</td>
<td>812 d</td>
<td>30.65 cd</td>
</tr>
<tr>
<td>CP:PL</td>
<td>34 bc</td>
<td>23.00 c</td>
<td>57 b</td>
<td>339.80 a</td>
<td>1262 a</td>
<td>53.55 a</td>
</tr>
<tr>
<td>CP:PL</td>
<td>32 c</td>
<td>25.00 b</td>
<td>57 b</td>
<td>236.06 b</td>
<td>958 c</td>
<td>35.95 cb</td>
</tr>
<tr>
<td>CP:PL</td>
<td>31 c</td>
<td>28.00 a</td>
<td>59 a</td>
<td>196.80 c</td>
<td>690 e</td>
<td>30.35 cd</td>
</tr>
<tr>
<td>CP:PL</td>
<td>34 bc</td>
<td>23.50 bc</td>
<td>57.50 b</td>
<td>263.60 b</td>
<td>1060.80 b</td>
<td>40.50 b</td>
</tr>
</tbody>
</table>

There is no statistical difference between means represented by the same letter in the same column (P<0.01)

Fig. 1: Effect of perlite, coco-peat and their composition as growing media on air filled capacity (AFP) and water holding capacity (WHC)

root zone of tomato [14]. Therewas anexcessive difference in the physical properties of the planned growing media (Table 3). The WHC and AFPvalue indicated hugelydifferent (P ≤ 0.01). The AFP of growing media oscillated between 18 and 28% by volume whereas the amount of WHC was between 30 and 39% by volume for six growing media, depending on the composition. The highest AFP value was obtained by pure coco-peat while the highest WHC value was obtained by pure perlite. In contrast, the lowest AFP and WHC value was calculated for pure perlite (19%) and pure coco-peat (31%), respectively. The total porosity of the investigated growing media differed significantly from each other. As such, the highest total porosity was caused by 100CP:0PL (59 vol %), followed by growing medium make up 0CP:100PL (58 vol %), which did not differ significantly from each other (Table 3). Nevertheless, all growing media were in the range of the mentioned optimum values concerning the total pore space (> 85 vol %) as validated by De Boodt and Verdonck (1972) [17]. Container media should contain 50 to 85% pore space. For total porosity of container the media is important, but perhaps more vital than this is the portion that is AFP versus WHC. Some plants prefer wet soils while others prefer dry soils. Altland (2006) proved that onaverage, 10 to 30% of the container volumeshould be composed of air space while 45 to 65% should be water [18]. A reverse significant relationship was detected between AFP and WHC for different grades of perlite composed with coco-peat (P ≤ 0.01). Also, this reverse significant relationship was
observed for different grades of coco-peat (Fig. 1). There was a trend of increasing AFP and decreasing WHC with increasing coco-peat to perlite ratio compared to perlite in composition media or vice versa. The same trend has been stated by Wada et al. (2005) and Samadi (2011) [14, 19]. Adding perlite substrate from 25 to 100% to growing media decreased AFP whereas adding coco-peat substrate from 25 to 100% to growing media led to increase AFP and vice versa was confirmed for WHC. All of the growing media except pure perlite did not markedly affect WHC compared to control. The pure coco-peat only could increase AFP; however (0CP:100 PL) and (25CP:75PL) significantly decreased AFP compared to control (Table 3).

**Vegetative Growth of Tomato Seedling, Quantity and Quality Fruits:** The vegetative growth parameters of tomato hydroponic seedlings including chlorophyll...
content, length and weight of aerial shoots (LAS and WAS) were also significantly affected by the growing media (Table 2, P ≤ 0.01). As presented in Table 3, the LAS, WAS and IPI values in the mixture with 50% coco-peat + 50% perlite (50CP: 50PL) were found statistically higher than other growing media. When the effect of media on LAS parameter is considered, significant decrease was seen between pure perlite, pure coco-peat and their mixtures except to 50CP: 50PL compared to control medium. However, numerically the longest of LAS seedlings were obtained as 339.80 cm in 50CP: 50PL treatment. The maximum WAS parameter were also obtained in the same mixture. Indeed, this is confirm to direct relationship between LAS and WAS parameter. Actually, with the increase perlite to coco-peat ratio from 50 to 100% or with the increase ratio of coco-peat to perlite ratio from 50 to 100% in growing media, the LAS and WAS decreased, so that the only 50CP: 50PL produced the highest LAS and WAS and consequently, the primary inflorescence was appeared later than other growing media in tomato seedlings (Table 3). The good results obtained with the 50CP: 50PL mixture are probably related to the physical characteristics, in particular, to its higher water holding capacity (WHC= 34 vol %) and air filled porosity (AFP= 23 vol %). The earliest inflorescence as the lowest of IPI value was observed in tomato grown using alone perlite and coco-peat, respectively. The chemical analysis for the chlorophyll content of the leaves showed that by mixing coco-peat with perlite in 1:1 ratio, significant increase in chlorophyll content of tomato leaves by 64.16 (SPAD unit) were obtained comparison with control medium (Fig. 2C). The visible symptom decrease in chlorophyll content is the loss of green color. This phenomenon was caused by chlorophyll degradation that is catalyzed by the chlorophyllase that converts the chlorophyll a and b to chlorophyllide and phytol [20]. In the present study, the chlorophyll degradation was accelerated in leaves of plants grown using all growing media except 50CP: 50PL so that significant decrease in chlorophyll content was observed in comparison with the control (Fig. 2C).

Results indicated that the growing medium affected the dry matter content (DMF) and total soluble solid (TSS) as well as quality of tomato as judged (P ≤ 0.01). In the present study, it was found that the highest DMF and TSS of tomato seedling grown in pure coco-peat, 75CP:25PL and 50CP: 50PL, respectively, compared to control medium (Fig. 2A, B). As the coco-peat amount increased in the media, an increase was observed in DMF and TSS content. In contrast, increase in perlite amount in the media, a decrease was measured in DMF and TSS content so that the pure perlite produced lowest them. However, this decrease was not statistically significant for most of them compared to control medium.

It was demonstrated that the growing medium also affected the yield of single seedling (YSS) and fruit number (FN) as well as quality of tomato as judged (P ≤ 0.01). The further YSS (4.51 kg plant−1) and FN (40.20 fruit) of tomato fruits was achieved when fruits from plant grown in 50% coco-peat + 50% perlite (50CP: 50PL) as growing media (Fig. 2D, E). While the other growing media were significantly resulted in decreased YSS and FN of fruits compared to control medium. Hence, this decrease was not statistically significant for pure perlite or pure coco-peat and their composition except to 50CP: 50PL. The results were in accordance with the finding of Dilmaghaniand Hemmati. (2011) indicated that the highest yield of strawberry fruits and fruit's number was obtained by 50% coco-peat + 50% perlite compared with other growing media [21].

**CONCLUSION**

Overall, in the present study, it was found that positive results were obtained in seedling production of tomato (*Lycopersicon esculentum* Mill var. K-21) with optimizing growing media to a certain level of perlite and coco-peat substrates. It was suggested that healthy, high quality and quantity fruits can be attained by 50% coco-peat + 50% perlite (50CP: 50PL) in growing media hydroponictomato production. This output of results might be due to the combination of these substrates affects nutrient holding capacity, better element exchange and optimum distribution of moisture and air root zone which consequently, affects the formation of rooting system, absorption of nutrients and plant growth [22]. Hence, the high porosity (57 vol %) of coco-peat: perlite (1:1) ratio media allowed the tomato seedling root to penetrate in substrate easily and it could use more volume and space of media, thus available water was sufficient for tomato seedlings grow up. Results obtained have shown that among the growing media tested, application of coco-peat: perlite (1:1) ratio media not only enhanced the hydro-physical properties but also vegetative growth parameters of tomato. The high weight and length aerial shoots and further chlorophyll content by 1262 gr, 339.80 cm and 64.16 SPAD unit, respectively were calculated for coco-peat: perlite (1:1) ratio (Table 3, Fig. 2C). The suitable vegetative growth result in appearance of inflorescence in tomato seedlings grown
using coco-peat: perlite (1:1) ratio media later than other growing media. Physiologically, early flowering or appearance inflorescence happens in water deficit, salinity, low nutrition, insufficient oxygen, and other stress condition for flowering plants, which have represented to adverse vegetative growth. However, the decrease LAS, WAS and chlorophyll content in all growing media except 50CP:50PL imply on this subject. According to these reasons, the best yield and fruit number attained by tomato seedling grown using coco-peat: perlite (1:1) ratio media (Fig. 2D, E). Overall, these findings suggested that optimized coco-peat and perlite in 1:1 ratio growing media could be used as successful particle method for enhancing suitable vegetative growth, high yield and best quality fruits to hydroponic tomato production (Lycopersicon esculentum Mill var K-21).

REFERENCES


