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Evaluation of different growth media for tomato seedlings to optimize production and water use

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ABSTRACT- Soilless cultivation systems are used to attain higher performance, improve crop quality, conserve water and land, and protect the environment better. This study has attempted to use some agricultural wastes and organic matter, and management practices to optimize water holding capacity of cultural media, which are suitable for the growth of tomato seedlings (*Solanum lycopersicum*). Fifteen different substrate (growth media) mixtures with a mineral fraction (sand and perlite) and organic fractions (bagasse, oak tree bark, poplar wood chips) were prepared and compared. Sand (2-4mm) and perlite (4-6 mm) were mixed at 0, 10, 20, 30 and 40 percent volume ratios with organic fractions at 0, 30 and 60 percent. The experiment was arranged in a completely randomized design with 15 treatments and 3 replications with 6 observations per treatment. During the seedling growth period (45 days), every 7 days, 90 seedlings were harvested (data for three periods were used) to determine the effect of the growth media on different growth parameters (plant dry matter and leaf area) and indices (RGR, NAR, and SER). The growth rate of tomato seedlings generally increased over time the rate of which varied with treatments. Seedling height, stem diameter, plant fresh weight and dry matter indicated that the highest length (25.91 cm) and diameter (4.83 cm) of the tomato seedlings was in treatment eight ($S_{30}P_{10}T_{30}B_{0}C_{30}$). It was also shown that the sand fraction as a mineral component had a better performance compared to perlite in growth parameters. For the organic component of the growth media, tree bark treatments were better than wood chips or bagasse. The bagasse treatment had the lowest fresh weight and dry weight of shoot and root. The treatments with water holding capacity of 90-100% showed the best response in the growth of tomato seedlings.

INTRODUCTION

Agriculture sector is the largest consumer of water in the world. Due to the lack of water resources, especially in arid and semi-arid regions, use of this vital resource is facing constraints. In recent decades, culture sin green houses and controlled environment that can be applied under a variety of climatic conditions, with soil, growth media and different water conditions have provided an effective way to increase the yield and production, particularly in developing countries. (Heydari et al. 2006). Given the problems of growing crops in soil (e.g., salinity, poor soil structure and unpredictable interactions) and restricting water resources, the use of soilless culture system with mixed substrates or hydroponic cultivation has expanded in recent years. Various inorganic and organic materials in these systems are used as seedbed. Soilless culture is widely used in the greenhouse, particularly during periods when production is not possible in the field, to improve the control of growing conditions and avoid unfavorable weather conditions and soil nutrient imbalance. Using waste material and the plant remains in these systems has the benefits of reducing negative impacts on the environment and uncontrolled harvesting of peat, the accumulation of waste and has economic advantages of lower cost compared to other common growth media (Youssefian et al., 2009).

Growth media should have the basic properties such as proper drainage, water holding capacity, right cat ion exchange capacity and lack of weed seeds, pests and diseases and other harmful materials (Gauar et al., 1990; Mitchell et al., 1991). They should preferably have organic sources which are more easily returned to nature and be relatively inexpensive or available to reduce production costs (Delshad et al., 2011). Finally, if possible, they should be by-products of other industries or agricultural production systems which are produced and their cycling can decrease costs or help in environmental sustainability.

Tomato (*Solanum Lycopersicum*) from family solanaceae is a popular cultivated vegetable in the world; it has a high nutritive value and good source of vitamins (A, C, E), calcium, niacin and minerals (Olaniyi et al., 2010). It grows in different soils and under soilless conditions with very high yields. Healthy seedlings production is a prerequisite for raising vigorous and profitable crops. Seedlings are grown in different growth media, which plays a vital role in efficient production of horticultural seedlings in nurseries (Sterrett, 2001). Soilless substrates have been used for the production of horticultural crops in containers including organic materials such as peat moss and compost. This research work focused on the production of quality seedling with desired morphological and physiological features that guarantee crop success after transplanting using a more efficient and economical growth media.

Albaho et al. (2008) emphasized that soilless culture systems must be compatible with the environment and the use of natural organic substrates in the production of horticultural crops has the potential and high economical value. The use of organic waste from agriculture and forestry in floriculture and ornamental plants has a long history. A wide range of materials including hardwood bark, leaves, leaf composts, and sewage sludge have been used as growth media (Inden&torres,2004).One material that has been under consideration and extensive research for its physicochemical properties in relation to plant growth is sawdust which is a by-product of the wood industries (Cid-Ballar in et al., 1995). Using a variety of sawdust, Kang et al. (2004), in their research, showed that these materials improve physical and chemical conditions of growth media and can increase the growth of the plant in the proposed mixed growth media.

Tuzel et al. (2001) stated that perlite: peat (4:1) showed better results in total yield of tomato compared to other mineral compounds mixed with peat. They also stated that the composition of peat and perlite has a good relationship with the growth and yield of tomato. The results of Delshad et al. (2011) showed that strawberries grown under soilless conditions with low water holding capacities performed better under more frequent watering and showed improvement in growing conditions, yield production and water use efficiency compared to longer watering durations. Perlite, an alumino silicate of volcanic origin, can improve physical properties of the growth media and increase drainage and improve aeration of substrate (VerdoncK et al., 1992). It has been shown that irrigation frequency depends on the physical characteristics of growth media and affects the quality and quantity of fruit in soilless cultures (Islam et al., 2002; Kang et al., 2004). The effect of different growth media on the yield and quality of greenhouse tomato showed that maximum plant height and number of inflorescences were obtained in gravel bed and mixed with compost and leaf bed and most of the leaves were in sand bed, rock wool and mixtures (Islam et al., 2002).

Properties of the growth media affect plant growth parameter and indices which are also helpful means to compare substrate quality and efficiency. Samiei et al. (2005) compared different seedbeds of peat moss, palm peat, coco peat and bagasse and concluded that bagasse cultures had the lowest plant indices and produced low quality plants. This can be due to high porosity of growth media, which reduces the moisture retention capacity.

Preparing transplants is one of the most important steps in various stages of production of tomato which is effective in terms of time and quality and will play a decisive role. It seems that two factors of irrigation frequency and type of substrate can highly affect the yield and quality of tomato in soilless culture. For this reason, we studied the effects of these factors on the growth of tomato seedlings in order to select and suggest alternative or appropriate growth media prepared from lower cost and more available materials.

MATERIALS AND METHODS

Experimental Design

A growth room experiment was conducted with a completely randomized design and 15 (treatments), three replicates and 6 observations per replication for a total of 270 experimental units (pots12cm diameter by 15 cm height). The treatments included different combinations of one mineral component (sand (S)2-4 mm or perlite (P) 4-6 mm) and one or two organic components (Poplar wood chips (C), Sugarcane bagasse (B), and Oak tree bark (T)) at different volume percentages, based on water holding capacity of selected materials and according to Table 1. All pots were sterilized in 2% sodium hypochlorite before the experiment and after preparing the growth room.

Table 1. Percentage of mineral and organic components used in preparing the treatments

Treatment	Sand (S)	Perlite (P)	Oak Tree Bark(T)	Sugarcane Bagasse (B)	Poplar wood Chips(C)
	%				
1$S_{10}P_{30}T_{30}B_0C_{30}$	10	30	30	0	30
2 $S_{10}P_{30}T_0B_0C_{30}$	10	30	0	30	30
3 $S_{10}P_{30}T_{30}B_{30}C_0$	10	30	30	30	0
4 $S_{20}P_{20}T_0B_{30}C_{30}$	20	20	0	30	30
5$S_{20}P_{20}T_{30}B_{30}C_0$	20	20	30	30	0
6 $S_{20}P_{20}T_{30}B_{30}C_0$	20	20	30	0	30
7 $S_{30}P_{30}T_{30}B_{30}C_0$	30	10	30	30	0
8 $S_{30}P_{10}T_{30}B_0C_{30}$	30	10	30	0	30
9 $S_{30}P_{10}T_0B_{30}C_{30}$	30	10	0	30	30
10 $S_0P_{40}T_{60}B_0C_0$	0	40	60	0	0
11 $S_0P_{40}T_{30}B_{30}C_0$	0	40	0	60	0
12 $S_0P_{40}T_0B_0C_{60}$	0	40	0	0	60
13$S_{40}P_0T_{60}B_0C_0$	40	0	60	0	0
14$S_{40}P_0T_0B_{60}C_0$	40	0	0	60	0
15 $S_{40}P_0T_0B_0C_{60}$	40	0	0	0	60

Table 2. Nutrient solution composition including concentration of each element (ppm) used in preparing the final solution

Nutrient Recipes	Ca^{2+}	Mg^{2+}	K^{+}	N as NH_4^{+}	N as NO_3^{-}	P as PO_4^{2-}	S as SO_4^{2-}	Fe	Mn	Cu	Zn	B	Mo
H.M Resh	180	50	352	-	140	50	168	5	0.8	0.07	0.1	0.3	0.03

*Howard M. Resh, Hydroponic food formula

A total of 540 tomato seeds (Super chef variety, Bonanza, Company. USA) were planted (two seedlings per pot). Nutrient solution was prepared and used during the growth period based on formula proposed by (Resh H, M., 1993, 2004) (Table 2). Nutrient solution and watering was applied according to water-holding capacity of different treatments and according to Table3. The growth chamber temperature was set at 24-26°C daily and 18° Cat night and relative humidity was adjusted to60 to 70 percent, light intensity was 14000 lux().

Table 3. Irrigation frequency of various treatments based on water-holding capacity

Water holding capacity	*Treatment	Frequency of irrigation	Time of irrigation
8,16,24hrs	3 times per day	1,2,5,10,11,12	90<
12,24	2	3,4,8,14,15	90-100
12	1	6,9,7,13	100>

*Treatment numbers correspond to the percentage of different materials in the mixture as described in Table 1

Characteristics of the Growth Media

Some physical and chemical properties of growth media were determined in3samples of each treatment, and the mean values were recorded. The growth media physical characteristics such as water-holding capacity (WHC), bulk density (Bd), field capacity (FC), and permanent wilting point (PWP) were determined. In order to characterize the chemical properties of substrates, distilled water extracts were prepared at ratio of 5:1 with 150 ml of water and 30g of dry material shaken for30minutes (Kang et al., 2004). The pH of the extracts was measured with pH / ISSE meter Unicom 9455and the EC was read by a conductivity meter Jen way. Organic matter in the substrates was determined by Walkey and Black method (Black, et al., 1989), available potassium with ammonium acetate method and available phosphorous using Olsen method with spectrophotometer at 450 nm wavelength (Black et al., 1989). Cat ion exchange capacity was measured by Lax (1986) method (Table 4).

Growth Indices

At the end of the experiment (45 days), growth parameters such as leaf area, stem length (from the surface of the growth media to the site of the last leaf), stem diameter (at a distance of 2 cm above bed level), and shoot dry weight were measured. A number of growth indices including relative growth rate (RGR, Equation 1), net assimilation rate (NAR, Equation 2), and leaf expansion rate (LER, Equation 3) were calculated using seedlings shoot length, shoot and root dry weight, and wet weight of roots and leaf area was measured at different stages and an average value over time of growth was used to compare different treatments. To calculate the above-mentioned indices, the following equations were used (Gul et al., 2007);

$$RGR = (\ LnW_2 - LnW_1) \div (t_2 - t_1) \quad (1)$$

Where RGR is relative growth rate, Ln is natural logarithm base number, W_2 is total plant dry matter at time t_2 and W_1 is total dry matter at time t_1. RGR for each period t_0-t_1, and t_1-t_2 was calculated and expressed in terms of milligrams per milligrams per day.

$$NAR = \big((W2 - W1) \times (Ln2 - Ln1)\big) \div ((A2 - A1) \times (T2 - T1)) \quad (2)$$

Where W_2 and W_1 stand for total plant dry matter at times t_2 and t_1, Ln_2 and Ln_1 are natural logarithm base number, and A_2 and A_1 are leaf area at time t_2 and $t_1$which is expressed in weight units per square meter or square cm per day.

$$3. LER = \Delta LA \div \Delta T \quad (3)$$

The leaf surface difference in two time per time interval between them and is expressed in terms of cm per day.

$$4. SER = \Delta SE \div \Delta T$$

(4

Seedling dry weight was taken by drying fresh seedling at 70°C in oven for 72 hours. After complete drying, a digital scale with an accuracy of0.01 g was used to determine dry weight. In order to measure the fresh weigh roots, they were dipped in water to remove excess material from them, and after drying the excess water, they were weighed. All Data were analyzed by SAS software. The analysis of variance and Duncan multiple range test were used to find significant differences in the means at 5% Level, and graphs were drawn with Excel software.

Table 4. Some properties of the materials used in growth media

Raw material	Size (mm)	WH C (%)	Bulk Density (g cm^{-3})	pH	EC dS m^{-1}
Poplar wood hips	2-4	60	0.15	5.3	0.305
Oak tree bark	2-4	34	0.3	4.8	0.374
Bagasse	2-4	55.37	0.08	5.3	3.98
Sand	1-2	16	1.5	6.5	0.201
Perlite	4-6	13.93	0.2	6.9	1

RESULTS AND DISCUSSION

Some physical and chemical properties of materials used in this experiment as indicated in tables5 and 6were different in the treatments due to the nature of the mineral or organic components used. Water-holding capacity of different media varied from a minimum of 60/1 to a maximum of 129.5 percent for treatments 2 and 13 ($S_{10}P_{30}T_0B_0C_{30}$; $S_{40}P_0T_{60}B_0C_0$), respectively. The percentage of pore volume, in treatments containing sand + organic component (14,13 and 15) was lowest (30-35%)and for the organic treatments + perlite treatments, (11 and 12) it had the highest value (62-67%), with the highest volume percentage of pores in perlite treatments at 67% (Table 5).

Comparing the chemical properties of the growth media before sowing, the value of the cation exchange capacity showed the highest and lowest values (124.41 and 75.32Cmol$^+$kg^{-1}), respectively in treatments 3 ($S_{10}P_{30}T_{30}B_{30}C_0$) and 15 ($S_{40}P_0T_0B_0C_{60}$). With regard to organic component, the CEC changes in media containing perlite or sand were in the order of tree bark> bagasse> wood chips (Table 6).

Among the treatments in terms of the available phosphorus content before sowing, significant differences existed, the maximum amount of phosphorus was obtained from treatment 10 ($S_0P_{40}T_{60}B_0C_0$) and the lowest from treatment 1 ($S_{10}P_{30}T_{30}B_0C_{30}$), respectively. Results showed that tree bark and bagasse have more available phosphorus compared to wood chips. Mean comparison of phosphorus concentration of the media after planting showed that treatment11 (perlite: bagasse) had the highest (170.3 pp m) while treatment13 (Sand: bark) hadthe lowest (32.7 ppm) available phosphorus (Fig. 1)

Measurement of potassium in the media before sowing showed that the addition of bagasse increases seedbed potassium concentration and treatments 11 ($S_0P_{40}T_{30}B_{30}C_0$) and 14 ($S_{40}P_0T_0B_{60}C_0$) had maximum potassium while treatment6 ($S_{20}P_{20}T_{30}B_{30}C_0$) had the lowest potassium content (Table 6).

Table 5. Physical properties of treatments before planting

Treatment	Bulk density (gr.cm^{-3})	Total porosity	WHC	PWP	FC
		%			
1$S_{10}P_{30}T_{30}B_0C_{30}$	0.31	50.36	75.54	36.8	94.7
2 $S_{10}P_{30}T_0B_0C_{30}$	0.22	50.47	60.6	26.40	70.51
3 $S_{10}P_{30}T_{30}B_{30}C_0$	0.50	44.75	93.08	45.50	72.61
4 $S_{20}P_{20}T_0B_{30}C_{30}$	0.52	45.84	94.4	49.73	77.17
5$S_{20}P_{20}T_{30}B_{30}C_0$	0.33	38.98	83.80	33.65	63.09
6 $S_{20}P_{20}T_{30}B_{30}C_0$	0.41	51.65	124.15	21	33.72
7 $S_{30}P_{30}T_{30}B_{30}C_0$	0.7	36	117.36	18	30.09
8 $S_{30}P_{10}T_{30}B_0C_{30}$	0.52	35.40	99.82	23.49	49.95
9 $S_{30}P_{10}T_0B_{30}C_{30}$	0.56	46.94	131.43	25	35.05
10 $S_0P_{40}T_{60}B_0C_0$	0.3	42.6	61.55	123	210
11 $S_0P_{40}T_{30}B_{30}C_0$	0.13	67	87.45	106.86	200.89
12 $S_0P_{40}T_0B_0C_{60}$	0.16	62	86.80	94	158.6
13$S_{40}P_0T_{60}B_0C_0$	0.85	32.45	129.48	17.58	24
14$S_{40}P_0T_0B_{60}C_0$	0.68	35	96.60	16.6	46.31
15 $S_{40}P_0T_0B_0C_{60}$	0.67	30.45	90	15.63	40.30

Table 6. Chemical properties of treatments before sowing

Treatment	pH	CEC (Cmol$^+$.kg^{-1})	EC (dS.m^{-1})	P (ppm)	K (ppm)	O.C %
١ **$S_{10}P_{30}T_{30}B_0C_{30}$**	5.987	114.5	0.142	6.9	66.98	14.88
٢ **$S_{10}P_{30}T_0B_0C_{30}$**	6.39	107.75	0.964	7.4	147.55	12.787
٣ **$S_{10}P_{30}T_{30}B_{30}C_0$**	5.635	124.41	0.602	26.08	131.2	18.371
٤ **$S_{20}P_{20}T_0B_{30}C_{30}$**	6.788	116.30	0.641	8.8	127.6	19.704
٥ **$S_{20}P_{20}T_{30}B_{30}C_0$**	5.976	120.35	0.729	24.4	140.3	27.038
٦ **$S_{20}P_{20}T_{30}B_{30}C_0$**	6.25	118.55	0.136	22.32	47.97	27.038
٧ **$S_{30}P_{30}T_{30}B_{30}C_0$**	5.453	110.45	0.648	19.6	126.73	40.52
٨ **$S_{30}P_{10}T_{30}B_0C_{30}$**	6.330	99.63	0.136	14.64	62.46	34.742
٩ **$S_{30}P_{10}T_0B_{30}C_{30}$**	6.489	96.94	0.650	9.84	128.54	38.596
١٠ **$S_0P_{40}T_{60}B_0C_0$**	5.165	101.84	0.227	53.8	131.25	47.261
١١ **$S_0P_{40}T_{30}B_{30}C_0$**	5.86	95.64	1.886	11.2	556.77	39.551
١٢ **$S_0P_{40}T_0B_0C_{60}$**	5.523	88.84	0.274	39.2	19.65	23.186
١٣ **$S_{40}P_0T_{60}B_0C_0$**	6.203	102.34	0.815	22.16	51.59	52.669
١٤ **$S_{40}P_0T_0B_{60}C_0$**	6.016	87.94	0.828	8.9	115.86	36.66
١٥ **$S_{40}P_0T_0B_0C_{60}$**	7.008	75.32	0.136	12.64	13.397	23.519

Table 7. The means effect of treatment on fresh and dry weight of roots and shoot and stem length and diameter

Treatment	Stem diameter (mm	Stem Length (cm)	Shoot dry weight (gr)	Shoot fresh weight (gr)	Roots dry weight (gr)	Roots fresh weight (gr)
١ $S_{10}P_{30}T_{30}B_0C_{30}$	4.745^{ab}	21.75^{bc}	2.76^{e}	20.56^{c}	3.67^{a}	22.87^{a}
٢ $S_{10}P_{30}T_0B_0C_{30}$	2.8^{g}	10.96^{g}	0.70^{k}	6.11^{h}	0.577^{g}	3.4^{j}
٣ $S_{10}P_{30}T_{30}B_{30}C_0$	3.97^{cde}	16.66^{d}	2.15^{g}	16.95^{e}	1.89^{bcd}	15.04^{d}
٤ $S_{20}P_{20}T_0B_{30}C_{30}$	3.05^{g}	10.86^{g}	0.75^{k}	5.72^{h}	0.72^{fg}	7.8^{i}
٥ $S_{20}P_{20}T_{30}B_{30}C_0$	4.13^{bc}	19.61^{c}	3.45^{b}	25.87^{b}	2.4^{b}	20.71^{b}
٦ $S_{20}P_{20}T_{30}B_{30}C_0$	3.9^{cde}	16^{de}	2.47^{g}	15.94^{d}	1.19^{ef}	12.69^{ef}
٧ $S_{30}P_{30}T_{30}B_{30}C_0$	3.45^{defg}	13.88^{ef}	2.51^{f}	19.21^{d}	1.64^{cde}	14.10^{de}
٨ $S_{30}P_{10}T_{30}B_0C_{30}$	4.83^{a}	25.91^{a}	4.28^{a}	28.15^{a}	2.34^{b}	19.36^{b}
٩ $S_{30}P_{10}T_0B_{30}C_{30}$	3.2^{g}	11.78^{fg}	1.49^{h}	14^{f}	0.66^{fg}	5.16^{j}
١٠ $S_0P_{40}T_{60}B_0C_0$	4.07^{cd}	21.5^{bc}	2.61^{c}	22.8^{cd}	2.14^{bc}	16.93^{c}
١١ $S_0P_{40}T_{30}B_{30}C_0$	3.41^{efg}	11.91^{fg}	1.33^{i}	11.73^{fg}	0.81^{fg}	9.72^{gh}
١٢ $S_0P_{40}T_0B_0C_{60}$	3.24^{fg}	11.41^{g}	1.23^{j}	9.54^{g}	0.65^{fg}	8.31^{hi}
١٣ $S_{40}P_0T_{60}B_0C_0$	4.32^{abc}	19.58^{c}	2.83^{d}	21.99^{c}	1.58^{de}	9.89^{gh}
١٤ $S_{40}P_0T_0B_{60}C_0$	3.85^{cdef}	15.33^{de}	1.99^{g}	15.72^{e}	1.45^{de}	10.99^{fg}
١٥ $S_{40}P_0T_0B_0C_{60}$	4.79^{a}	22^{b}	3.45^{c}	24.10^{c}	1.58^{de}	10.99^{fg}

Significant difference by Duncan's multiple range test (P <0.05) for values within a column

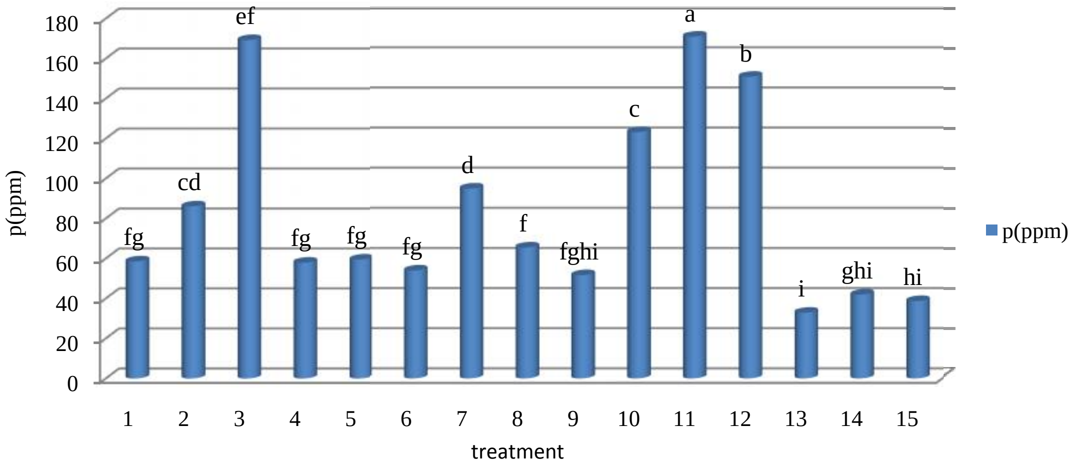

Fig. 1. Comparison of the effect of treatments (numbers correspond to the percentage of different materials in the mixture as indicated in Table 1) on available phosphorus content of growth media after planting. Bars with different letter are significantly (P<0.05) different

The seedling growth parameters showed that stem length and diameter in treatment 8 were the highest (25.91 cm and 4.83 mm) and for treatments 2 and 4 were the lowest (10.96 cm and 2.8 mm). Mineral component of treatments 14 and 15 had more effects on length and stem diameter compared to 11 and 12 (Table 7).

Comparison of means during the growth of tomato seedling showed fastest growing rate and shoot weight of tomato seedling in treatment 8, while treatments 2 and 4 had significantly lowest growth rate. Result of analysis of variance for growth indices in the vegetative stage (t5-0) revealed a significant effect of the treatments on RGR, NAR at 1% and LER at 5% level (Table 7) and (Table 8).

Means of relative growth rate showed that treatment 5 (sand, perlite, tree bark, bagasse) (2:2:3:3) had the highest and treatment 2 the lowest RGR. For the organic components in seedling growth media, the tree bark showed a greater effect in RGR compared to other materials used (Table 8).

NAR index changes for treatments10 and 13 (bark: perlite and bark: sand) were at a higher level among the 15 treatments. Net photosynthetic rate in treatments containing sand showed a statistical difference $P<1\%$ between treatments compared to perlite (Table 8). These results when related to stem elongation rate (SER) (data not shown) were also indicating a significant difference between treatments at each harvest time. As it was expected, the trend of this index in all treatments compared to the original value was increasing with the highest speed in treatment 8.According to the analysis of variance; Leaf expansion rate (LER) differences were significant at 5% level among treatments. The process of removal for 3organic substrate containing oak tree bark increased leaf surface more quickly and bagasse, in terms of this index, was the level on the bottom. And the lowest rate leaves develop in the treated 2 and 4 was observed (Fig. 2).

In general, adding a substrate increased water-holding capacity value (by weight) of the growth media mixture. The perlite also increased the capacity to hold moisture, because in this experiment the same volume of each treatment was used, and WHC was reported on weight basis, lower weight of perlite decreased WHC value in these treatments. Samiei et al. (2005), Verdonck and Demeyer (2004) stated that the use of coarse perlite due to the high pore space (57.7 %) causes nutrient losses and therefore should receive less nutrient solution and can be watered more frequently (Cid-Ballarin et al., 1995, Pete and Willtis, 1995).

The highest percentage of pore volume obtained for perlite is higher than the values reported by Verdonck and Demeyer (2004). This is probably due to differences in particle size, the percentage of content in the growth media or the nature of certain organic components. Comparison of treatments with an equal amount of mineral component indicated that treatment 11 ($S_0P_{40}T_{30}B_{30}C_0$) and treatment 14 ($S_{40}P_0T_0B_{60}C_0$), with 67 and 35% respectively, had a higher pore volume compared to tree bark and wood chips (Table 6).

Mommy et al. (2008) in their study found a significant difference in the relationship of total porosity and water-holding capacity of different ratios of substrates prepared from rice husk and peat. They stated that although peat have emore porosity, carbonized rice husk have better distribution of pore compared to peat and better air movement. Pete and Willits (1995) related the higher pore volume percentage in sawdust to large particles that also causes larger pore size. This can cause easy circulation of air in the growth bed, more drainage, and results in rapid drying.

Higher CEC of oak tree bark and bagasse compared to poplar wood chips caused all mixed treatments of tree bark and bagasse to have higher CEC values regardless of the mineral component (Table 5).

Table 8. The means of the effect of treatmenton growth index in stage (t5-0)

Treatment	LER ($cm^2.g^{-1}$)	NAR ($mg.m^{-2}.d^{-1}$)	RGR ($mg.mg^{-1}.d^{-1}$)
١ $S_{10}P_{30}T_{30}B_0C_{30}$	3.46^{d}	9.38^{ef}	0.155^{bc}
٢ $S_{10}P_{30}T_0B_0C_{30}$	7.17^{a}	6.2^{i}	0.125^{d}
٣ $S_{10}P_{30}T_{30}B_{30}C_0$	2.20^{d}	8.03^{gh}	0.167^{b}
٤ $S_{20}P_{20}T_0B_{30}C_{30}$	5.55^{b}	5.78^{i}	0.139^{bcd}
٥ $S_{20}P_{20}T_{30}B_{30}C_0$	1.60^{ef}	11.81^{bc}	0.202^{a}
٦ $S_{20}P_{20}T_{30}B_{30}C_0$	1.75^{ef}	10.74^{cd}	0.137^{cd}
٧ $S_{30}P_{30}T_{30}B_{30}C_0$	1.87^{ef}	9.96^{de}	0.153^{bc}
٨ $S_{30}P_{10}T_{30}B_0C_{30}$	1.11^{f}	13.28^{a}	0.156^{bc}
٩ $S_{30}P_{10}T_0B_{30}C_{30}$	2.99^{cde}	6.92^{hi}	0.143^{bcd}
١٠ $S_0P_{40}T_{60}B_0C_0$	1.96^{efd}	9.21^{efg}	$0/155^{bc}$
١١ $S_0P_{40}T_{30}B_{30}C_0$	4.06^{c}	6.7^{i}	0.156^{bc}
١٢ $S_0P_{40}T_0B_0C_{60}$	4.12^{c}	8.28^{fg}	0.145^{bcd}
١٣ $S_{40}P_0T_{60}B_0C_0$	1.64^{ef}	11.9^{bc}	0.15^{bcd}
١٤ $S_{40}P_0T_0B_{60}C_0$	2.84^{cde}	9.51^{def}	0.164^{bc}
١٥ $S_{40}P_0T_0B_0C_{60}$	1.41^{ef}	12.62^{ab}	0.163^{bc}

Significant difference by Duncan's multiple range test $P<0.05$) for values within a column.

Samii et al. (2005) reported the CEC of beds prepared with cocopeat, peat moss, palm peat and bagasse were 120, 165, 96 and 64 meq/100g, respectively. Khalighi (2000) reported a 87 meq/100g cation exchange capacity for the tree bark bed.High levels of phosphorus in treatment 11 can be due to the bagasse and the higher CEC of this component. In this study, the effect of inorganic components on phosphorus concentration was higher for the perlite treatments compared to sand. Among the organic components, the bagasse had the largest and tree bark had the lowest phosphorus. Another factor affecting P concentration could be the pH. In treatment 11 ($S_0P_{40}T_{30}B_{30}C_0$)with a pH of about 6, solubility and P sorption capacity increased as compared totreatment13 ($S_{40}P_0T_{60}B_0C_0$)with pH= 7 which showed a lower P concentration in the bed.

Ribeiro et al. (2007), while assessing the effect of compost on growing tomatoes and lettuce, reported that increasing the percentage of compost in the bed decreases the concentration of phosphorus. Plants in beds containing bagasse had the lowest weight which was due to the high percentage of potassium, EC and pH in bagasse. Papadopoulos (1994) have pointed out that the addition of potassium to growth media can be one of the factors slowing done the growth of tomato seedlings. The sand treatments showed better response compared to perlite, which can be due to higher water-holding capacity of the mixture. According to Verdonck et al. (1992), low total porosity, water-holding capacity and lack of nutrients such as phosphorus, iron, manganese and boron can be reasons for weaker plant growth and weight loss in beds containing peat + sawdust compared to 100% peat.

The results showed that the root weight in treatments containing tree bark + wood chip increased along with an increase in perlite content from 10 to 30%. Fresh and dry weights of roots in perlite-containing treatments compared to sand with the same amount of organic components were higher.Verdonck et al. (1982) reported that although the perlite has poor CEC, with high moisture-holding capacity and capillary potential, it would increase nutrient-holding capacity and exchange cations with in the media better. The proper distribution of moisture in the roots results in an extensive root system and increases nutrient absorption leading to strong growth of plants and increasing crop production (Radwan et al. 1979). Organic material around the roots has a positive impact on root growth. Positive impacts of rhizosphere organic material in plant growth under ecological stress conditions have been reported by Luo et al. (2001) too.

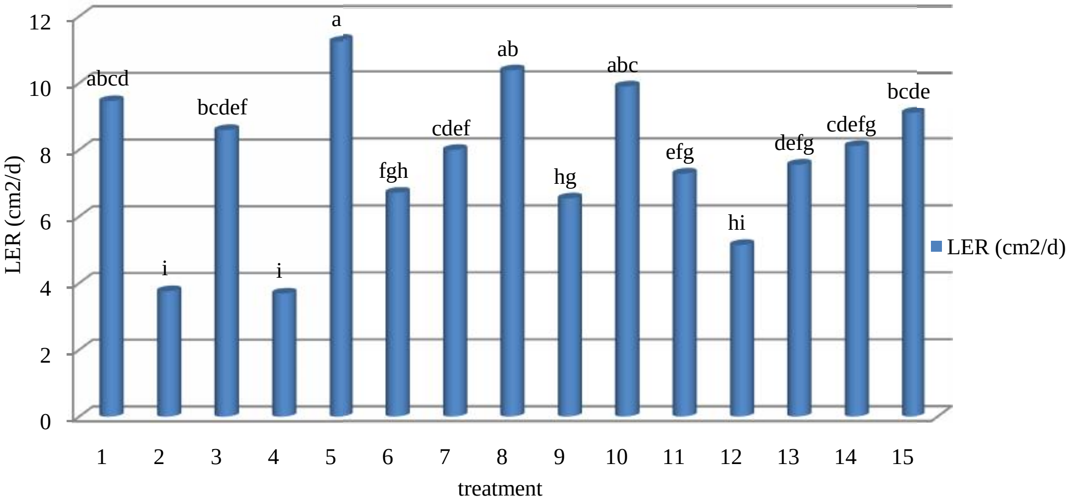

Fig. 2. Comparison of LER index tomato seedlings substrates during the growing time (numbers corresponds to the percentage of different materials in the mixture as indicated in Table 1).

Differences in the relative growth rate between treatments are due to differences of the composition of the growth media. Addition of mineral component in creased large spaces and reduced water-holding capacity and improved drainage as well as aeration in the media (Heydari, 2006). Higher ventilation, yet at the same time, better moisture-holding capacity of the growth media can increase the rate of plant growth. Papadopoulos and Hao (2002) reported that the relative growth rate (RGR) is mainly reduced due to the inhibition of net assimilation rate (NAR). The amount of NAR depends on the rate of increase in dry weight per unit leaf area within a specified time which indicates the rate of photosynthesis and cellular respiration of non-photosynthetic organs.These results can mainly be attributed to porosity percentage, water-holding capacity, and proper electrical conductivity in the growth media that can ease the development of roots, nutrient uptake and increase growth and plant yield . The growth media used can also be ranked based on the water-holding capacity, with 6 treatments (1, 2, 5, 10, 11, and 12) in the first group (water-holding capacity less than 90%),five treatments (3, 4, 8, 14, and 15) which performed well for growing tomato transplants in the second group (90-100 % of water-holding capacity) and the 4treatmentsmixture (13, 6, 7, and 9) in the third group (water-holding capacity greater than 100%). The effects of substrate on the growth and yield of tomato seedlings were not much different and the best or worst treatment could not be determined; however, treatments 3 ($S_{10} P_{30} T_{30} B_{30} C_0$), 8 ($S_{30}P_{10}T_{30}B_0 C_{30}$) and 15 ($S_{40} P_0 T_0B_0 C_{60}$) had the best performance among the 15 growth media compared.

Generally, the 90to 100 percentage moisture range with the most optimal humidity range is considered suitable for tomato transplant growth. The results also showed that the use of bagasse as raw waste plant material is not suitable for growth media and produces weak seedlings. High levels of salt in this material may cause the adverse effects.

CONCLUSIONS

Based on these results, seedlings grown on substrates containing oak tree bark and wood chips as the organic component with both mineral fractions had thicker and longer stem and higher growth rate, which indicates better rate of photosynthesis. Also, the increase in leaf area for increase in dry matter was higher which produces better transplants in these growth media. These can be attributed to higher porosity, water-holding capacity and better electrical conductivity of these substrates. Our results also showed that raw sugar cane bagasse is not a good component for plant growth media mixtures. Therefore, it can be recommended that more research be concentrated on the use of different tree bark or wood chips in growth media mixes for tomato transplants.

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تحقیقات کشاورزی ایران (۱۳۹۶) ۳۶(۲) ۶۱-۷۰

ارزیابی بسترهای کشت مختلف برای رشد نشاء گوجه فرنگی در جهت بهینه سازی تولید و مصرف آب

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واژه های کلیدی:

کشت بدون خاک

ضایعات کشاورزی

ظرفیت نگهداری رطوبت

باگاس

چکیده- سیستم‌های کشت بدون خاک برای رسیدن به عملکرد بیشتربا کیفیت بهتر، صرفه جویی در مصرف آب و زمین و حفاظت بهتر از محیط زیست به وجود آمده‌اند. ظرفیت نگهداری پایین آب بسترهای مورد استفاده در سیستمهای کشت بدون خاک باعث افزایش هدررفت آب و تنش در این کشت ها می‌شود .تنظیم دور آبیاری و مدیریت محلول رسانی می‌تواند سبب کاهش مشکلات احتمالی گردد. در این تحقیق تلاش شده است تا بااستفاده از ضایعات کشاورزی و مواد آلی و مدیریت محلول‌دهی براساس ظرفیت نگهداری رطوبت بستر، بسترهای کشت مناسب جهت رشد نشاء گوجه فرنگی (Solanum Lycopersicon Mill) تهیه و عملکرد آنها بررسی گردد. جهت تهیه این بسترها باگاسنی شکر، پوست درخت بلوط و تراشه چوب صنوبر در نسبت‌های حجمی مختلف با ماسه و پرلیت مخلوط و در قالب یک طرح کاملا تصادفی با ۱۵تیمار و ۳ تکرار و ۶ مشاهده در کشت نشاء مورد آزمایش قرار گرفت. محلول غذایی براساس فرمول تهیه و درفرکانس‌های زمانی مشخص در اختیارگیاه قرار گرفت، هر۷ روز ۹۰ نشاء برداشت و اثر بسترها مورد بررسی قرار گرفت. نتایج نشان داد بیشترین طول و قطرنشای گوجه فرنگی مربوط به تیمار ۸ ($S_{30}P_{10}T_{30}B_{0}C_{30}$) بود و از نظر بخش معدنی ماسه نسبت به پرلیت در افزایش شاخص‌های رشد گیاه موثرتر بود. از نظر بخش آلی نتایج نشان دهنده‌ی مطلوب بودن پوست درخت نسبت به تیمارهای دیگر بود و تیمارهای حاوی باگاس کمترین وزن تر و وزن خشک اندام هوایی و ریشه را به خود اختصاص دادند. تیمارهای با ظرفیت نگهداری رطوبت ۹۰-۱۰۰٪ بهترین واکنش را نسبت به رشد گیاهچه های گوجه فرنگی نشان دادند.